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EFFECTS OF BACKGROUND ILLUMINATION AND TARGET CONTRAST ON FLASH--ETC(U)

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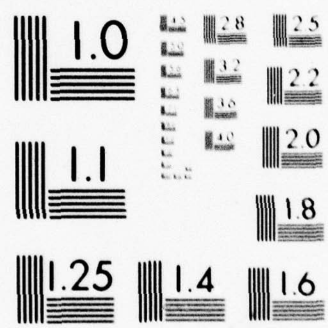

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EFFECTS OF BACKGROUND ILLUMINATION AND TARGET CONTRAST ON FLASHBLINDNESS RECOVERY TIME

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April 1979

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Seven subjects were shown a series of Landolt Cs with gaps oriented toward one of eight compass directions. After a randomly occurring flash, the subjects were asked to identify the gap orientation of the target. A tungsten-halogen lamp was used as the flash source. The duration was 100 msec and the luminance was 60000 foot-lamberts. Five background luminances (16,62,120,230, and 575 foot-lamberts) and four target contrast ratios (0.1,0.2,0.3 and 0.5) were used in this experiment. Results show recovery times at the 0.1 contrast level differ significantly from those obtained at the other levels regardless of

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background. Recovery times on the 16 foot-lambert background level were significantly different from all other backgrounds regardless of contrast. There were no differences between recovery times at the other constrast levels or background luminances.

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SUMMARY

Previous studies of flashblindness measured recovery time as a function of target acuity, background luminance, flash luminance and flash duration. These studies used square wave acuity gratings or transilluminated letters as targets. A background luminance was increased; target contrast also increased thereby confounding the two variables. The present experiment was designed to determine the effect of background luminance on flashblindness recovery time for recognition of targets of specific suprathreshold contrasts.

A 35 mm slide projector was used to present images of Landolt C targets to the subjects. The gaps in the Cs were oriented toward one of eight compass directions. The subjects' task was to identify (with a joystick) the direction of the gap. The flash source was a tungsten-halogen lamp with a duration of 100 msec and a luminance of 60,000 foot-lamberts. Background luminance levels were 16,62,120,230 and 535 foot-lamberts. Target contrast $\frac{\Delta B}{B}$ levels were 0.1,0.2,0.3, and 0.5.

Results showed recovery times at the 0.1 contrast level differed significantly ($p<0.01$) from those obtained at the other levels regardless of background. There were no differences between the other contrast levels. Recovery times at the 16 foot-lambert level were significantly ($p<0.01$) different from those at all other backgrounds. There were no differences between recovery times at the other background levels regardless of contrast.

PREFACE

This study was conducted at the Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio.

David C. Smedley and Diana R. Nelson were the project officers for Systems Research Laboratories, Inc., 2800 Indian Ripple Road, Dayton, Ohio.

The authors are indebted to Captain Allan Dickson of the Aerospace Medical Research Laboratory, who served as consultant and project monitor for this experiment and Mr. Radames Gebel, of Systems Research Laboratories, Inc., who aided in light measurements and eye safety calculations.

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INTRODUCTION

In conducting simulation research, it is important to be able to apply data obtained in the laboratory to real world situations. The laboratory equipment to be used, however, may restrict the range of certain variables. For example, the maximum luminance of a cathode ray tube (CRT) is less than the luminance of a clear sky at noon. In order to use the CRT in a flashblindness study, it was necessary to determine the range of background luminance and target contrast over which recovery times following a flash presentations are linear.

Previous studies of flashblindness (1,2) measured recovery time as a function of target acuity, background luminance, flash luminance and flash duration. Increasing target acuity, flash luminance or flash duration increased recovery time. Increasing background luminance decreased recovery time. Target acuity, flash luminance and flash duration were held constant for the present experiment. Target contrast and background luminance were varied. Earlier studies of flashblindness used square wave acquity gratings (1,2) or transilluminated letters (3) as targets. As background luminance increased, target contrast also increased, thereby confounding the two variables. The Landolt Cs used in the present experiment had densities of .1, .2, .3, and 0.5 to produce contrasts $\frac{\Delta B}{B}$ of .1, .2, .3, and .5 regardless of background luminance.

