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DARK ADAPTATION AND THE NEAR ULTRAVIOLET

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Bureau of Medicine and Surgery, Navy Department,
Project NM 002 014.09.05

DARK ADAPTATION AND THE NEAR ULTRAVIOLET

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SUMMARY PAGE

THE PROBLEM

To determine the effect of exposure to near ultraviolet light such as is emitted by fluorescent lamps upon dark adaptation.

THE FINDINGS

No evidence of a deleterious effect of exposure to the near ultraviolet upon subsequent dark adaptation was found.

APPLICATIONS

Installations of fluorescent fixtures may be continued for all applications in submarines and other military craft without danger of injurious effect on night vision.

ADMINISTRATIVE INFORMATION

This investigation was undertaken as a phase of subtask .09 (title: Psychophysical studies of visual factors important in submarine operations), which is one of the subtasks under investigation in connection with Bureau of Medicine and Surgery Research Project NM 002 014, Human Engineering and Associated Psychophysiological Studies in Underwater Operations. The present report is Report No. 5 on this subtask. The previous four reports were titled as follows: (1) Preliminary Field Evaluation of Detectability of Colors for Air-Sea Rescue; (2) Color Perception of Small Stimuli with Central Vision; (3) Field Study of Detectability of Colored Targets at Sea; (4) Brightness Thresholds as a Function of Target Contrast and Retinal Position.

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ABSTRACT

Two studies of the effects of exposure to the near ultraviolet (principally 334, 365, and 366 m μ .) upon subsequent dark adaptation are reported.

For the first study, a Hecht-Shlaer adaptometer was modified so that radiation from either a mercury-arc lamp, or incandescent lamp (control), could be added to the light adaptation field of the adaptometer. The light adaptation component from the incandescent lamp was equated visually to that of the mercury-arc. Four conditions of light adaptation were employed: exposure for 10 minutes to a 3.6 mL field to which ultraviolet or control radiation had been added, or exposure for 10 minutes to a 288 mL field to which either the UV or control components had been added.

Performance under either of the ultraviolet conditions did not differ in any respect from that under the corresponding control conditions. Brightness of the light adaptation field did, of course, affect subsequent dark adaptation. Exposure to the higher brightness delayed the onset of rod adaptation, and raised the threshold at 25-30 minutes by 0.12 log units.

The second experiment was designed to determine whether or not the negative findings of the first study were due to equation of the light adaptation fields in color and brightness and the relatively low brightnesses of those fields. The ultraviolet and control light adaptation fields differed from each other in both color and spectral composition, and were much brighter than those employed in the first experiment.

Again there was no reliable evidence that exposure to the near ultraviolet affects subsequent dark adaptation deleteriously. The source of the discrepancy between these negative findings and the positive results reported by others has not as yet been identified.

DARK ADAPTATION AND THE NEAR ULTRAVIOLET

INTRODUCTION

Until recently there has been little interest in the effect of the near ultraviolet, approximately 330-380 μ ., upon vision. This portion of the spectrum does not seem to share the powerful antibiotic effects of the far ultraviolet; it is of no value in ordinary visual tasks and it is not generated in appreciable amounts by ordinary incandescent lamps. Further, most of such radiation from the sun is absorbed before it reaches the earth's surface. Recent development in illumination practices and visual research have, however, made it imperative that the effects of the near ultraviolet upon vision be investigated completely. In many lighting installations incandescent lamps are being supplanted by fluorescent tubes which do emit appreciable amounts of near ultraviolet radiation. Coupled with this change in illumination practices there were reports that the near ultraviolet affects at least one type of visual performance deleteriously.

The sudden increase in the number of complaints of eye trouble following the installation of fluorescent fixtures in some situations has been attributed by several authorities to the ultraviolet content of such radiation (4). Those speculations have received their strongest support from the research of Wolf and his associates (9, 10, 11, 12, 13, 14, 15) which shows that exposure to the near ultraviolet does retard subsequent dark adaptation. In the first of those studies conducted with humans (11), the proportions of ultraviolet and visible radiation in the light adaptation field were varied by means of filters placed between a mercury-arc and S's eye.

The level of dark adaptation attained after 30-35 minutes was found to be inversely related to the lower limits of the light adaptation spectrum; the farther into the ultraviolet that spectrum extended, the higher was the final level of dark adaptation.

Wolf suggested that the effect might be the result of direct action of the near ultraviolet upon the photosensitive material of

the rods, or that it might be due to fluorescence of the ocular media in the presence of the ultraviolet (11). In subsequent papers Wolf has presented evidence of an effect upon the cones as well as the rods and now seems to be certain that the effect upon the photosensitive receptors is a direct one (14).

However, Wolf's findings and his interpretations of those findings have been challenged (6, 7, 8). Wald failed to find any effect of ultraviolet with normal subjects in a repetition of the Wolf experiment (8). He did find that the cone portion of the aphakic's dark adaptation curves was distorted following exposure to the near ultraviolet. This conflicted directly with the results of the Wolf experiment (11), in which the rod segment of the aphakic's dark adaptation was distorted. Wald is convinced from his own studies of the transmission of the lens that no significant amount of the near ultraviolet can reach the retina. Wald attributed the effects observed in the aphakics to a tremendous increase in the brightness of the light adaptation field for those persons who have no lens to absorb the near ultraviolet. Wolf, however, believes that there are other reasons for Wald's negative findings which he has discussed in a recent article (15).

