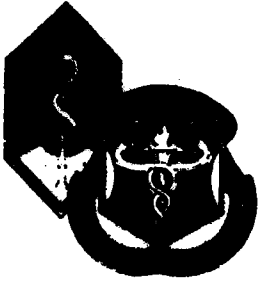


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LABORATORY NOTE NO. 86-58

EFFECTS OF BROADBANDED EYE PROTECTION ON DARK ADAPTATION

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Effects of Broadbanded Eye Protection on Dark Adaptation
--Zwick, Garcia, Beatrice, Bloom

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Effects of Broadbanded Eye Protection on Dark Adaptation

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SUMMARY

Modern combat scenarios require the ability to perform military tasks under night time conditions. While image enhancement devices are vital to such military performance, unimpaired human night vision retinal mechanisms are essential for such performance success. Protection of the human biological sensor is of utmost importance. In this investigation we have reexamined earlier findings that indicated the use of sunglasses could prevent deleterious effects of bright light environments on dark adaptation. We found that the use of broad band attenuating spectacles could improve absolute visual thresholds but had minimal effect on central retinal mechanisms. Dark adaptation functions measured with long wavelength light showed no significant sunglass effect whereas such functions measured with intermediate spectral light increased in final visual thresholds. These differential effects were obtained under environmental light conditions insufficient to produce an elevation in final visual thresholds for control group subjects not provided with sunglasses. The results of this study strongly support previous arguments for providing standard visible and near UV protection to personnel required to perform military tasks under extremely bright environmental light levels.

Many current field exercises conducted within the Army involve extensive night maneuvers and must involve optimal human night vision performance. With the availability of modern night vision devices, dependence upon unaided human night vision has been minimized. Yet the usefulness of unaided night vision must not be overlooked, as the present generation of modern night vision devices is still only available in limited quantities, may produce visual fatigue after short periods of time, and may have restricted fields of view. In this experiment we have investigated the potential for augmenting natural human night vision function as an alternative to its artificial augmentation.

Exposure to bright daylight conditions has occasionally been associated with a decreased rate of dark adaptation and delayed ability to reach maximal night vision sensitivity levels (1,2).



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Furthermore, chronic daily exposure to bright environmental light levels has been associated with changes in gross retinal morphology and visual function(3,4). Investigations in animal subjects has shown that such levels can produce significant retinal degeneration as well as permanent elevation in rod absolute threshold.

While more recent investigations have concentrated on detailing environmental light effects of a non-reversible nature, the early effects obtained on the rate and final level of human dark adaptation were found to be reversible, if broad banded absorption filters (sunglasses) were worn during working exposure to bright environmental light conditions (2). These filters absorbed through the visible and near ultra-violet spectral regions. Without these filters, final absolute levels of dark adapted visual sensitivity were delayed in achieving maximal rod sensitivity; with these filters such effects on dark adaptation were not obtained.

Although bright light environments can elevate final dark adapted visual sensitivity thresholds, little is known about the differential effects on the types of photoreceptor systems or whether the ability of sunglasses to change final visual threshold levels occurs only for light levels that are excessive. Such additional information can elucidate the nature of the retinal mechanisms involved in these effects, thereby increasing our ability to understand how to best augment unaided night visual function. The present experiment was undertaken to answer such questions.

METHOD

A light emitting diode (LED) dark adaptometer (5,6) was used in this experiment. A composite illustration of this device -- its principle of operation, pulse modulation; its product, a sample dark adaptation function; and its available LED spectrum -- is presented in Figure 1. Red, and green LED sources are mounted inside a plexiglass hemisphere. Measurements of visual threshold following a standard period of light adaptation are made with a tracking technique for measurement of visual threshold. Visual sensitivity is the reciprocal of visual threshold. The 36-inch hemisphere, fitted with a chin support and headrest, and indirectly illuminated with conventional tungsten lamps, provides a constant uniform light adaptation source of 110 candela/m². Threshold measurements are alternately determined for both red and green LED sources during the course of dark adaptation.