Because the stimuli of interest were of suprathreshold, negative contrast, data obtained from studies of brightness discrimination and dark adaptation were not considered useful in predicting the effects of background luminance.

The present experiment was designed to determine the effect of background luminance on flashblindness recovery time for recognition of targets of specific (suprathreshold) contrasts.

MATERIALS

Optical System

A two channel optical system was used to present the stimuli to the subjects (in Figure 1.) A Kodak Carousel 500 W slide projector fitted with an electrically operated shutter and variable voltage control (50V - 120V) was used to project Landolt C targets onto a rear projection screen. The Cs were presented within a circle of 27.9° on the screen. The subjects focused on this circle prior to each target presentation.

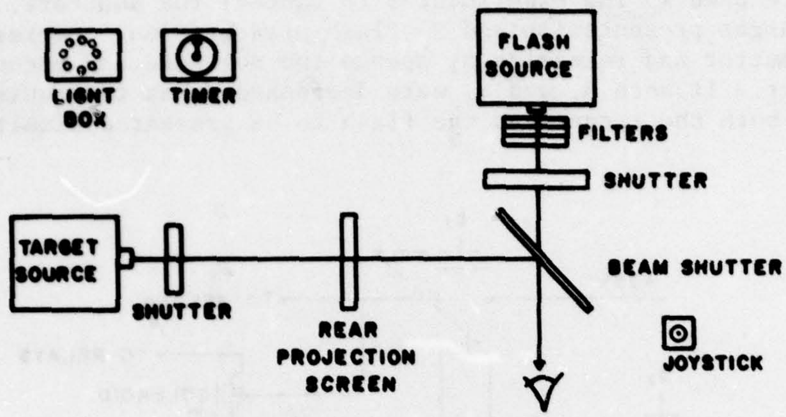

Figure 1. A Schematic of the Two Channel Optical System Used in the Experiment

An Airequipt 500 W slide projector, fitted with an 11.8 cm focal length lens and an electromagnetic shutter (Uniblitz), was the flashblinding source. The 11.8 cm lens, in conjunction with a 27.3 cm flash-to-eye distance, was selected to illuminate a 3 mm diameter retinal circle when the subject focused on the 25 cm distant target screen. Since the image of a Landolt C target on the screen produced a 0.7 mm retinal image (2.5° visual angle with a gap of 0.5°) the flash image completely covered the image of the target. The flash was directed at the subject through a beamsplitter, allowing 80% of the flash and 20% of the target luminance to reach the eye. Target luminance was controlled by a series of neutral density filters placed in front of the target slide projector. Background brightnesses were set at 575, 230, 120, 62 and 16 foot-lamberts. Both the flash and target background color temperatures were 3200°K.

To insure eye safety, the retinal radiation load was kept to a minimum by eliminating energy not contributing to vision. This was accomplished by placing two 3 mm thick KG3 glass filters to eliminate the infrared and two Shott GG435 glass filters to eliminate the ultraviolet portions of the spectrum in front of the flash unit.

Reaction Time Apparatus

An electric timer was started simultaneously with target presentation (and flash) and stopped by the subject when the target was identified. The clock-stop mechanism consisted of a joystick with eight gated positions corresponding to the eight compass directions indicated by the Landolt C targets. The clock was stopped by pushing the joystick into any one of the gates.

A schematic of the electrical system for the reaction time apparatus is shown in Figure 2. Shutters were used to control the presentation of the target slides and the flash. The target presentation shutter was operated by a solenoid and the flash was controlled by an electromagnetic leaf shutter (Uniblitz). A double pole pushbutton switch S_1 and momentary pushbutton switch S_2 were used by the experimenter to control the shutters. S_1 was used to control target presentation and S_2 flash presentation. Depressing S_1 closed the target shutter and releasing S_1 opened the solenoid and presented a target to the subject. If both S_1 and S_2 were depressed, then the subsequent release of S_1 caused both the target and the flash to be presented simultaneously.