Experiment I

Since several investigators have suggested that the positive findings might have resulted from a difference in the brightness of the light adaptation fields with and without ultraviolet components (4, 6), it seemed that investigation of that factor might be fruitful. It is clear that if the Wolf effect is due to a direct action of the invisible near ultraviolet on retinal elements, it would be important for both practical affairs and theories of vision. If the effect is due to differences in brightness from the ultraviolet source and control light adaptation field, or to fluorescence of the ocular media in the presence of the near ultraviolet, it could be compensated for in practice and would have no significance for visual theory. Therefore, the present experiment was conducted to determine whether or not exposure to the

near ultraviolet has any effect upon dark adaptation when the contributions to brightness of adjacent portions of the spectrum have been controlled as completely as possible. Dark adaptation measures were obtained following exposure of the S to a field containing ultraviolet and visible components, or to an equally bright field composed only of radiation above 400 m μ . In addition, two levels of light adaptation brightness were employed in an attempt to ascertain the effects, if any, of variation in the ratio of ultraviolet to visible radiation in the light adaptation field when the absolute amount of the ultraviolet is held constant. Since the midday sun in summer is richer in ultraviolet content than the sources employed in the analytic experiments to date (2), and there is no unequivocal evidence that solar ultraviolet radiation affects vision detrimentally, it seemed that Wolf's findings might be dependent upon a particular ratio of near ultraviolet to the total radiant energy in the light adaptation field.

METHOD

A Hecht-Shlaer adaptometer was modified

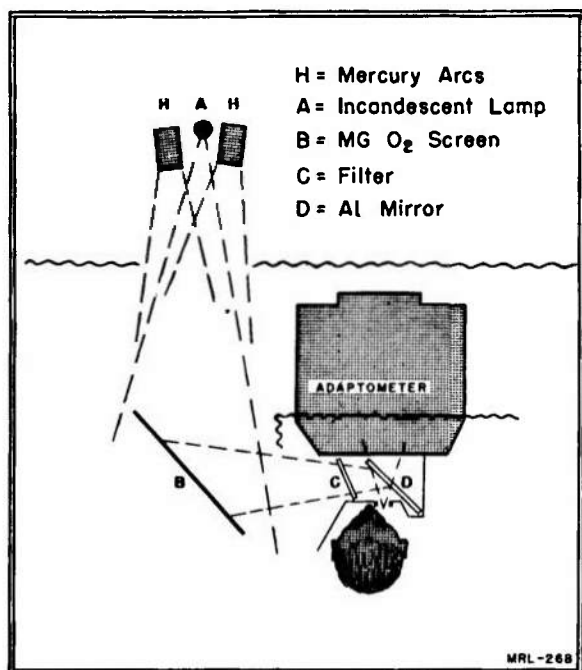


Figure 1. - Schematic diagram of the arrangement of sources, mirrors, and filters for addition of UV or control radiation to the light adaptation field of the adaptometer.

so that a fixed amount of ultraviolet, (which necessarily included a small visible component), or equally bright ultraviolet-free, radiation could be added to the light adapting field of that apparatus. This arrangement permitted manipulation of the total brightness of the light adapting field while the contribution of the near ultraviolet to that field was held constant. As shown in Figure 1, the radiation from either a pair of Hanovia type SH 100-watt mercury-arc lamps (H), or a suitably filtered 10-watt incandescent lamp (A), was directed through an opening in the wall of S's cubicle to a magnesium oxide screen (B). The radiation reflected from the screen then passed through the appropriate filter (C) to the front-surfaced aluminized mirror of 90% reflectance (D) which S viewed. The lamps were mounted in a vertical array upon a single laboratory stand and adjusted so that S viewed an evenly illuminated field. The field provided by the mercury-arc lamps will be called the UV field, and that provided by the incandescent source will be called the control field. The housing for the filter (C) and aluminized mirror (D) was designed and mounted so that its substitution for the reg-

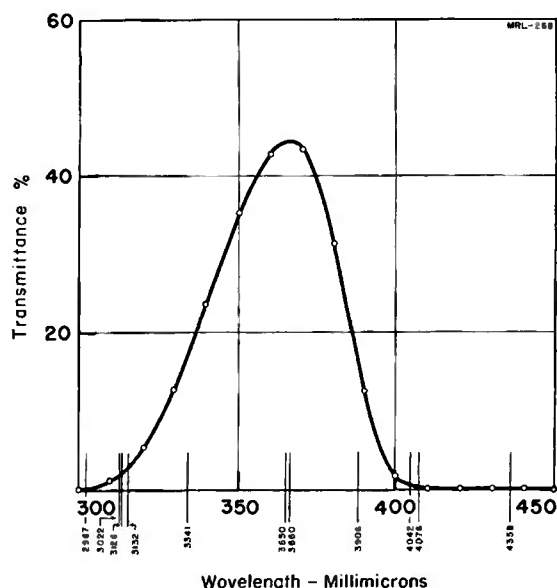


Figure 2. - Transmission of Corning 5840 Filter used to restrict the spectrum of the ultraviolet light adaption field to the 300-400 m μ . range. Measurements were made with a Beckman Model DU Spectrophotometer. The principle mercury lines in this region are shown.

ular eyepiece did not alter the optical system of the adaptometer.

The spectral transmission of the Corning 5840 filter (C above) which in conjunction with the mercury-arc lamps provided the near ultraviolet component added to the light adapting field is shown in Figure 2.