In these experiments all threshold measurements were made at 16 degrees from fixation for the red (E) and green (C) LED sources. Both vertical and horizontal LED sources were simultaneously illuminated for each source.

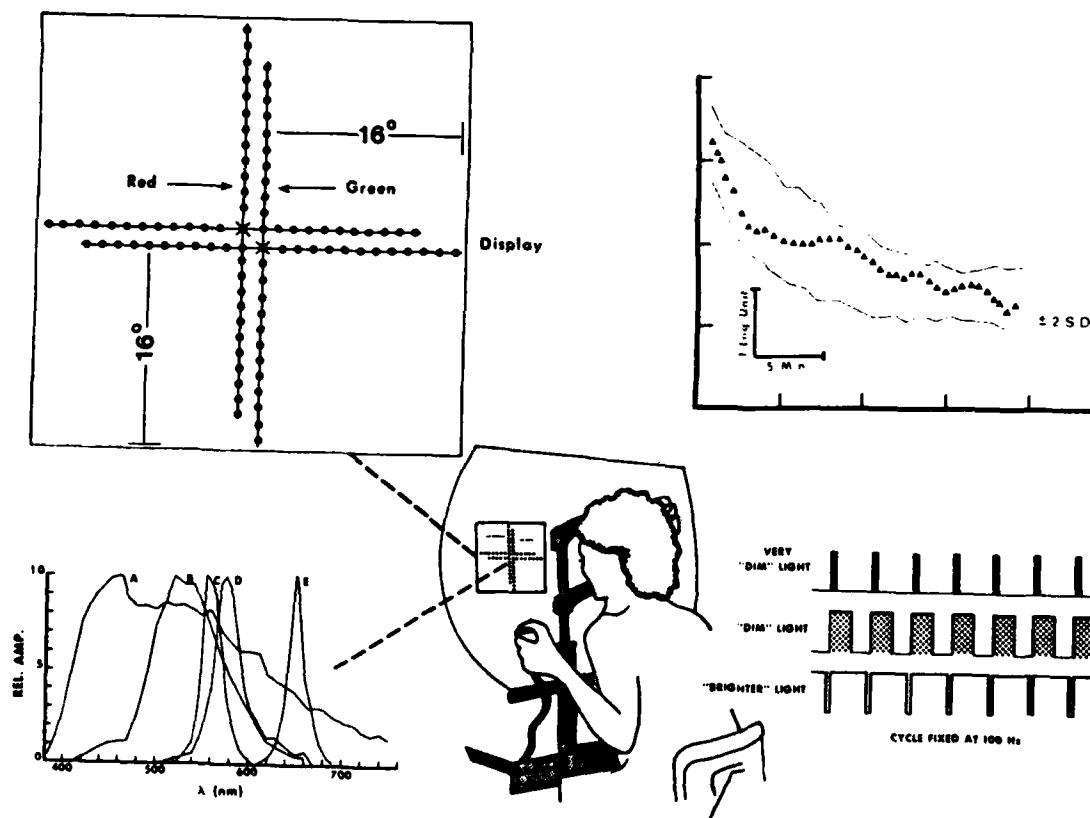


Figure 1. A schematic illustration of the LED dark adaptometer. In the upper right, a sample dark adaptation function from one individual is shown. The upper and lower solid lines represent two standard deviations about the mean function. The duty cycle or pulse width modulation for a dim light (late dark adaptation) is shown in the lower right insert. Threshold pulse width decreases as dark adaptation increases. The relative spectral transmission curves of the LED sources available to this apparatus are shown in the lower left corner. For this experiment only the green (C) and red (E) diodes were used.

The spectral distributions of the two kinds of sunglasses used in this experiment are shown in Figure 2a,b. The luminance transmittance of the Olo sunglasses using the CIE C source equalled 1.3 %, while that for the Gargoyle sunglass equalled 18%. For both of these filters, transmission in the near ultra-violet spectrum was no more than 5%.