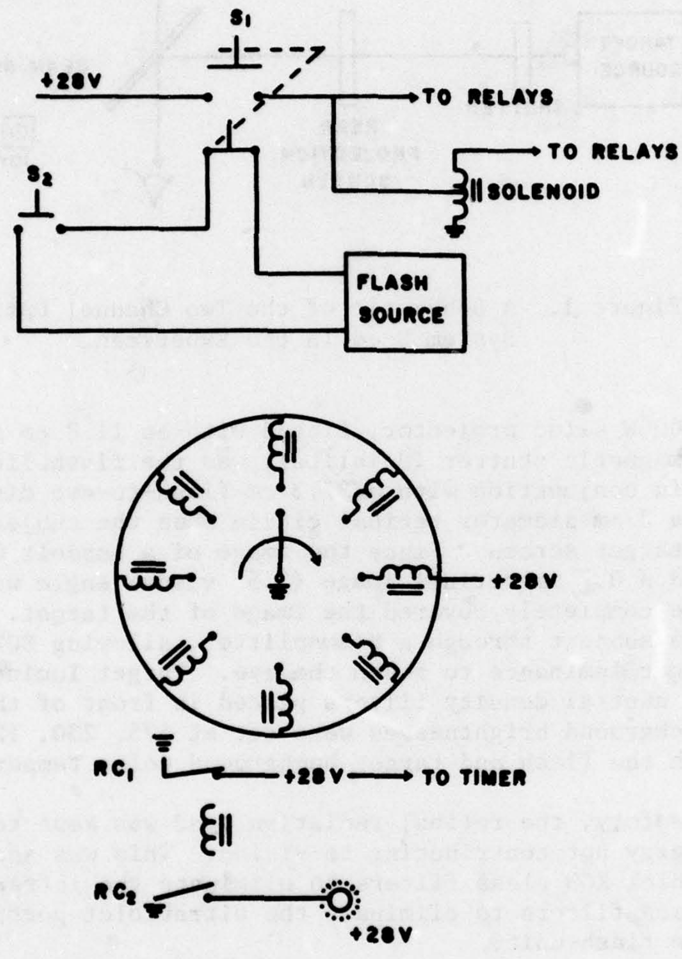

Figure 2. A Schematic of the Electrical System Used For Target Presentation and Identification

Relays in the joystick controlled the clock and lights in the light box. Each relay had two sets of contacts. One set was normally closed and, if any one was opened, the clock circuit was broken and the timer stopped. The second set of relays was normally open and, if closed, a circuit was completed to the appropriate indicator light in the light box.

Stimuli

The gaps on the Landolt Cs were oriented toward one of eight compass directions (N,NE,E,SE,S,SW,W,NW). A Prichard photometer was used to determine the luminance of the background and the luminance of the target area of each slide. From these measurements a contrast ratio $\frac{B_B - B_T}{B_B}$ (where B_B is the background luminance, and B_T the target luminance) was assigned to each slide. Four contrast ratios (0.1, 0.2, 0.3, and 0.5) were selected. Four sets of eight slides (one set of Landolt Cs at each contrast level were presented to the subjects). The background luminance remained the same for any given session.

METHODS

Training

Prior to data collection, the seven subjects were shown the Landolt C targets in the various compass orientations (N,NE, E,SE,S,SW,W,NW) to gain a familiarity with them. They also operated the joystick to gain familiarity with the clock-stop mechanism.

The subjects were given a series of training sessions, without flashblinding, that lasted three weeks. By the end of the third week their reaction times had reached asymptote. Each training session consisted of 24 black-on-white slides (three sets of the eight compass positions) presented in a random sequence. Each subject ran three sessions per day. A box with light at each of the 8 compass positions was used to display the subjects' response to the experimenter. After each response, the subject was told if his choice was correct, and his reaction time in seconds. The slides were presented at the rate of one every five seconds. The study was conducted monocularly using the right eye. The left eye was covered with a patch.

