TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No. FAA-AM-72-8	2. Government Accession No.	3. Recipient's Catalog No.

4. Title and Subtitle
EFFECTS OF BACKSCATTER OF BRIEF HIGH INTENSITY LIGHT ON PHYSIOLOGICAL RESPONSES OF INSTRUMENT-RATED PILOTS AND NON-PILOTS

5. Report Date
March 1972

6. Performing Organization Code

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10. Work Unit No.

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
OAM Report

14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

Thirty-nine human subjects were exposed to repetitive backscatter light stimulation (off a white wall or fog) from a Grimes capacitance discharge airplane anticollision light flashing at 1.27 Hertz. Both tonic (light stimulus absent) and phasic (light stimulus present) stimulus-bound occipital EEG, heart rate, respiration, skin potentials, and eyeblinks were recorded. In the first experiment, response decrement (habituation) to the flashing light occurred only with one out of five response measures (skin potential) over a 40-trial session indicating that the flashing light was a potent stimulus. None of the subjects demonstrated photic driving, seizure activity, or theta wave activity in his EEG. Most subjects reported the light as noxious, none became nauseated, but many became drowsy over the course of the experiment and several reported dark deadaptation from the flashing light. In Experiment II, eyeblink and skin potential measures differentiated between an instrument-rated pilot group and an age-matched control group of non-pilot professional men.

The results suggest that, although the flashing anticollision light induces changes in physiological measures which are resistant to habituation, these changes do not extend to the induction of nausea.

7. Key Words
Effects of Backscatter, EEG, Heart Rate, Respiration, Skin Potential, Eyeblinks, Anticollision Light

18. Distribution Statement
Availability is unlimited. Document may be released to the National Technical Service, Springfield, Virginia 22151, for sale to the public.

9. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 9	22. Price $3.00

rm DOT F 1700.7 (8-69)

ACKNOWLEDGMENTS

We wish to thank the FAA Civil Aeromedical Institute in Oklahoma City, Oklahoma, for the use of its facilities during our data collection for Experiment II and Drs. P. F. Iampietro and C. E. Melton for their assistance and advice. We also thank Dr. E. A. Higgins, who manned the fog generator in Experiment II, and Gerald Vardiman, who worked hard and ably as our assistant.

EFFECTS OF BACKSCATTER OF BRIEF HIGH INTENSITY LIGHT ON PHYSIOLOGICAL REPONSES OF INSTRUMENT-RATED PILOTS AND NON-PILOTS

The view is fairly common that some of the mmediate effects of intermittent photic stimula-ion may result in altered states of consciousness, ertigo, fear and visceral disturbances.[2 3 17 18 19] 'his has wide implications for people exposed o flickering light stimulation. Of most concern s the effect of intermittent light stimulation on irplane pilots since impairment of ability to unction can have the gravest consequences in he event of an emergency.

The nature of the evidence for the view that ıtermittent photic stimulation can cause impair-ıent of ability to function comes from several ources. First, much of the evidence is of an necdotal sort and as such presents problems of valuation. The second form of evidence comes rom clinical EEG laboratories where intermit-nt photic stimulation is used as a tool in assess-ıg epilepsy. The third type of evidence comes om experimental research laboratories. Since ıere are wide variations in research methodol-gy, the intensity of the photic stimuli used, the ıte at which the light pulses were presented, ıd in the subject populations employed, there room for contradictory claims. Discussion of ifferent aspects of the problem as well as good views of the literature are abundant.[1 4 7–11 15 16 20]

Most of the earlier experiments dealing with ıe effects of intermittent light stimulation on ıysiological indices and performance have em-oyed frequencies higher than the flash rates of ost airplane anticollision lights and have used ectroencephalograms almost exclusively as the dex of physiological response. These studies not bear as directly on the problem confront-g pilots flying through clouds or fog as would udies which use flash frequencies in the range countered by pilots. It was the purpose of the st experiment to determine under controlled nditions the effects of brief high intensity light pulses from an actual airplane anticollision light flashing at 1.27 Hertz on a variety of physiological measures in a normal non-pilot population. Post-experimental verbal reports of the experience were also obtained from the subjects.