Experimental and control group subjects were military personnel on maneuvers in a semi-arid environment at Fort Hunter Liggett Military Reservation in California. All subjects were in their mid-twenties. Both experimental (n=15) and control (n=15) groups received a standard dark adaptation test, which consisted of a 2 minute light adaptation period to the hemisphere followed by visual threshold measurements made for both the red and green LED sources. Visual threshold measurements were made 16 degrees from fixation over a twenty minute dark adaptation period. The experimental group was given one of the two kinds of sunglasses described in Figure 2 and asked to use these filters, when outdoors, as much as they possibly could. No filters were given control group subjects, who were engaged in similar activities under nearly identical environmental conditions. Reported average usage of sunglasses over the four day period between pre- and post- measurements of dark adaptation equalled about 20 hours for each subject.

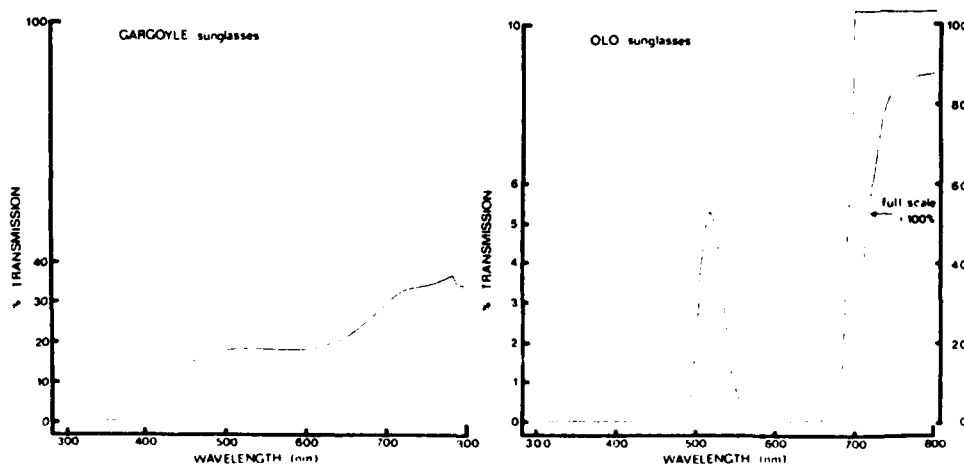


Figure 2a,b. Spectral transmittance of Gargoyle and OLO sunglasses. The luminance transmission of these filters using the CIE C source was 18% and 1.3%, respectively.

RESULTS

Pre- and post-exposure dark adaptation functions for spectral test stimuli are shown for two subjects in Figure 3a,b. While both subjects show large individual variation in the effects of pre- vs post-exposure, their functions demonstrate the trends that were found in all of the subjects tested. Both show that throughout the dark adaptation measurement period, post-exposure sensitivity for the green LED source was always greater than that obtained for the preexposure period. On the other hand, pre- and post-exposure measurements of sensitivity for the red LED show much smaller differences as well as crossovers during the 20 min dark adaptation period.

Differences in either the spectral transmission of these filters or in the amount of time filters were actually worn by these subjects may account for the large individual differences observed here. However, when the average over the 15 subjects given sunglasses was taken, the same observations are supported (Figure 4). Average post-exposure measurements of sensitivity for the green LED light source are approximately a quarter of a log unit more sensitive than average preexposure measurements over most of the dark adaptation period, but differences are minimal for the red LED.

Comparable dark adaptation measurements made with the 15 control subjects show no differences between pre- and post-exposure for either the green or red LED test stimuli.

The data from these two groups were examined with a 4-way ANOVA, which revealed a statistically significant 4-way interaction ($P < .05$) for filter, LED color, time, and pre-/post-exposure. Statistical analysis was conducted for the first and last five-minute blocks in the dark adaptation period. To further parcel out the significant contributing factors to this 4-way interaction, we examined the factors of LED color, time, and pre- vs post exposure for sunglass group vs control group. The results of the three-way analysis for both of these groups are shown in Tables 1 and 2. The major differences in these separate ANOVAs lay in the significance of the interactions between pre- and post-exposure and color. The sunglass group had significant interactions between color and time and between pre-/post and time.