Data Collection

Five background luminances (16, 62, 120, 230 and 575 footlamberts) and four contrast ratios (0.1, 0.2, 0.3, and 0.5) were used in this experiment (one background for each session). Each subject ran three sessions a day for 20 days (3 replications of each experimental condition). A session consisted of 32 negative contrast slides (eight compass positions at each of the four contrast ratios) presented in a random sequence. The subject indicated identification of the target by moving the joystick to one of the compass positions. As the stick was pushed into a gate, the clock stopped and the target presentation was terminated. The slides were presented to the subject at 5 second intervals with a 30 second interval after the flash in order to allow the subject time to fully recover. At the end of each session the subject was given his mean reaction time for the non-flash trials as well as the flash trial, and number of incorrect identifications.

The flash was presented simultaneously with a target on a randomly selected trial between the seventh and seventeenth trials in order to avoid a presentation at the beginning or end of a session. The duration of the flash was 100 msec and the luminance was 60,000 footlamberts. The investigator observed the subjects'eye through a neutral density filter which permitted observation only during the moment of flash presentation since attenuation by the filter did not allow the eye to be seen at room light levels. If the subject blinked during the instant of flash, the trial was repeated.

Each day a UDT 80X optometer was used to check the luminance of the flash source. A Prichard photometer was used to check the target background levels.

RESULTS

An analysis was done to estimate the effect of contrast and brightness on the recovery time after flashblindness.

The sequence of treatments was randomized so that all treatments for one replication were administered before the next replication began. Within a given block, the average reaction time without flashblindness was computed for each treatment and each subject. The recovery time after flashblindness was the difference between the reaction time after flashblindness and the average reaction time without flashblindness.

Since an analysis of variance was used to analyze the data from this experiment, and since an ANOVA requires a normal distribution of data, an inverse square root transformation was used on recovery time so that the distribution of residuals would be approximately normal. This transformation was chosen from among the following: inverse, inverse square root, logarithm, square root, and no transformation. In each instance, means and standard deviations for each treatment across all subjects and replications were computed. Histograms of residuals (the difference between observed value and treatment mean) were examined for normality. Correlations of the treatment means and standard deviations were computed. Since one characteristic of the normal distribution is that the mean and standard deviation are independent, a low correlation between sample means and standard deviations is desirable. The inverse square root transformation yielded the lowest correlation between means and standard deviations of the transformations investigated and the distribution of residuals was approximately normal.

Using the transformed recovery time, an analysis of variance was performed to test the effect of contrast and brightness. The effects of contrast and brightness were significant ($p < .01$) and the interaction between the two was significant ($p < .05$). Pairwise Tukey comparisons were made for each of the main effects and for the interaction effect. A 99% confidence interval was computed for each main effect and the interaction effect. Means and confidence intervals were plotted by re-transforming the means and the bounds of the confidence intervals from the inverse square root to original units.

The results of the Tukey tests show recovery times at the 0.1 contrast level differ significantly ($p < 0.01$) from those obtained at the other levels regardless of background (Figure 3). There are no significant differences between the other contrast levels. Figure 4 shows that no significant differences exist between the recovery times with the 535 and 230, 120 and 62 footlambert backgrounds regardless of contrast. Recovery times at the 16 footlambert level, however, are significantly different from those at all other backgrounds.

Figure 5 shows average recovery time as a function of contrast and Figure 6 shows average recovery time as a function of background brightness. These figures represent data that was not transformed for analysis, and show, as in Figures 3 and 4, that recovery times at the 16 footlambert background level and the 0.1 contrast level are different from all other conditions tested.