EXPERIMENT I

Methods

Subjects. A group of 13 young adult males (age range 17–25 years) comprised of medical students from the University of Oklahoma Medical School and introductory psychology classes from Oklahoma City University with no history of epilepsy participated in the experiment. Each experiment lasted for about one hour. Subjects were paid for participation in the experiment.

Procedure. Upon arriving at the laboratory, subjects were told that they would be part of a visual stimulation experiment and that a variety of physiological responses would be monitored. Skin surfaces where recording electrodes were to be attached were cleaned with acetone. Grass silver cup electrodes were used to record EEG and eye blinks. The occipital EEG lead was attached 1 cm above and 1 cm to the right of the occiput. This lead was referenced to the ipsilateral ear lobe. For eye blinks, leads were attached above and below the left eye. Plate EKG leads were attached on the right shoulder and on the chest below the heart. Beckman skin potential leads were attached to the second finger tip of the left hand and to the volar surface of the left arm. A common ground lead was attached to the volar surface of the left arm above the reference skin potential lead. A strain gauge respiration lead was attached across the chest at the bottom of the rib cage. Physiological responses were recorded on a Beckman Type RM rectilinear inkwriting dynograph running at a paper speed of 10 mm/sec.

Design. The experiment was set up to provide 40 trials, each of which was 10 seconds in duration, of high intensity condenser discharge light stimulation. The light source was a Grimes model no. 30–360–1 high intensity condenser discharge airplane anticollision light. Flash rate was constant at 1.27 flashes per second. The intertrial interval between each 10 seconds of flash stimulation was 30–90 seconds, varying randomly in 15-sec steps as determined by a table of random numbers. A Gerbrands tape programmer turned on a Hunter 111C timer for 10-second periods at the randomly prescribed intervals. The Hunter timer, in turn, controlled the power source to the Grimes light. Preliminary tests indicated that the sound of the capacitor charging in the Grimes light was a confounding cue which would trigger physiological responses not due to the light flashes. To circumvent this problem, a Grason-Stadler 901B white noise generator was employed in conjunction with a Koss Pro 4A headphone set. Further testing revealed that an 80 db re: .0002 dyne/cm^2 white noise effectively masked the capacitor charging sound and other equipment sounds.

Response quantification. Occipital EEG was recorded with a 0.3-second time constant and at a gain of 50 μ volts/cm. To be scored as alpha wave activity, two or more consecutive brain waves of 8–12 Hertz had to be present in the EEG. Visually, alpha stands out from the background EEG in the awake subject by being of larger amplitude than the background activity and by exhibiting synchrony (i.e., when alpha occurs, it is generally present in "bursts" of several waves in a row). The percent alpha in the 10 seconds preceding each stimulus was scored as well as the percent alpha in the 10 seconds during flashing light stimulation.

Eye blinks were recorded at a gain of 0.2 mv/cm with a 0.1-sec time constant. Since spontaneous blinks occur with a frequency greater than zero and the spontaneous blink rate varies among individuals, blinks were scored both during the 10 sec preceding each stimulus and during the 10 sec of each stimulus.

Skin potential responses were recorded with a 1.0-sec time constant at a gain of 0.5 millivolts/cm. Response amplitude was measured in millivolts from response onset to peak of response. Response amplitudes were summed separately for the 10-sec pre-stimulus periods and 10 sec during light stimulation periods to yield baseline and stimulus-elicited responding scores, respectively.

Respiration rate was recorded with a 1.0-se time constant. A flexible tube, which change its resistance when stretched, was taped to th subject's chest. This changing resistance wa part of one arm of a Wheatstone bridge circuit The distance between respiration peaks wa measured and converted to rate/min. Rate i the 10 sec preceding a stimulus and the firs complete respiration cycle during the stimulu were recorded for each trial.

Heart rate was recorded by a cardiotachomete coupler. It was qualified in terms of mean beat per minute change from the mean of the 10-se period before stimulation compared to the 10 se during stimulation.