A pair of spectrographs obtained at the eyepiece of the adaptometer with and without that filter in its usual position is presented

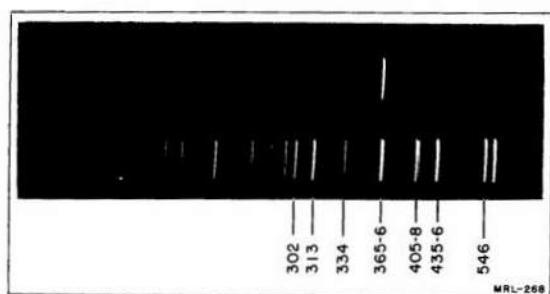


Figure 3. - Spectrographs of radiation from two Hanovia type SH mercury-arc lamps obtained at the adaptometer eyepiece. The lower spectrum is unfiltered; the upper is that passed by the Corning 5840 filter used in this experiment.

in Figure 3. The spectrographs show clearly that the UV field provided two fairly strong lines at 365-366 mμ. and one line at 334 mμ. The total irradiance in the plane of the pupil during exposure to this field was measured with a photomultiplier photometer which had been calibrated for absolute response to the 365.5 mμ. line by the National Bureau of Standards. For comparison, measurements were made of a 40-w. daylight fluorescent tube and an 8-w. blacklite tube with the same Corning 5840 filter before the photomultiplier receiver. The mean energy values recorded in these measurements are presented in Table I. The table entry "UV Field-Exp II" will be discussed later. In the last column of Table I, the measured irradiances of the fluorescent and blacklite tubes have been corrected for the transmission of the Corning filter at 365 mμ. (43%) on the assumption that this gives a fair approximation to the strength of the near ultraviolet spectrum of those sources. Table I shows that the observers in this experiment received quantities of near ultraviolet energy over a fairly prolonged period which are within the

TABLE I - Irradiance of those portions of: (1) the UV fields, and the spectra of; (2) a 40-w. Daylight Fluorescent tube; and (3) an 8-w. Blacklite tube; transmitted by the Corning 5840 filter.

Source	Filter Position	Distance	Measured Irradiance uw/cm ²	Calculated Irradiance uw/cm ²
UV Field-Exp I.	Adaptometer Housing	Adaptometer Eye-Piece	2.5	
40-w. Fluorescent tube	Face of phototube	1 meter	0.6	1.4
8-w. Blacklite tube	Face of phototube	1 meter	2.5	5.8
UV Field-Exp II.	Adaptometer Housing	Adaptometer Eye-Piece	8.0	16.7

range which would be encountered even in the unlikely event of direct fixation of fluorescent or blacklite sources at short distances.

In order to equate the brightnesses of the UV and control components which would be added to the light adaptation field, the adaptometer was used as a photometer. A piece of black felt was placed on the magnesium oxide screen so that the radiation generated by the UV, or the control, source was reflected from that screen to the aluminized mirror as a square field with a black circular area in the center. The dark adaptation field of the adaptometer then appeared to fill this central area when the adaptometer shutter was set for "time". This arrangement made it possible for each S to match the brightness of the adaptometer field to that of the UV field. The adaptometer field was then employed as a standard for adjustment of the control field brightness. This system insured the equivalence of the UV and control fields in brightness in the experiment proper. A further advantage of this system was that the matches could be made with fixation upon the source provided for that purpose in the adaptometer. Since the S's were not equally sensitive to the brightness component in the ultraviolet source, it was necessary to substitute a 15-watt incandescent lamp for the 10-watt lamp for one S (BH).

In order that the brightness matches would not be affected by discrepancies in color between the several sources, Wratten neutral and Corning 5850 filters were placed in front of the 10-watt lamp and the adaptometer source. The Corning filters placed in front of the 10-watt source remained there

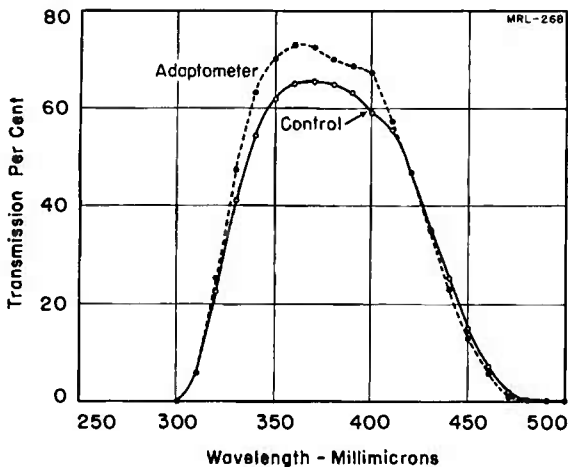


Figure 4.- Transmission of Corning 5850 filters placed before the adaptometer source and the control source. Measurements were made with a Beckman Model DU Spectrophotometer.

throughout the course of the experiment; their combined spectral transmission is shown in Figure 4. The combined spectral transmission of the Corning filters placed temporarily before the adaptometer source in order to make the brightness matches is also shown in Figure 4.

Each of three Ss contributed twenty dark adaptation curves, five under each of the four conditions obtainable with combination of high (288mL) or low (3.6mL) brightness light adaptation fields with UV and control fields. These fields were not nearly as bright as those used in most of the previous experiments with humans (8,11); instead they were chosen to approximate the extremes of the brightness range encountered under most artificial lighting conditions. The order in which the conditions were presented was varied randomly from S to S and week to week so that the Ss remained naive as to whether they were receiving UV or control stimulation in any particular session. Each condition was presented once during a given week.

Following a 15 minute period in the dark, S adapted to the appropriate field for 10 minutes. The fixation point was situated 10° temporally in the 35° light adaptation field. During dark adaptation, a 9.5° temporal area situated 10° from the fixation point was stimulated by the test flash. Threshold

at any given moment was determined by the ascending series of the method of limits with brightness steps of 0.06-0.09 log units for successive test flashes in a series. For each determination in a series, the field was exposed for 1/25 sec. approximately every 5 sec.

Although the adaptometer wedge had a slight greenish tint, the fact that it was tinted probably had no effect upon the outcome of the experiment. Wolf has found that he can almost obliterate any evidence of a UV effect by use of a nearly monochromatic green testlight instead of a white testlight (15). However, the excitation purity of the wedge employed in the study reported here was only 0.1016 while that of Wolf's green testlight must have been very close to unity. Obviously, our wedge was, in comparison with the green interference filter used by Wolf, for all intents and purposes equivalent to a neutral density filter. The near-neutrality of the wedge is clearly shown by the fact that the greenish tint of the dark adaptation field was detectable only during "time" exposures of that field to the light-adapted eye.