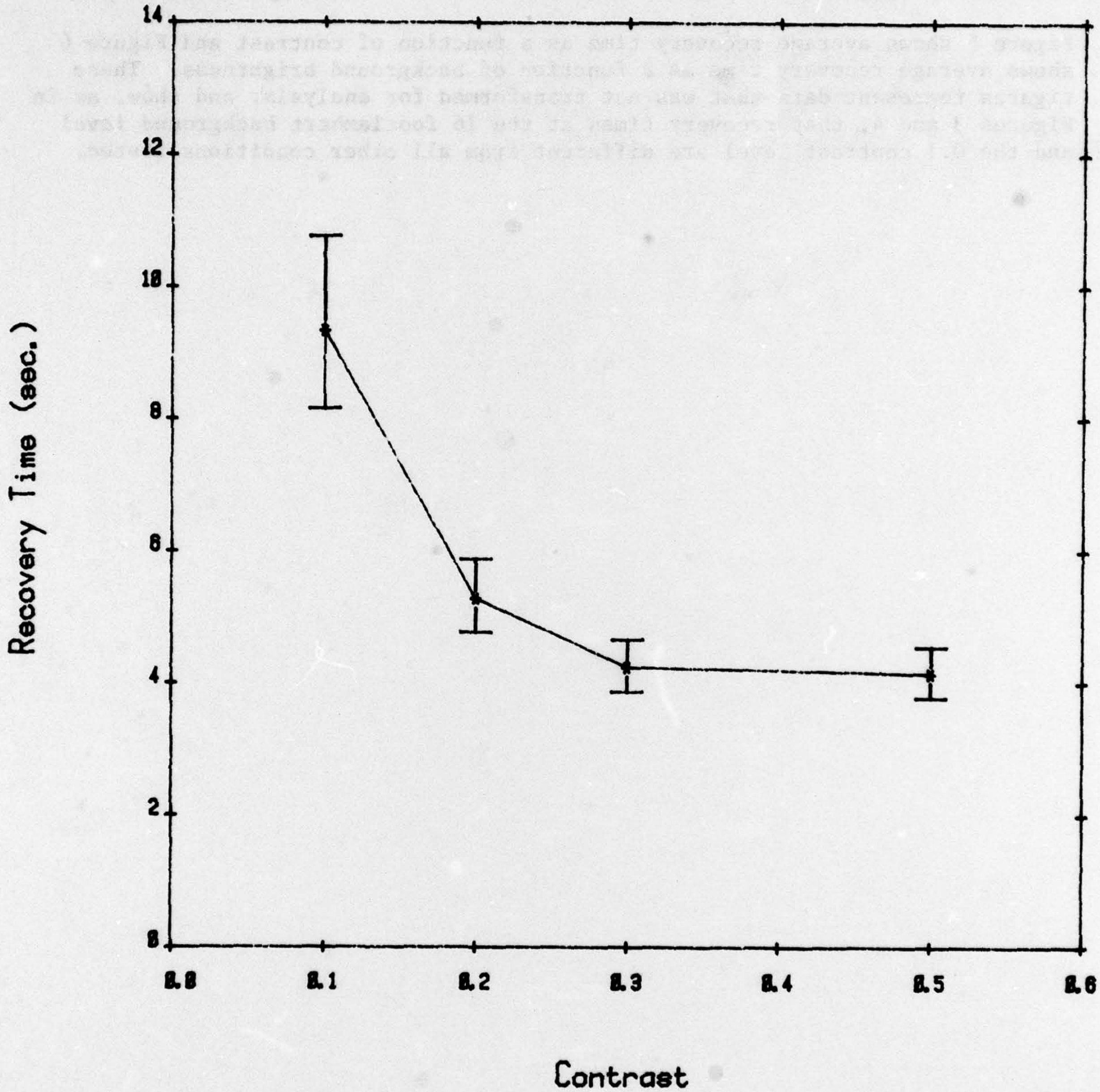

Figure 3. Recovery time as a function of contrast for transformed data (p<0.01)

