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NEAR VISUAL ACUITY UNDER LOW-LEVEL RED AND WHITE LIGHT

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FOREWORD

This report was prepared in the Ophthalmology Branch under task No. 775509. The research was initiated as part of a study to assess the effect of cockpit lighting systems on visual performance and was accomplished from October 1966 to January 1968. The paper was submitted for publication on 26 July 1968.

The author expresses his appreciation to Lieutenant Colonel Donald G. Pitts, Ophthalmology Branch, and to Kenneth Kay, Technology Incorporated, San Antonio, Tex., for their assistance in the calibration of the light-measuring instruments used in this study.

This report has been reviewed and is approved.

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Commander

ABSTRACT

The near visual acuity of 17 subjects between the ages of 35 and 45 years was measured under white light and red light of a 0.1 ft.-L. luminance level. The near visual acuity was significantly better under white light for the acuity demands of 20/30, 20/40, and 20/50. The visual acuity was equally good under red or white light when the acuity demand was 20/70 or larger, and the visual acuity was equally poor under red or white light when the acuity demand was 20/20.

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I. INTRODUCTION

This study was designed to measure the near visual acuity of pre-presbyopes between the ages of 35 and 45 years under a low level of red versus white light. Since subjects of this age have a relatively low amplitude of accommodation, it theoretically is conceivable that their near visual acuity will be reduced under red light. It may be more difficult for the older subject than for the younger subject to produce the increased accommodation required to overcome ocular chromatic aberration of red light (1).

Previous studies of visual acuity under low-level red versus white light are inconclusive. Some studies show better visual acuity under red light, while others have shown equal or better visual acuity under white light. Luckiesh and Taylor (2) reported that visual acuity was better under red light for luminance levels below 0.05 ft.-L. Luria and Schwartz (3) demonstrated a consistently better visual acuity under white light at the 11.2, 1.2, and 0.34 ft.-L. levels. Spragg and Rock (4, 5) measured the dial-reading performance of young subjects under colored lights and found that dial reading was poorest for red light when the luminance level was below 0.01 ft.-L. When the luminance level was above 0.1 ft.-L., there was no difference in dial-reading performance.

This apparent inconsistency may occur because some experiments measured near visual acuity, some measured distance visual acuity, and others used gross acuity demands while measuring performance time and errors. Also, some experiments used young subjects with large amplitudes of accommodation, while other experiments used older subjects with relatively low amplitudes of accommodation.

If there is a difference in visual acuity under red versus white light, theoretically, the greatest acuity decrement should occur under red light and for subjects with low amplitudes of accommodation while near visual acuity tasks are attempted.

Since a great number of Air Force pilots are between 35 and 45 years old, it is important to determine if there is a degradation of pilots' near acuity for the low-level red light found in many operational aircraft cockpits.

II. PROCEDURE AND APPARATUS

The near visual acuity of 17 subjects between the ages of 35 and 45 years was measured under red light and white light conditions. Each subject was first adapted for 3 minutes to 250 ft.-L. of white light in a Goldmann-Weekers adaptometer. The subject was then adapted for 15 minutes to 0.1 ft.-L. of red light or 0.1 ft.-L. of white light. The adapting booth was illuminated with G.E. No. 327, 28 v. bulbs. Voltage was held constant with a d.c. power supply. White light was obtained from unfiltered bulbs, but the bulbs were filtered through Wratten filter (F-29) to obtain the red illumination.

The visual acuity was tested at 14 inches with the Armed Forces Standard Tumble E Near Visual Acuity Test Form 3N. The subjects were encouraged to read all possible letters under both red and white light. The sequence of red or white light in the adaptation booth was reversed for half of the subjects.