Results

All trials effect comparisons were based on th nonparametric Friedman analyses of varianc pre-during stimulus comparisons and specif trial comparisons were based on correlated di ference between means t-tests. The $p<.05$ tw tailed rejection region was adopted throughou

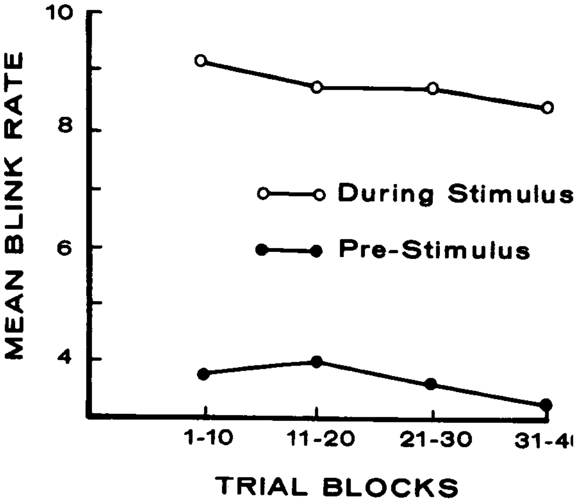
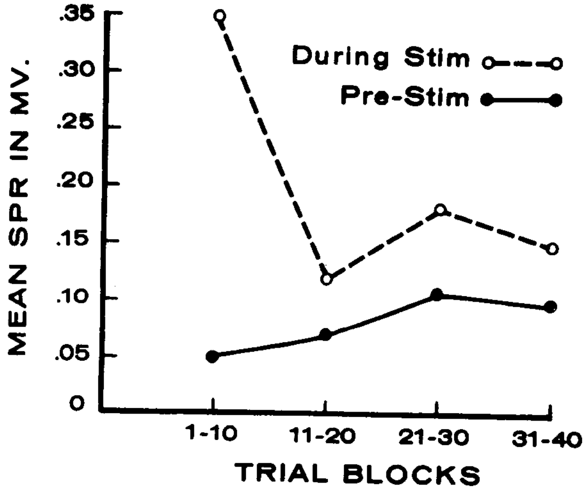


FIGURE 1. Mean number of eye blinks in 10 trial blo pre- and during- light flash stimulation.

Figure 1 summarizes the results for the e blink data. Both the mean pre-stimulus bl rate and the mean rate of blinking during ph stimulation are presented in 10 trial blo Several results are evident from this fig First, collapsing the data across trials, there a highly significant increase in blinking to the light flashes when compared with the pre-stimulus blink rate ($t=8.30$, $df=12$, $p<.001$). Second, *the blinking* rate to the flashing lights did not habituate as indicated by a nonsignificant Friedman nonparametric analysis of variance for trend across trials. Third, no significant changes in basal blink rate occurred over trials as indicated by a second Friedman analysis of variance.



IGURE 2. Mean magnitude of skin potential responses in millivolts for 10 trial blocks pre- and during-light flash stimulation.

Figure 2 summarizes the results for the skin otential data. A Friedman nonparametric alysis of variance indicated that the decrement responding across trial blocks was significant C=12.15, df=3, p<.01). Further testing incated that a significant decrement occurred beeen the first and second trial blocks ($t=2.51$, $=9$, $p<.05$). None of the other comparisons as significant. Thus, most of the decrement curred in the first 10 trials with no consistent ange occurring thereafter.

Figure 3 summarizes the results for respiration ta in 10 trial blocks. Collapsing across trials, significant difference in respiration rate was und with rate increasing during photic stimution when compared to the rate just preceding otic stimulation ($t=2.83$, $df=9$, $p<.02$). The spiration changes across trial blocks were not gnificant for either the pre- or during-stimulus te.

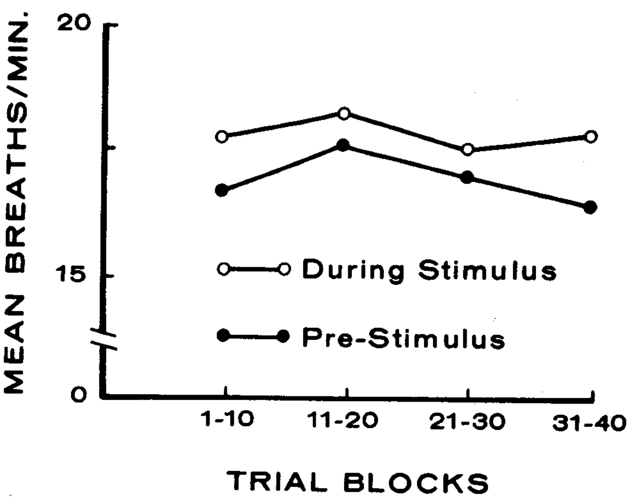


FIGURE 3. Mean rate of respiration in 10 trial blocks pre- and during- light flash stimulation.