All Ss had normal color vision; one had normal acuity (BH), the other two Ss were myopic. Despite their visual handicaps, the performances of GF and HW do not seem to differ in any significant way from that of BH.

RESULTS

The course of dark adaptation following exposure to the UV and control fields at high brightness is depicted in Figure 5; that following light adaptation to the corresponding fields at low brightness is shown in Figure 6. In both figures the I-shaped bars represent the mean threshold plus and minus one standard deviation at a given time after exposure to the control field; the filled circles represent the mean threshold after exposure to the UV field. The variability under the UV conditions was comparable to that for the control conditions; therefore, an index of its magnitude was omitted from Figures 5 and 6 in the interests of clarity of presentation. The mean standard deviations obtained under each of the four conditions

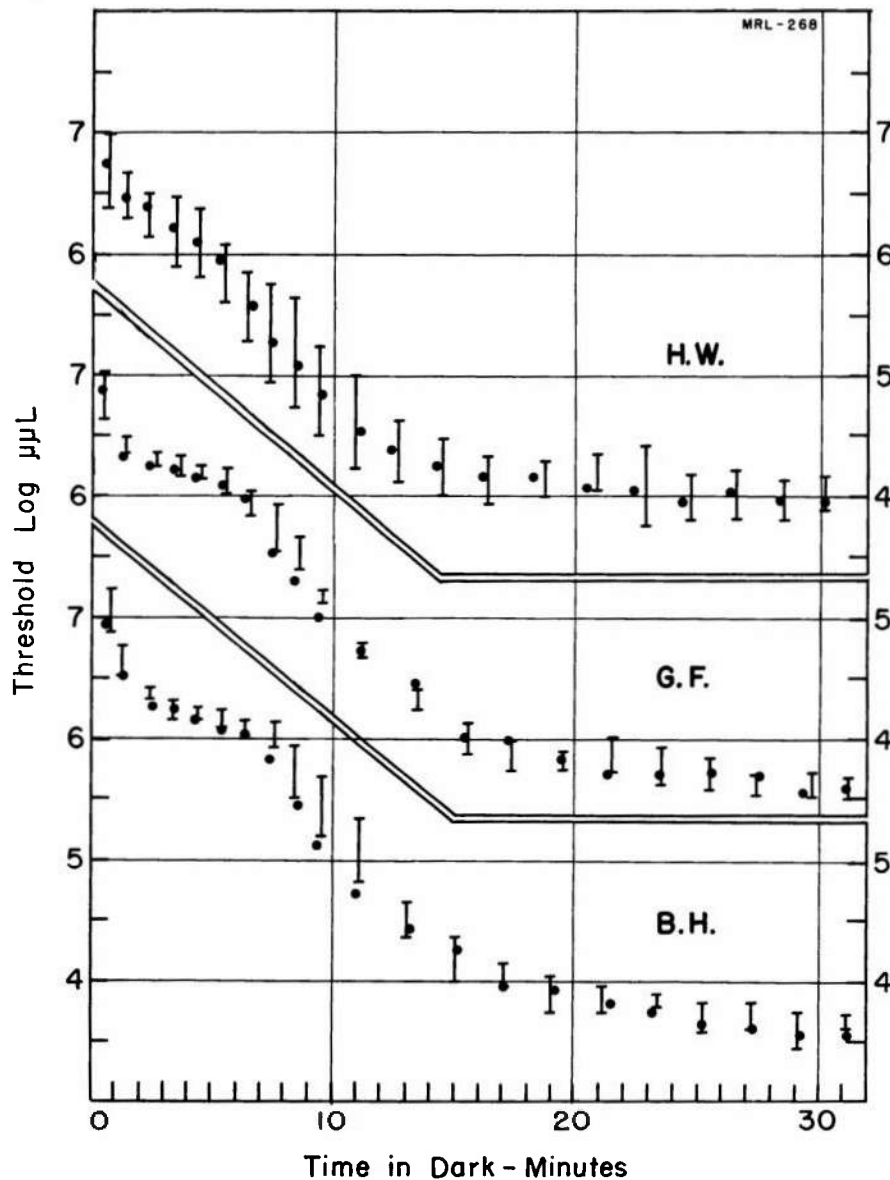


Figure 5. - Mean dark-adaptation threshold values and the limits of plus and minus 1SD following light adaptation to 288mL with or without ultraviolet components. The SDs are shown for the control condition only. Each pair of curves represents the performance of one subject.

of this experiment are of the same order of magnitude as those found by Mote, et al. (3) in a study of session-to-session variability in dark adaptation.

The important aspect of Figures 5 and 6 is the relation between the thresholds obtained after exposure to the UV and control fields. Clearly, there is no evidence of effects such as those observed by Wolf. However, comparison of Figures 5 and 6 reveals that

exposure to the higher brightness delayed the appearance of the rod portion of the curves and raised the threshold during the last 5-6 minutes relative to that obtained following exposure to the lower brightness. Increasing the brightness of the light adaptation field raised the mean threshold during the last 5-6 minutes by 0.12 log units for three Ss, but the mean difference due to variation in the spectral composition of the light adaptation source was only -0.02 log units.