Multiple comparisons with paired t - tests were done for the sunglass group only since pre-/post did not show up as a significant factor in any of the interactions tested for the control group. The post- measurements were found statistically significant ($p < .05$) for the green LED over the last 5 minutes of dark adaptation but was not statistically significant for the first five minutes of dark adaptation.

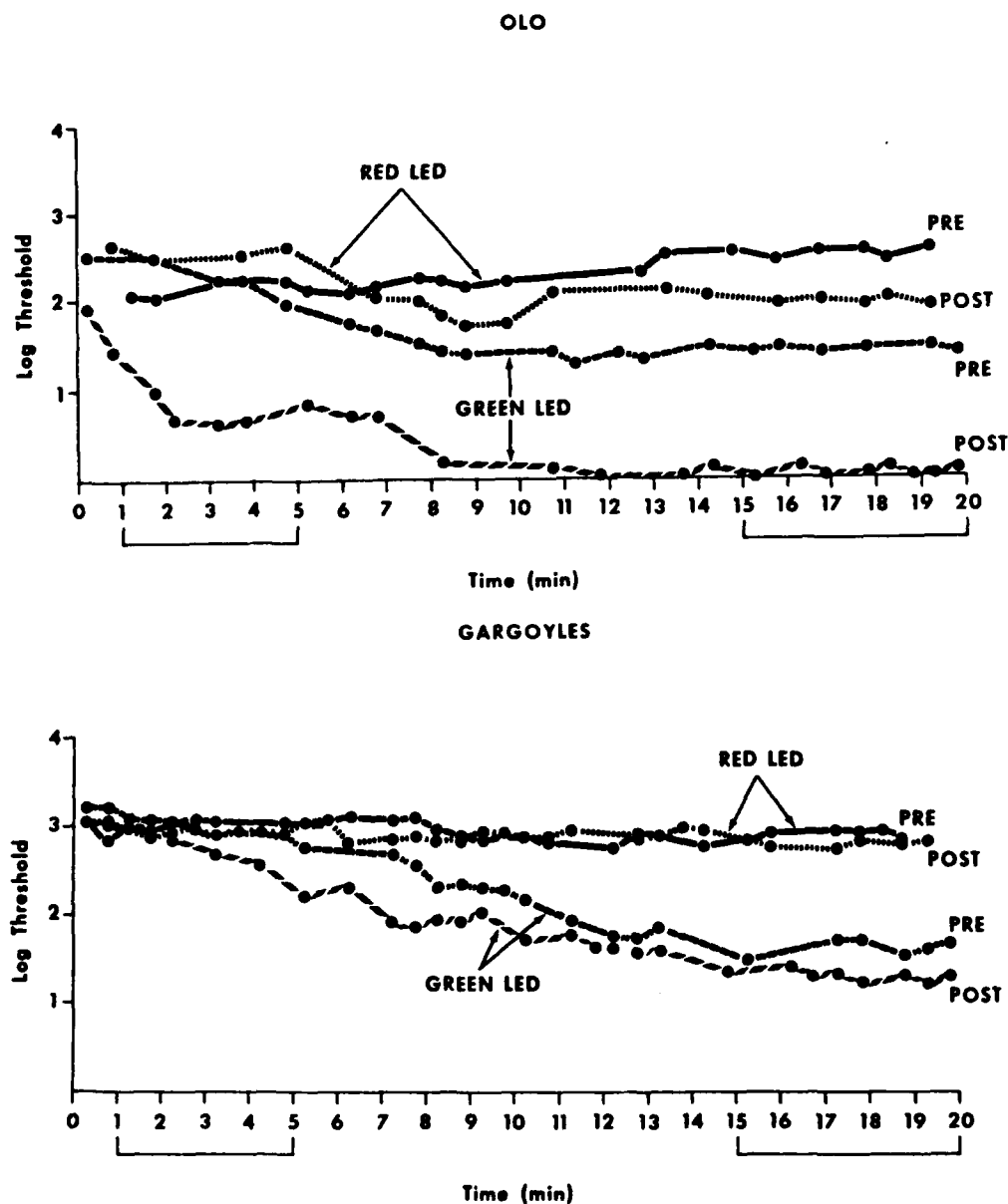


Figure 3a,b. Two individual subjects showing the pre- and post-exposure dark adaptation measurements. One subject used the OLO filter and the other used the Gargoyle filter. Both subjects show the same relative effects for pre and post spectral dark adaptation measurements, although absolute differences were greater for the subject wearing the OLO filter as compared with the one wearing the Gargoyle filter.