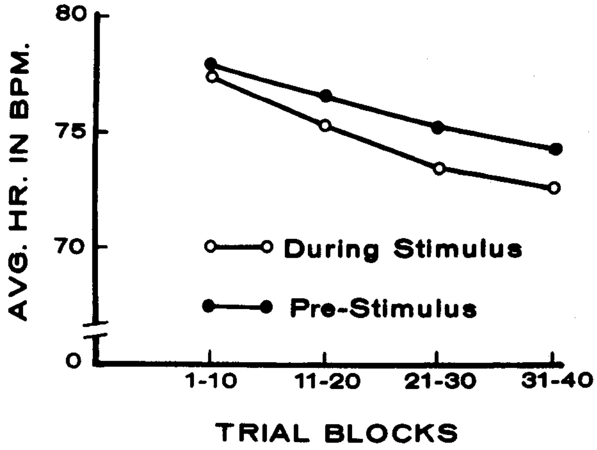


FIGURE 4. Mean heart rate over 10 trial blocks pre- and during- light flash stimulation.

Figure 4 summarizes the results for heart rate data over trial blocks. Collapsing across trials, a small but highly reliable heart rate deceleration was found when comparing pre- with during-stimulus heart rate ($t=5.65$, $df=12$, $p<.001$). The decrease in basal heart rate as measured over trial blocks in the pre-stimulus interval was not significant ($C=4.88$, $df=3$, $p<.05$). However, the heart rate decrease across trial blocks during light stimulation was significant ($C=13.3$, $df=3$, $p<.01$).

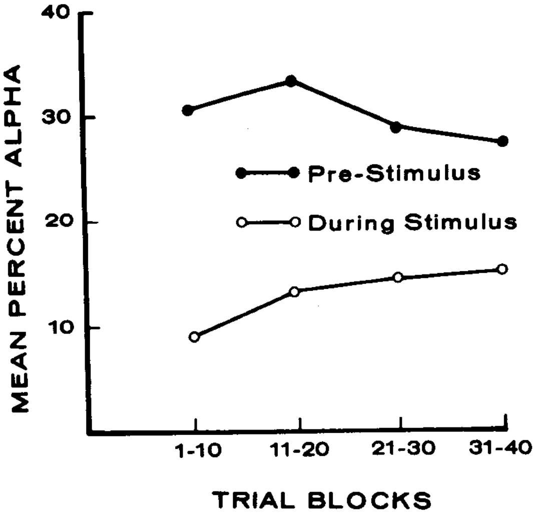


FIGURE 5. Mean percent brain wave activity in the alpha range (8–12 Hertz) for 10 trial blocks in the pre- and during- light flash periods.

Figure 5 presents the mean percent brain wave activity in the alpha range (8–12 Hertz) in the pre-stimulus period and in the light stimulus period across trial blocks. As is evident from Figure 5, there was a highly reliable reduction in alpha activity while the light was flashing when compared to the pre-stimulus alpha baseline ($t=3.68$, $df=12$, $p<.001$). Although Figure 5 shows an increase in percent alpha over trial blocks in response to the light stimulus, the trend was not significant ($C=2.82$, $df=3$, $p>.05$). Similarly, the changes in percent baseline alpha over trial blocks were also nonsignificant ($C=1.2$, $df=3$, $p>.05$). In summary, these tests indicate that habituation of alpha blocking to light stimulation did not occur.

Questionnaire data indicated that none of the subjects became nauseated during the experiment. A majority found the light flashes irritating or annoying. A couple of subjects claim that they experienced "eye strain" or "eye fatigue" from exposure to the light flashes. Several reported that for about 1–2 seconds after photic stimulus offset the room background illumination seemed to dim and the room and everything in it appeared subjectively darker. Most of the subjects reported drowsiness toward the end of the experiment.