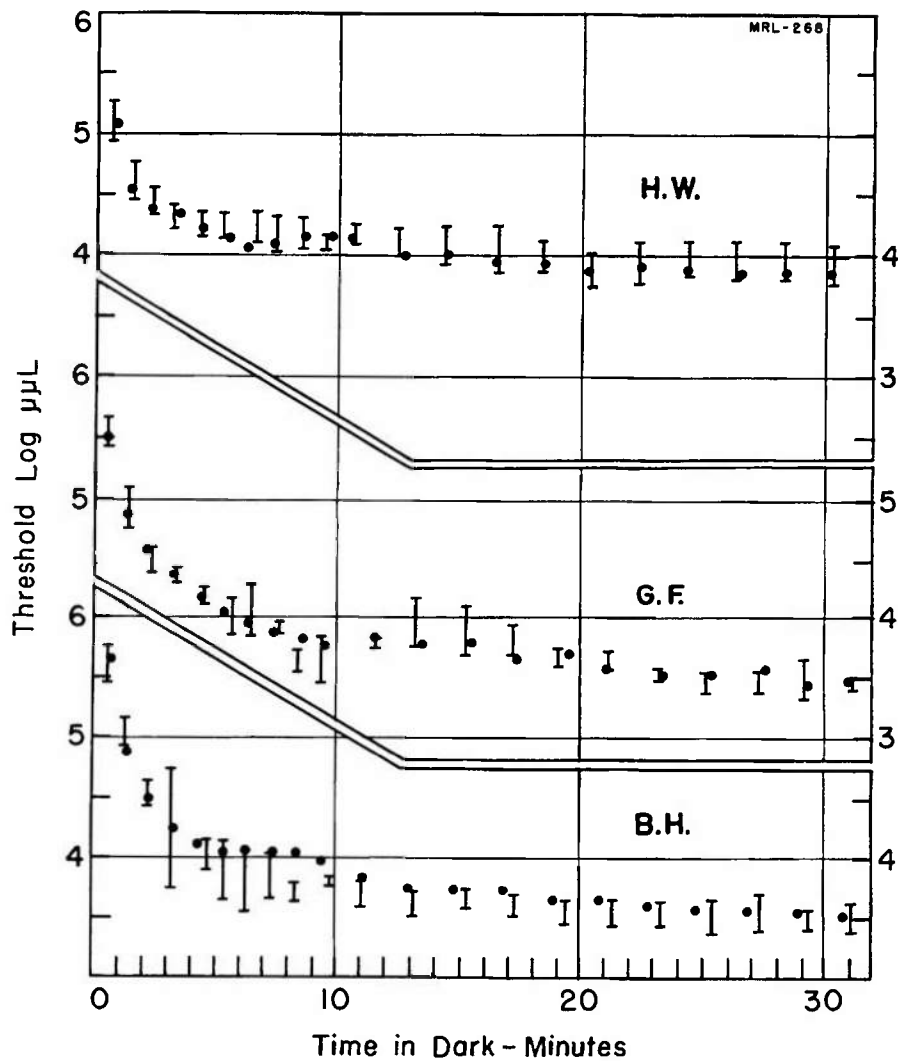


Figure 6 - Mean dark adaptation threshold values and the limits of ± 1 SD following light adaptation to a 3.6 m μL field with or without ultraviolet components. The SDs are shown for the control condition only.

The results of an analysis of variance of the means of the last four measures obtained in each session are presented in Table II. This analysis shows that the difference between thresholds due to variation in brightness of the light adaptation field is reliable; that arising from variation in the spectral composition of the source is not. The non-significant F for weeks simply indicates that there were no reliable systematic variations in the Ss thresholds from week to week.

Since the interaction of brightness levels with spectral composition of the source is not significant, there is no evidence in this experiment that the Wolf effect depends upon the proportion of near ultraviolet radiation in the light adaptation field. The remaining interactions are not significant; this indicates that the relations between the measures obtained under the several conditions were relatively stable.

TABLE II - Summary of Analysis of Variance for Final Threshold Values.

Source	df	Mean Square	F	F	P
Spectrum (A)	1	0.0077	A/AS	1.54	
Brightness (B)	1	0.1995	B/BS	19.56	.05
Weeks (W)	4	0.0459	W/WS	1.59	
Subjects (S)	2	0.8926			
A x B	1	0.0038	AB/ABS	0.24	
A x W	4	0.0050	AW/AWS	0.53	
A x S	2	0.0050			
B x W	4	0.0057	BW/BWS	0.39	
B x S	2	0.0102			
W x S	8	0.0289			
A x B x S	2	0.0158			
A x B x W	4	0.0012	ABW/ABWS	0.14	
A x W x S	8	0.0095			
B x W x S	8	0.0146			
A x B x W x S	8	0.0086			
Total	59				

DISCUSSION

The experiment reported here does not provide any evidence that exposure to substantial quantities of near ultraviolet energy has a direct deleterious effect upon subsequent dark adaptation. In particular, the course of dark adaptation and the threshold at 25-30 minutes were found to be the same following exposure to fields of equal brightness with or without ultraviolet components. Further, since the difference between the thresholds at 25-30 minutes after exposure to the ultraviolet and control fields is negligible for both brightness conditions, there is no evidence that the ratio of ultraviolet to visible energies in the light adaptation fields is a significant variable in studies such as this.

Viewed formally, failure to find an effect does not establish that there is none. However, the demonstration of a brightness effect of only 0.12 log units in this study seems to indicate that the techniques employed in the collection and analysis of the data were sensitive enough to permit detection of any appreciable influence of the near ultraviolet. It should be noted that the F for comparison of the UV and control conditions is non-significant because the mean effect of spectral composition was small not because the error term is large or the degrees of freedom are few. The analysis would have detected a deleterious UV effect of only 0.09 log units if such an effect had occurred, and the contributions of all other factors had remained as they were in this experiment.