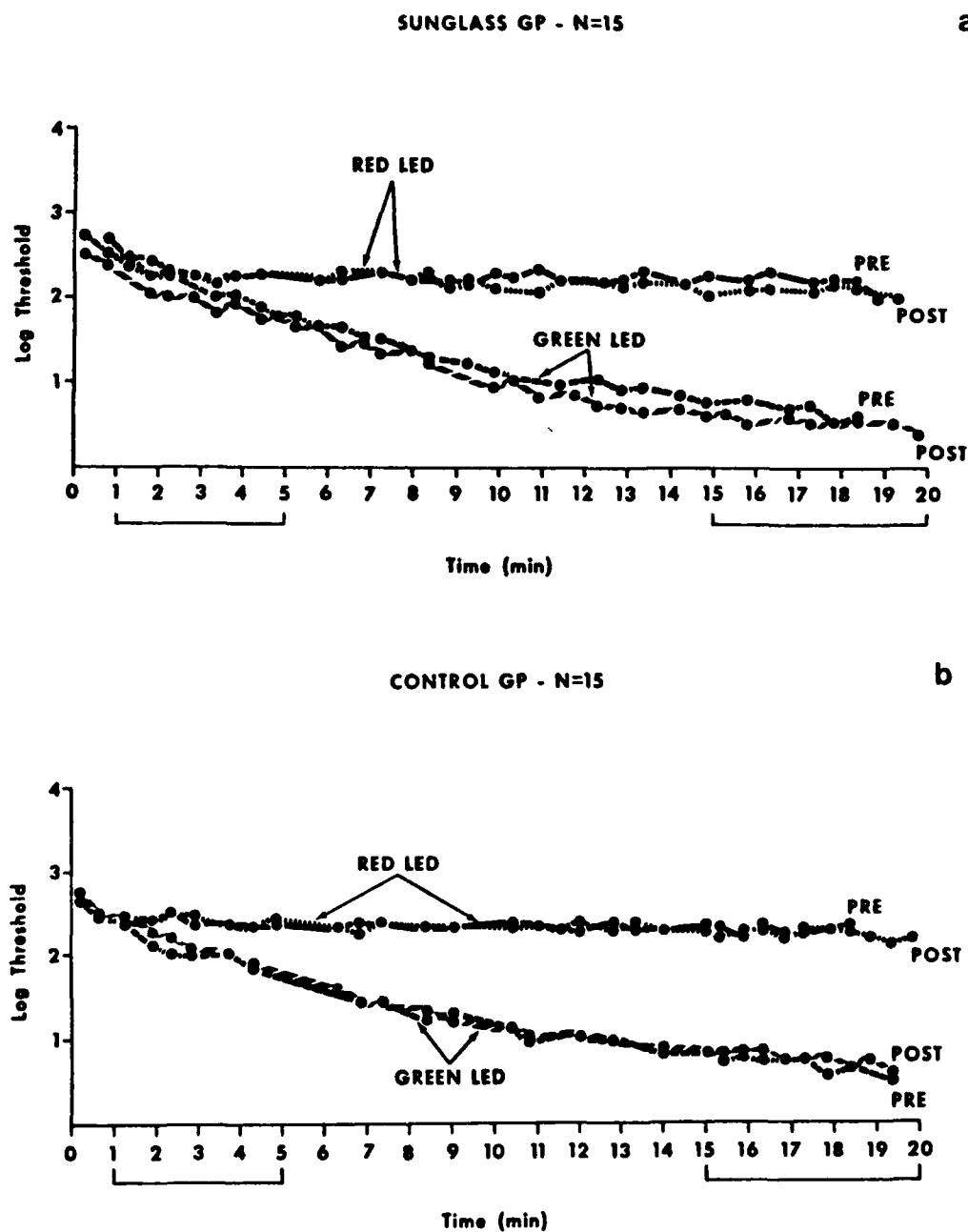


TABLE 1
SUMMARY OF ANALYSIS OF VARIANCE
FOR EXPERIMENTAL GROUP*

SOURCE	DEGREES OF FREEDOM	MEAN SQUARE	F	PROBABILITY†
MEAN	1	542.17254	1865.2	ns
ERROR	14	.29061		
PRE/POST	1	.19764	.90	ns
ERROR	14	.21954		
COLOR	1	18.07304	1127.94	.0000
ERROR	14	.01602		
PRE/POST X COLOR	1	.02002	.66	ns
ERROR	14	.03016		
TIME	1	30.77494	414.27	.0000
ERROR	14			
PRE/POST X TIME	1	.34454	6.97	.0194
ERROR	14	.04943		
COLOR X TIME	1	21.14280	1202.25	.0000
ERROR	14	.01759		
PRE/POST X COLOR X TIME	1	.28714	11.76	.0041
ERROR	14	.02442		

* THE ANALYSIS WAS PERFORMED USING BIOMEDICAL COMPUTER PROGRAMS BMDP2V.

† THE P = .05 LEVEL WAS USED FOR DETERMINING STATISTICAL SIGNIFICANCE.

TABLE 2
SUMMARY OF ANALYSIS OF VARIANCE
FOR CONTROL GROUP*

SOURCE	DEGREES OF FREEDOM	MEAN SQUARE	F	PROBABILITY†
MEAN	1	596.30209	1760.05	ns
ERROR	14	.33880		
PRE/POST	1	.01541	.22	ns
ERROR	14	.07160		
COLOR	1	11.32216	121.74	.0000
ERROR	14	.09301		
PRE/POST X COLOR	1	.01281	.39	ns
ERROR	14	.03248		
TIME	1	19.28009	410.05	.0000
ERROR	14	.04702		
PRE/POST X TIME	1	.00588	.19	ns
ERROR	14	.03081		
COLOR X TIME	1	12.81840	834.50	.0000
ERROR	14	.01536		
PRE/POST X COLOR X TIME	1	.01825	.79	ns
ERROR	14	.02321		

* THE ANALYSIS WAS PERFORMED USING BIOMEDICAL COMPUTER PROGRAMS BMDP2V.

† THE P = .05 LEVEL WAS USED FOR DETERMINING STATISTICAL SIGNIFICANCE

DISCUSSION

The results of this experiment support previous findings on the effects of sunglass usage on final dark adapted visual sensitivity; i.e. an increase in visual sensitivity was obtained for peripheral retinal measurements. However, this effect was spectrally selective, occurring for the intermediate but not for the long wavelength test light source. This finding would suggest that the long wavelength cone receptor system is insensitive while either the rods or possibly the intermediate cone system are sensitive to such light filtration. Furthermore, the increase in final sensitivity found here was obtained in the absence of an elevation in visual sensitivity produced by unfiltered environmental light, as evidenced by the control groups pre- and post-exposure data.

Augmentation of a natural photic protective mechanism is one explanation of the above findings. One difference between paramacular and macular receptors is that light for the latter group of receptors is filtered by macular pigment, which absorbs short wavelength visible light. Maximum absorption of the macular pigment is 460 nm. Estimates of the optical densities of this pigment range from 0.3 to 0.85 (7,8). As short wavelength light in the blue region of the spectrum has been postulated (9,10) to represent the most hazardous portion of the visible spectrum, the macular spectral absorption characteristics would seem to provide a natural protective filter from intense levels of short wavelength visible light. Sunglasses may afford a degree of spectral protection to the paramacular receptors.