EXPERIMENT II

Since the subjects in the first experiment were not pilots and the possibility exists that pilots may respond differently to flashing lights than non-pilots, the first experiment was repeated, but it utilized instrument-rated pilots as subjects as well as an age-matched control group of non-pilots. Secondly, the actual back-scatter conditions were simulated more closely by using back scatter from man-made fog as the stimulus.

Methods

Subjects. A group of 12 instrument-rate pilots from the Oklahoma City area and a grou of 14 non-pilot professional men from the University of Oklahoma Medical School served a subjects in the experiment. The average age o the subjects was 40 years. Pilots and non-pilot did not differ significantly on average age. Eac session lasted about 80 minutes. At the end c the experiment subjects were administered post-experimental questionnaire. Post-exper mental verbal reports and ratings were also ol tained from the subjects. Subjects were paid fc participation in the experiment.

Procedure. Upon arriving at the laborator subjects were told that they would be a part of visual stimulation experiment and that a varie of physiological responses would be monitore Electrode placements and data quantificatic were the same as in Experiment I except th the pulse train duration in Experiment II w extended to 40 seconds for pre- and durin stimulus measures. For eye blinks, skin pote tial responses, and alpha EEG activity, da were quantified over 40-second intervals inste of the 10-second intervals of Experiment I. F heart rate the data were scored over the 10 se onds preceding a stimulus and the first ten se onds during the stimulus because prelimina data indicated that that is where the chang were taking place. Respiration was not scor in the second experiment because of recordi difficulties with the transducer.

Experiment II was performed in the f chamber of the Civil Aeromedical Institute the FAA Center in Oklahoma City. After bei instrumented, the subject, clad in a surgi gown, was placed in a semi-reclining position a plastic lawn chair in the fog chamber. T temperature was 72° F.±2° and the humid vas 100%. A flashing Grimes airplane antiollision strobe light was placed below and beind the subject. The fog density was such that *either the* experimenters nor the subject could ee more than five feet in the fog chamber. On wo occasions the fog generator iced up and the ata from the subjects were not used because the og density thinned visibly.

Design. The experiment was designed to proide 20 trials, each 40 seconds in duration, of epetitive high intensity condenser discharge ght stimulation. The light source was a Grimes odel no. 30–360–1 high intensity condenser ischarge airplane anticollision light. Flash rate as constant at 1.27 flashes per second and flash uration was $\approx$ 10 μsec. The intertrial interval as 30–90 seconds, varying randomly in 15-sec eps as determined by a table of random numers. A Gerbrands tape programmer operated Hunter 111C timer for 40-second periods at the ndomly prescribed intervals. The Hunter timer, turn, controlled the power source to the Grimes ght. Sound masking was provided by a Grasontadler 901B white noise generator via a Koss ro 4A headphone set. The white noise genator was set to provide 80 db re: 0.0002 dyne/ n^2 white noise at the earphones.

Both instrument-rated pilots and the control oup of non-pilots received the same sequence 20 trials of flashing light stimulation. For e pilot group a 100-watt overhead light was in the fog chamber at all times during the periment.

The non-pilot matched control subjects reived the flashing light under two conditions. or one-half of the control subjects the overhead ght was on for the first half of the experiment d was turned off for the second half of the periment. For the second half of the control bjects, these conditions were reversed. This ocedure tested the hypothesis that the physiogical and subjective effects of the flashing ght stimulus are determined, in part, by conast or amount of light change.

For each response measure the data were alyzed by 3-factor repeated measures (Case 1) alyses of variance.[21] Factor one was the inument-rated pilot versus non-pilot dimension. ctor two was the pre-stimulus basal measure mpared with the during-stimulus measure. ctor three was repetition, i.e., response change over 4 trial blocks. In all cases two-tailed tests were used and the criterion for rejection of the null hypothesis was set up at $p<.05$ or better.

Results

Figure 6 summarizes the results for the eyeblink data. Both the mean pre-stimulus blink rate and the mean rate during light flash stimulation are presented for the four trial blocks. The instrument-rated pilots did not differ significantly in overall blink rate from the age-matched non-pilot group ($F<1$, $df=1, 22$, $p>.05$) indicating that the blink rate between groups was nondifferential. There was a significant groups-by-stimulus interaction ($F=11.46$, $df=1, 22$, $p<.01$), with the instrument-rated pilot group having a higher pre-stimulus blink rate than stimulus rate, whereas the group of non-pilot showed increased blinking during the flashing light stimulus over their pre-stimulus rate.