The results of this experiment are not in direct conflict with those reported by others insofar as no attempt was made to duplicate those experiments exactly. Aside from variations in procedure which should not lead to differential effects upon dark adaptation following exposure to the two kinds of radiation, this experiment differed from most previous studies in two ways. This was the first study in which the experimental and control light adaptation fields were exactly alike photometrically and colorimetrically for each observer. Also, in all other studies, except one (13), the light adaptation brightnesses were much higher than those employed in this experiment. High brightness of the light adaptation field does not seem to be necessary to production of the Wolf effect, for in his experiment cited above (13), the final rod threshold was raised 0.25 log units when the spectrum of the 50 m μ L light adaptation field contained near ultraviolet components. Since the ultraviolet effect has been observed with low levels of light adaptation brightness, it appears that this experiment can be reconciled with those yielding positive findings only in terms of the failure in those studies to match the fields photometrically and colorimetrically, or perhaps to some differences in procedure which have not been found relevant in studies of other aspects of dark adaptation. In order to further delimit the conditions necessary for production of the Wolf effect, a second experiment which more closely approximated the original Wolf study with humans was undertaken.

Experiment II

This study was an attempt to obtain results similar to those reported by Wolf (11) in a situation basically like that employed in the first experiment reported here. It was hoped that systematic investigation of the conditions yielding such findings might permit discovery of the source of the apparent contradiction between those data and the negative findings of the first experiment in this series. In order to provide more favorable conditions for demonstration of an ultraviolet effect with the kinds of optical systems employed in the first experiment,

the apparatus and procedure were modified in several respects. The period S spent in the dark prior to light adaptation was doubled in length as an extra precaution against contamination of the data by the effects of visual stimulation immediately prior to the experimental sessions. Light adaptation was carried out with a bright source rich in ultraviolet radiation and with filters of the type used in the original Wolf experiment with humans (11). This change was made so that the light adaptation fields would be comparable in brightness and in intensity of ultraviolet components to those employed by Wolf (11). Finally, the Hecht-Shlaer adaptometer used in this second experiment was equipped with a neutral density wedge rather than a tinted wedge such as was supplied with the adaptometer employed in the first study. This change was made so that there would be no possibility that the color of the test field would favor one condition over the other.

METHOD

The apparatus was arranged as in the first experiment except that a Hanovia type-560-watt mercury-arc lamp was the sole source for the ultraviolet and control light adaptation fields. Figure 7 shows the spec-

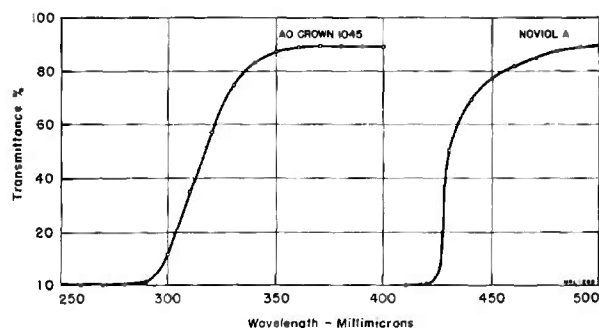


Figure 7. - Transmission of American Optical Company Crown 1045 and Corning Noviol A filters employed to control ultraviolet content of the light adaptation field.

tral transmission of the AO 1045 Crown and Corning Noviol A filters interposed between the magnesium oxide screen and the evaporated aluminum mirror to provide the near ultraviolet and control fields.* A spectrograph which was obtained at the eyepiece of the adaptometer is reproduced in Figure 8.

It shows that the mercury-arc lamp and the Crown filter together provided the complete mercury spectrum down to 290 mμ.; the

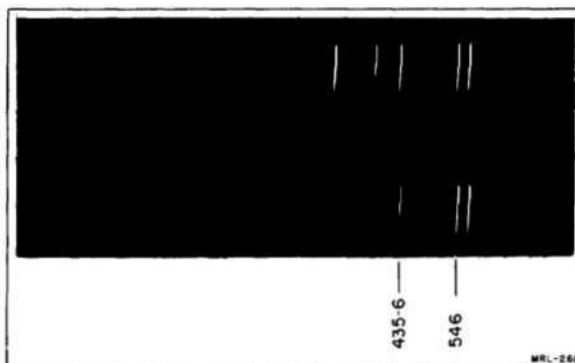


Figure 8. - Spectrographs of radiation from the Hanovia type A mercury-arc lamp incident upon the observer's eye under the two light adaptation conditions. The upper spectrum is that passed by the AO Crown 1045 filter; the lower is that passed by the Noviol A filter.

lamp and the Noviol A filter provided that portion of the mercury spectrum extending upward from 430 mμ. Similar spectrographs were obtained weekly during the experiment.

The powerful type-A mercury-arc lamp provided a brighter light adaptation field, 3000 mL, and stronger ultraviolet components than did the mercury-arc sources used in the first experiment. With the Corning 5840 filter used in the first experiment substituted for those used in this study, the total irradiance at the adaptometer eyepiece in the plane of the pupil was 8.0 uw/cm². That value appears as the measured irradiance of the "UV Field-Exp II" in Table I. The calculated energy value of the ultraviolet field presented in Table I was derived by correcting the measured value for the relative transmissions of the Corning 5840 and AO 1045 Crown filters at 365 mμ. This rough approximation indicates that the change in the light adaptation procedure from the first to the second study resulted in a six-fold increase in the ultraviolet energy content of the ultraviolet field.

The brightness of the light adaptation fields was determined by means of the technique employed for the brightness and color matches of the first experiment. During the first session of each week, S calibrated a 500-watt projection lamp, substituted for the 40

*The AO Crown Filters were generously supplied by Dr. Oscar Richards of the American Optical Company

w. working lamp of the adaptometer, against the standard lamp supplied with the adaptometer. A ground glass filter diffused the projection lamp beam. The projection lamp was then matched in brightness to both the control and the ultraviolet light adaptation fields. The two light adaptation fields were found consistently to be comparable in brightness although the order in which they were matched was varied at random from S to S and week to week. There were, however, appreciable differences in the colors of the two light adaptation fields which were accentuated when they appeared as surrounds for the 5° projection lamp field. For both matching and light adaptation, fixation was on a small black spot located on the magnesium oxide screen. The position within the visual field of the spot coincided with that of the adaptometer fixation light when the latter was placed 10° to the right of the dark adapta-

tion field.