However, the filters used in this experiment were of very different absorption characteristics in the visible spectrum, but nevertheless had similar effects on absolute visual thresholds. This lack of spectral specificity may reflect experimental conditions beyond our control or may be an indication of the importance of the high near ultra-violet absorption common to both of these filters. In the past (11,12,13) considerable discussion had been given to the relative contributions of this portion of the spectrum to elevations in final visual thresholds. More recent animal investigations have suggested that both the visible and near UV spectrum may mediate separate photochemical toxicity mechanisms (9,10).

While augmentation of the natural protection afforded by the macular pigment is reasonable at levels of environmental light where exposure does produce an observable decrement in sensitivity, no such decrement was obtained in this study, as evidenced by the control group pre- and post-exposure measurements of dark adaptation. The ability to produce an increase in sensitivity in the present study may, therefore, involve other retinal mechanisms in addition to that of natural filter augmentation. Such mechanisms could be more directly involved with the normal regulation of night visual function rather than a manifestation of its lability to light exposure, at least for

environmental light levels that do not elevate or retard achievement of final dark adapted visual thresholds.

One such mechanism would involve interference with normal rod-cone interaction processes. During the normal course of dark adaptation, cone activity initially produces the strongest neural response, able to neurally mask rod activity. As dark adaptation proceeds, the neural output of the rod system increases while that of the cone systems decreases. Measures of spectral sensitivity obtained during the course of dark adaptation reflect these dynamics by displaying a shape of the spectral sensitivity function that neither fully matches the photopic or the scotopic function during the intermediate temporal course of dark adaptation (5). The uniform filtration afforded by sunglasses to both the rod and cone receptor systems could alter the balance of rod/cone inhibitory influences, and selectively favor peripheral rods, as rods are the more numerous receptor system, and therefore, the receptor system having the greatest neural output.

A more direct explanation, however, involves minor changes in peripheral retinal receptor orientation induced by attenuated retinal irradiance. Normally, primate peripheral retinal rods are oriented toward the pupillary aperture (14), giving a maximally efficient response to light oriented normal to the pupil. Recent investigations have demonstrated that retinal receptor efficiency measurements can be altered by grossly attenuated light input over several hours or alteration in the location of the pupil (15,16). Other investigations have demonstrated the presence of striated tissue both in the photoreceptor itself as well as both proximal and distal to the photoreceptor outer segment (17,18,19). Under normal non-toxic light conditions it is possible that a receptor alignment mechanism may function, capable of fine tuning its orientation for maximal processing efficiency of light input. Under brighter light conditions, such a mechanism may serve to protect the photoreceptor system by slightly disorienting the photoreceptor, causing a reduction in visual efficiency while affording a degree of protection to the photoreceptor absorption apparatus. Such an explanation could also accommodate neural inhibitory processes as well as receptor alignment mechanisms, as a change in receptor orientation, affecting receptor efficiency would also affect the lateral neural inhibitory activity of one receptor on another receptor system.

In summary, the present investigation supports previous studies but suggests the presence of an active receptor alignment retinal mechanism capable of attenuating over a wide range of environmental light levels. Under environmental light levels that do not pose a hazard, sunglasses may serve to maximize normal visual efficiency by optimizing retinal receptor alignment to the pupillary aperture. For light levels that do pose a potential hazard (1,2), retinal receptor alignment processes may serve to "detune" fine receptor orientation to

the pupillary aperture, thereby, decreasing visual efficiency, but also affording a degree of protection to the receptor light absorption mechanism itself. Such mechanisms may be required to a lesser degree by macular receptor systems, as the macular pigment serves as a static protective absorption system, or may exist for macular receptors but require more specialized visual inquiry to elucidate their presence.

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Abstract cont.

mechanisms. Dark adaptation functions measured with long wavelength light showed no significant sunglass effect; whereas, such functions measured with intermediate spectral light decreased in final visual thresholds. These differential effects were obtained under environmental light conditions insufficient to produce an elevation in final visual thresholds for control group subjects not provided with sunglasses. The results of this study strongly support previous arguments for providing standard visible and near ultraviolet protection to personnel required to perform military tasks under extremely bright environmental light.

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