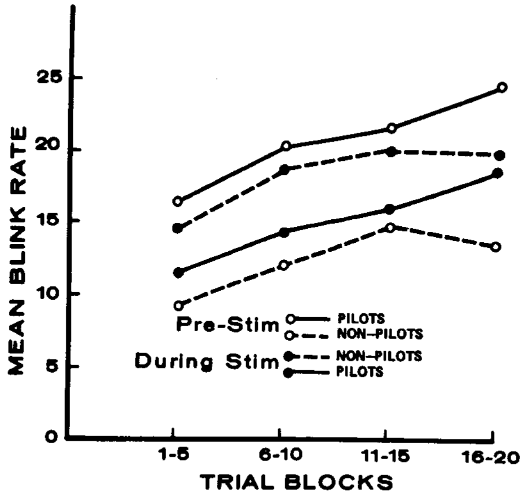


FIGURE 6. Mean number of eye blinks in 5 trial blocks pre- and during- light flash stimulation.

There was a significant trials effect ($F=4.64$, $df=3,66$, $p<.01$) indicating that blink rate increased over the course of the experiment. The groups-x-trials interaction was not significant, suggesting that both pilots and non-pilots contributed about equally to the significant trials effect.

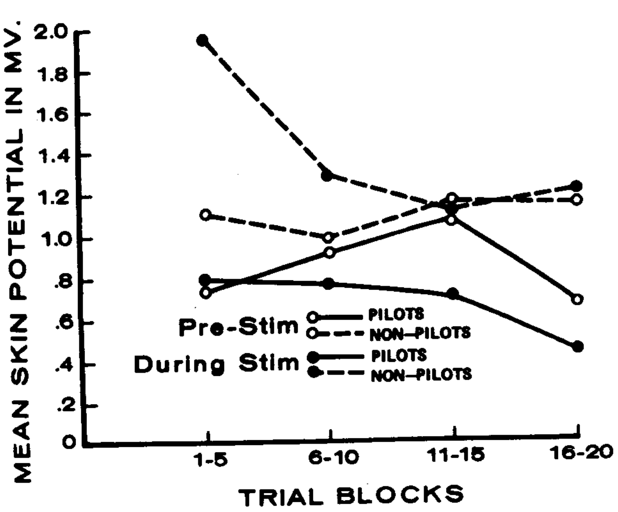


FIGURE 7. Mean magnitude of skin potential responses in millivolts for 5 trial blocks pre- and during- light flash stimulation.

Figure 7 presents the skin potential response data in summary form. The three-factor analysis of variance for the skin potential data indicates that (1) pilot and non-pilot groups did not differ in their overall level of skin potentail responding (F=1, df=1,22, p>.05); (2) there was a significant groups-x-trials interaction (F=3.48, df=3,66, p<.05). The interaction was due to the fact that pilots did not differ in their pre-stimulus or during-stimulus responses nor did they change their responding over trials. The non-pilot group, on the other hand, had a stable pre-stimulus response rate over trials but their response to the flashing light stimulus was largest initially and showed steady decrement (habituation) over trials.

Figure 8 summarizes the heart rate data. The analysis of variance of the heart rate data did not disclose any significnt differences between groups in either basal heart rate or in pre-during stimulus heart rate changes, although there was a non-significant decrease in rate from pre-stimulus base to stimulus for both groups. There was a significant trials effect (F=4.5, df=3,66, p<.01) indicating that for both groups heart rate decreased over trial blocks.

Figure 9 summarizes the EEG data. Figure 9, inconjunction with a three-factor analysis of variance, indicates that neither groups, nor stimulus, nor trials had any significant effect on percent alpha rhythm.