Each of the four Ss contributed eight dark adaptation curves, four under each condition. During each week, S adapted in one session to the UV field and in the other to the control field. The order in which the conditions were presented was varied randomly from S to S and week to week. AF, AM, and GS, had normal acuity; JS was myopic.

Following a 30 min. period in the dark, S adapted to the appropriate field for 10 minutes. The fixation point was located 10° temporally in the approximately 35° rectangular light adaptation field. During dark adaptation, the $1/25$ sec. test flash stimulated a 5° temporal area situated 10° from the red fixation light. Thresholds were determined with 5 mm. steps of the wedge except during the final five minutes of each session when 1 mm. steps (0.016 log units) were employed.

RESULTS

The findings of this experiment were essentially negative. As can be seen in Figure 9, there is no consistent evidence that exposure to the near ultraviolet has a deleterious effect upon subsequent dark adaptation. Each pair of curves in Figure 9 shows dark

adaptation thresholds for one subject. The I-shaped bars represent the mean threshold plus and minus one standard deviation at a given time after exposure to the control field; the filled circles represent the mean threshold after exposure to the UV field.

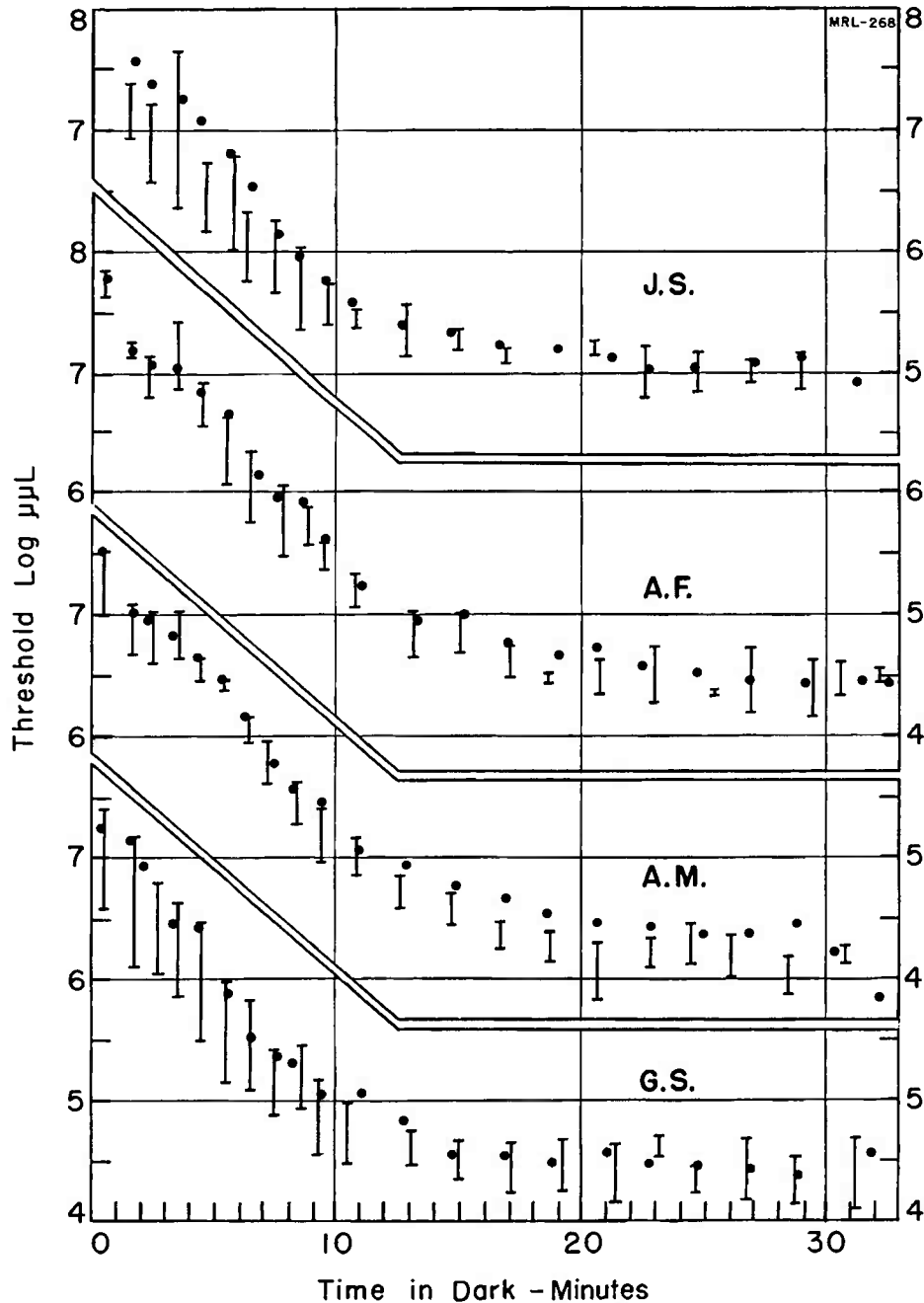


Figure 9. - Mean dark adaptation threshold values and the limits of ± 1 SD following light adaptation to radiation from a Hanovia Type A mercury-arc filtered by AO Crown 1045 or Corning Noviol A. The SDs are shown for the control condition only. Each pair of curves represents the performance of one subject.

The results of an analysis of the means for the last 6-8 minutes of each session are presented in Table III.

TABLE III - Summary of Analysis of Variance for Final Threshold Values in Experiment II.