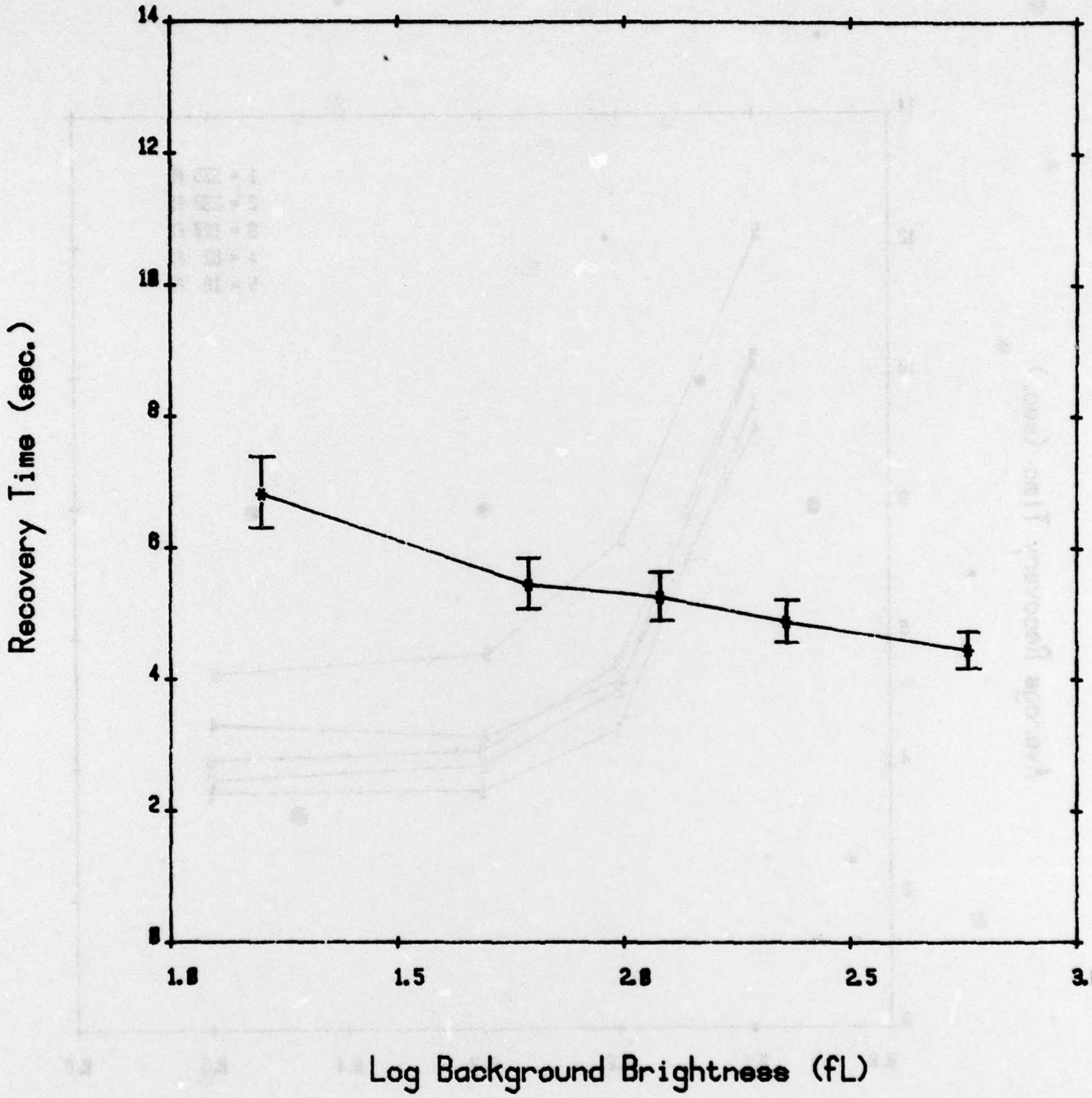

Figure 4. Recovery time as a function of background luminance for transformed data ($p<0.01$)