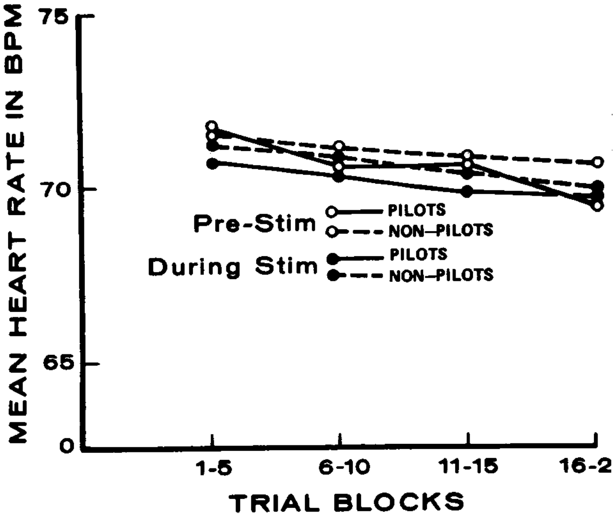


FIGURE 8. Mean heart rate in 5 trials blocks pre- anc during- light flash stimulation.

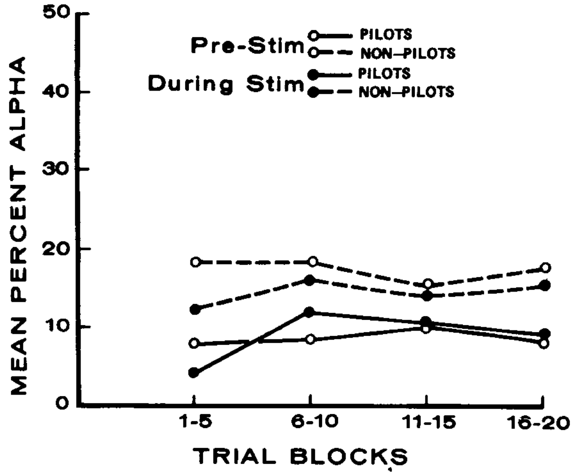


FIGURE 9. Mean percent brain wave activity in tl alpha range (8–12 Hertz) for 5 trial blocks in tl pre- and during- light flash periods.

In the control group there was suggestive ev dence with the physiological measures that tl degree of change or contrast determines tl amount of physiological responding to the flasl ing light. The control subjects who received tl flashing lights with the overhead light off r sponded with larger responses than did subjec who received the flashing light with the ove head lights on. The effect was not statistical significant because there was one reversal ar the sample size was too small to tolerate such reversal.

The post-experimental questionnaire results ndicated that none of the subjects in either pilot r non-pilot groups experienced any subjective eelings of nausea. Eight out of 12 pilots and even out of 12 non-pilots developed severe rowsiness over the course of the experiment. ome felt that had the experiment continued onger they could not have stayed awake. There as no difference in the noxiousness rating assigned to the flashing light by pilots or non-pilots. he non-pilot controls who received the flashing ght under overhead light-on and overhead ght-off conditions, rated the flashing light sigificantly more noxious when the overhead light as off (t=5.05, df=11, p<.001).

DISCUSSION

In Experiment I, 13 young adult males rang- g from 17–25 years of age were exposed to ery intense reflected intermittent light flashes om a Grimes condenser discharge airplane ticollision light. Their EEG, eye blinks, skin otential responses, heart rate, and respiration te were monitored. Over a 40-trial session, bituation (response decrement) occurred only ith the skin potential response.

In Experiment II, 26 adult males ranging om 31 to 51 years of age were exposed to very tense backscatter off man-made fog produced a Grimes condenser discharge airplane anti- llision light. Brain wave activity, eye blinks, in potential responses and heart rate were ntinuously monitored over the course of twenty -sec trains of light pulses. Heart rate and ain wave activity did not differentiate between oups, but significant differentiation occurred th eye blinks and skin potential measures.

In our sample of subjects neither photic driv- g nor EEG seizure activity occurred. These dings are in line with the results of previous periments which indicate that for both photic iving and EEG seizure activity, the adequate mulus is a light flashing at faster than 4 ertz.[8]

Data of the present experiment readily fit into e framework of the habituation literature.[6, 14] r finding that the skin potential response bituates sooner than does the occipital alpha ocking responses to intermittent light stimula- n supports the findings of Sokolov[12, 13] and his workers.