Source	df	Mean Square	F	F	p
Spectrum (A)	1	0.049	A/AS	3.50	
Weeks (B)	3	0.026	B/BS	0.33	
Subjects (S)	3	0.976			
A x B	3	0.012	AB/ABS	0.92	
A x S	3	0.014	AS/ABS	1.08	
B x S	9	0.079	BS/ABS	6.08	0.01
A x B x S	9	0.013			
Total	31				

The non-significant Fs for spectrum and the interactions involving spectrum mean that any differences which seem to be associated with variations in the nature of the light adaptation field are not reliable. The significant week by subjects interaction simply means that the subjects' general level of sensitivity during dark adaptation followed different trends for the several subjects from week to week. The non-significant F for weeks, however, shows that there were

no reliable systematic changes in dark adaptation thresholds during the experiment.

As a further check of the adequacy of the procedure employed in this study, tests of dark adaptation under the two conditions were conducted during a single three-hour session. During these tests, S served under one condition, then, after a half-hour rest in the dark, in the other condition. In all other respects these tests duplicated those made in the shorter sessions. The one S available for these tests (A.F.) participated in two sessions. In the first session the order of conditions was control-UV; in the second session the order was reversed to provide a basis for evaluation of order effects. The results of this exploratory study are shown in Figure 10. Again there is no evidence that exposure to the near ultraviolet affects the final threshold in subsequent dark adaptation. The data in Figure 10 also seem to indicate that there was no order effect.

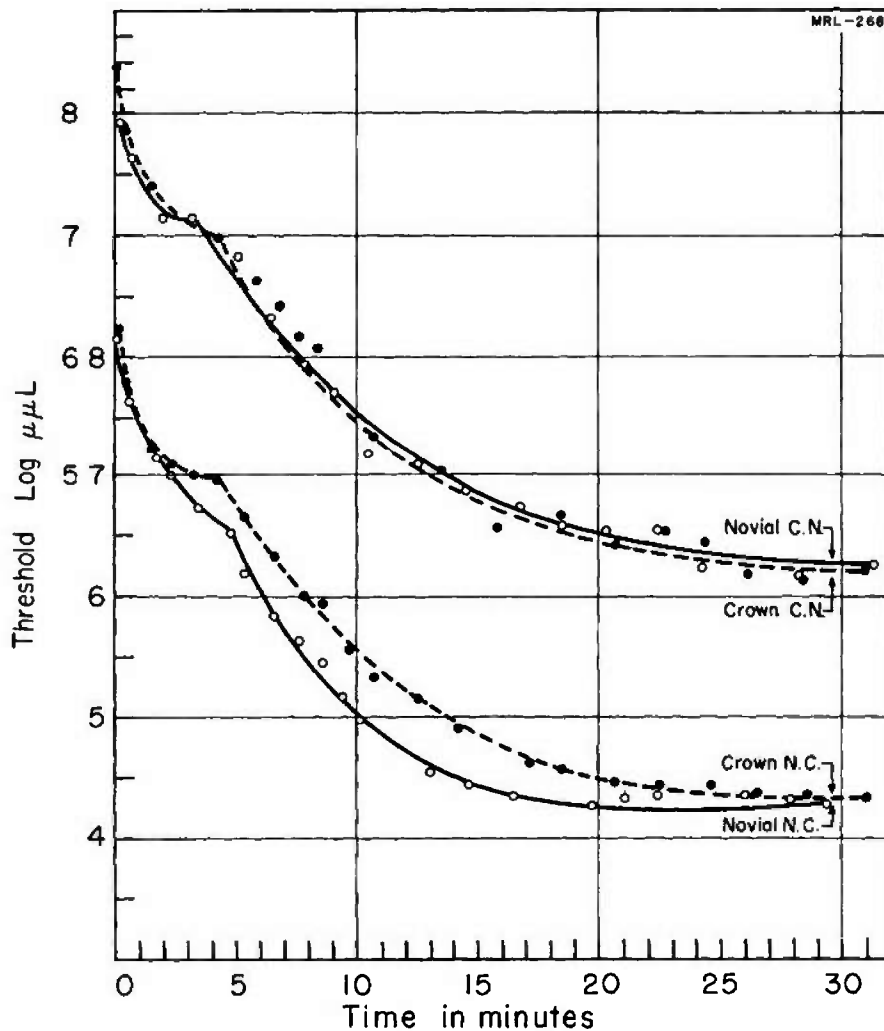


Figure 10.- Dark adaptation thresholds for AF in two 3-hour sessions.

DISCUSSION

Although more favorable conditions for demonstration of an ultraviolet effect, including a considerable increase in the amount of ultraviolet energy reaching Ss eye, were provided in these experiments than in the first study of this series, there is no clear evidence that exposure to the near ultraviolet retards subsequent dark adaptation.

The two studies reported here seem to cover the extremes of those situations in which any effect of the near ultraviolet upon dark adaptation should be demonstrable. In the first experiment, it would have been impossible to obtain evidence of an ultraviolet effect unless it were due to a simple reduction of retinal element sensitivity by the invisible near ultraviolet. That, then, was a very stringent test. The demonstration of a brightness effect, however, showed that the method and apparatus employed were adequate for demonstration of very slight disturbances of the course of dark adaptation. In the second experiment, a difference in dark adaptation thresholds under the two conditions could have arisen from extraneous factors such as differences between the visible spectra of the two light adaptation fields. That experiment, then, should have made demonstration of an ultraviolet effect very easy. The only conclusion possible is that the positive findings reported by others have arisen from the influence of a very complex set of factors. The recent report (15) that exposure of the right eye to a light adaptation field which had ultraviolet components raised the final dark adaptation threshold for the left eye is clearly in line with that conclusion.

Since the experiments which have resulted in positive findings have been conducted with some variation in the conditions of both light adaptation and dark adaptation, it should not be difficult to duplicate those findings. However, neither in the experiments reported here, nor in four other series of studies (1,5,7,8,) has such evidence been obtained. The influence upon dark adaptation of normal variations in the environment and in the subject's physiological condition seems to be considerably more potent than might be any exerted by the near ultraviolet.

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