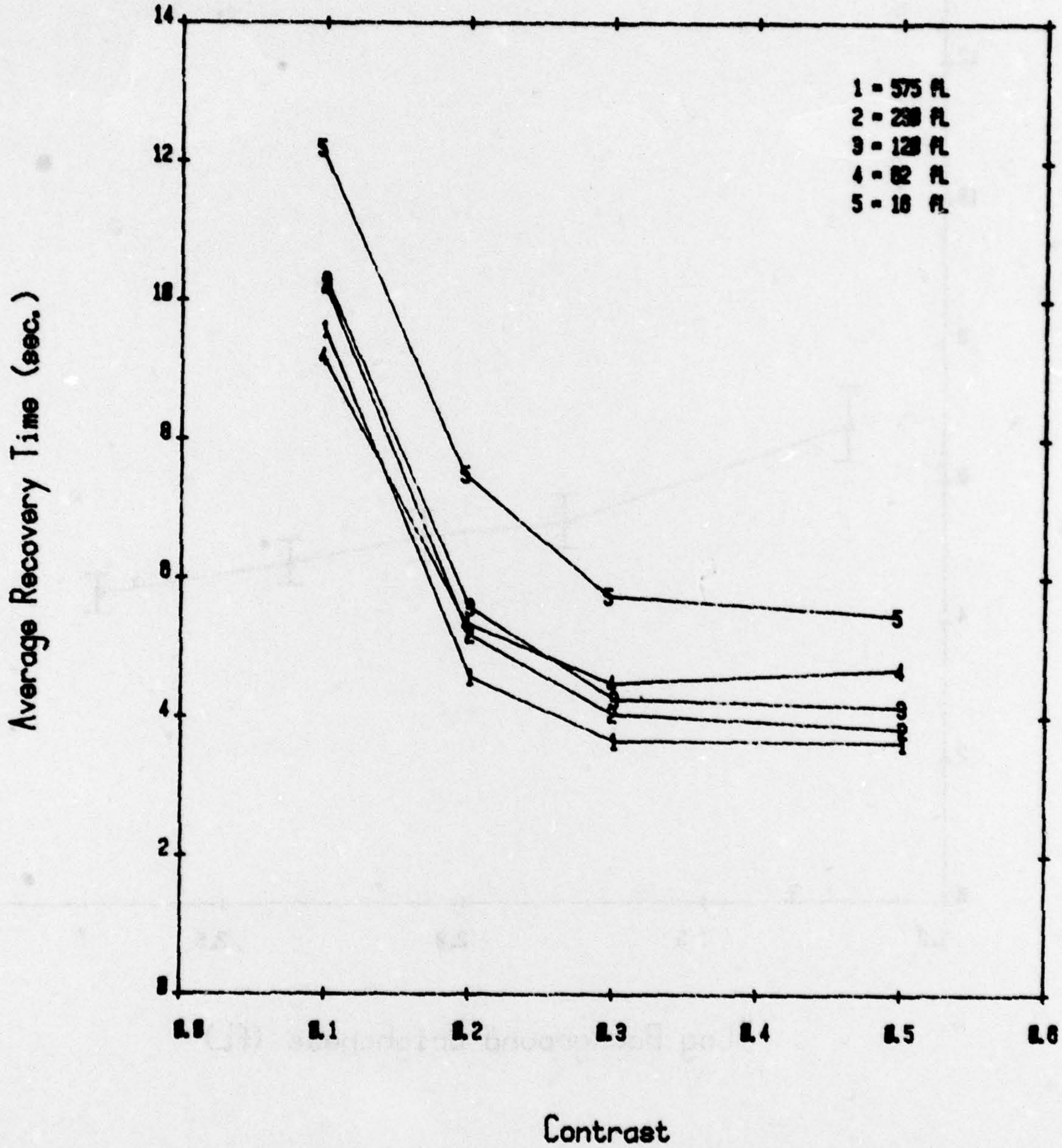

Figure 5. Recovery time as a function of contrast (non-transformed data)