The fact the eye blinks to the anticollision light flashes showed no decrement over trial blocks in either Experiment I or II suggests that the reflected light may have been intense enough to elicit a protective reflex. None of the commercially made photic stimulators on the market puts out a light even approaching the intensity of the Grimes anticollision light. Thus, there is a scarcity of data with which to compare our findings on this point.

In Experiment II there was actually a significant increase in blinking in the pilot and non-pilot groups over trials. Since the increase occurred not only to the light stimulus but also during the pre-stimulus base level periods, it was probably not due to the effects of the light becoming more noxious over repeated presentations. A more parsimonious explanation would ascribe the increase to the humid environment. This interpretation is supported by statements of subjects from the post-experimental questionnaire.

The fact that pilots blinked less to the flashing light than during the pre-stimulus period can be ascribed to a combination of greater familiarity and possible adaptation to flashing light and to greater defensiveness by the pilots than non-pilots. Support for the latter interpretation comes from the post-experimental questionnaire. Several pilots volunteered the information that they actively resisted the effects of the flashing lights by concentrating on their great toe or on an imaginary instrument panel. Non-pilot subjects did not report engaging in such activities.

The skin potential data also offer support for the view that instrument-rated pilots were more defensive than non-pilot subjects. Whereas non-pilot subjects showed habituation of responding to the flashing light as had college students in Experiment I, the pilots by concentrating on something else while the light was flashing, were able to suppress their responses so that there was no difference in their pre-stimulus base versus during-stimulus response measures.

In our first experiment in which a younger, more responsive college student population was utilized for subjects, significant physiological changes to backscatter off a white wall from the Grimes light occurred in all measures (occipital EEG, skin potential, heart rate, respiration, eye blinks). In the second experiment, responses with occipital EEG and heart rate measures were not significantly different although they were in the same direction as had been the case in the first experiment. A plausible explanation for this discrepancy is attributable to either (1) the fact that the intensity of backscatter from fog in the second experiment was much less than the backscatter from the white wall in the first experiment, or (2) the fact that young college-age subjects are more responsive than are older subjects.

Our finding, that none of the subjects in either experiment became nauseated, does not mean that under actual flying conditions pilots may not be affected. A potentially significant factor which was not present in our experiment but which is present under actual flying conditions is vestibular input and its interaction with visual phenomena.

Our finding that there was a consistent decrease in heart rate to the flashing light which did not habituate cannot be accounted for as an epi-phenomenon or by-product of respiration change. Since the first complete respiration cycle during light stimulation showed a consistent increase over the pre-stimulus respiration rate, then, if anything, heart rate during the light should have increased if it were positively related to respiration. Graham and Clifton[5] in reviewing the literature on heart rate change to a variety of stimuli have concluded that the orienting response to stimuli is heart rate deceleration, a conclusion in line with our findings.

Subjects in other experiments[9] as well as subjects in our experiments have noted that the experimental chamber appears appreciably darker just after light offset. This finding suggests that a marked degree of dark de-adaptation occurs which may lead to a brief temporar interference with seeing the instrument pane under conditions of backscatter from clouds o fog.

Conclusion

The purpose of the experiments was to dete mine, under controlled conditions, the effects o short, high-intensity light pulses from an actu aircraft anticollision light flashing at 1.27 Hert on a variety of physiological measures. Pos experimental verbal reports of the subjecti experience were also obtained from the partic pants. Three groups of subjects composed instrument-rated pilots, age matched non-pilot and medical students without flying experien were used for experiments in the laboratory the University of Oklahoma Medical School ar in the fog chamber of the FAA Civil Aeromed cal Institute in Oklahoma City. The light sour was a Grimes model No. 30–360–1 high-intensi condenser discharge flash tube. Heart, respir tion and blink rates, EEG, and galvanic sk response were recorded. In general, heart ra and skin potential were slightly elevated in t early part but decreased in the later part of t experiments. The blink-rate responses were di ferent for the three groups: the pilots showed decrease, and the non-pilots and medical studer showed an increase in eye blinks in the course exposure. None of the subjects demonstrat photic driving, seizure or theta-wave activity his EEG, or nausea but experienced the bac scattered light as noxious, and many beca drowsy. The results bear directly on the pro lem of anticollision lights used during flig under backscatter conditions.

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