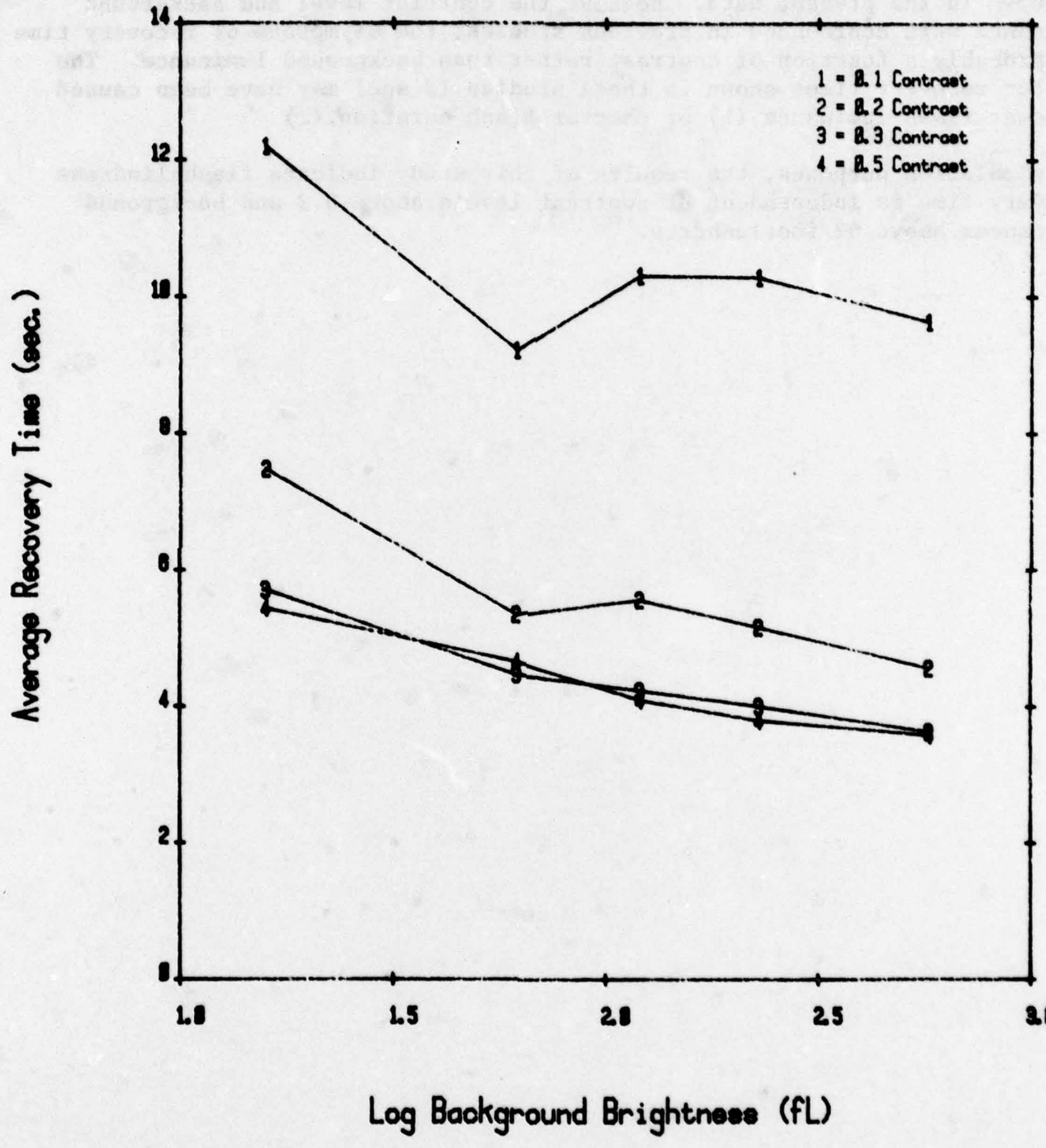

Figure 6. Recovery time as a function of background luminance (non-transformed data)

DISCUSSION

Previous studies of flashblindness indicate that recovery times as a function of background luminance reached asymptote at higher luminance levels than the recovery times obtained in this study.(1) This difference in the asymptote of recovery time was due to an increasing contrast level with increasing background luminance. Increasing the contrast level decreased the recovery time as shown in the present data. Because the contrast level and background luminance were confounded in previous studies, the asymptote of recovery time was probably a function of contrast rather than background luminance. The shorter recovery times shown in these studies (2 sec) may have been caused by lower flash luminance (1) or shorter flash duration.(2)

For simulation purposes, the results of this study indicate flashblindness recovery time is independent of contrast levels above 0.2 and background luminances above 62 footlamberts.

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