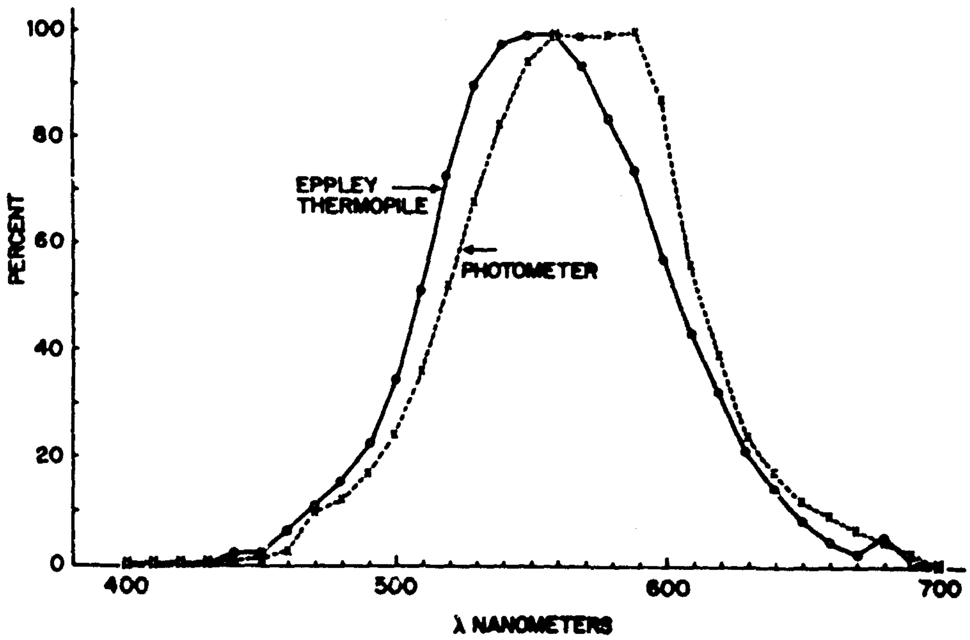

FIGURE 1

The relative spectral sensitivity of the Spectra brightness spot meter (model UB, ½ degree) photometer was calibrated against a National Bureau of Standards Eppley thermopile after the thermopile readings were multiplied by the C.I.E. relative luminous efficiency values.

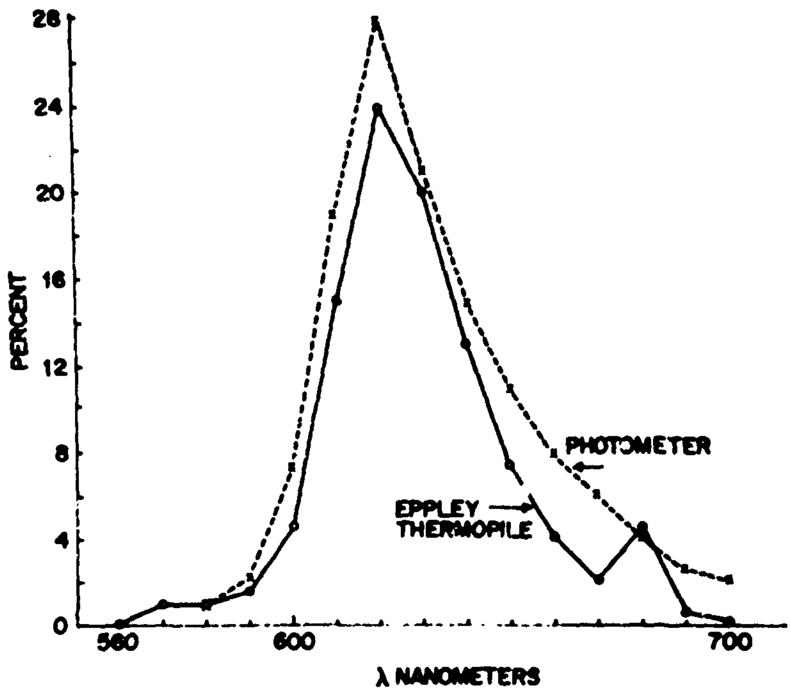

FIGURE 2

The relative spectral sensitivity of the photometer and thermopile were compared for the wavelengths passed by the Wratten filter (F-29).

The 0.1 ft.-L. luminance level for red and white light was measured with a Spectra brightness spot meter (model UB, ½ degree), which was calibrated against a National Bureau of Standards Eppley thermopile by the following procedure. Thermopile and photometer readings were taken at 10-nm. wavebands from 400 to 700 nm. through a Bausch and Lomb 500 mm. monochromator. The thermopile readings were multiplied by the C.I.E. relative luminous efficiency values, and then the photometer and thermopile readings were normalized at 560 nm. For the entire visible spectrum, the spectral sensitivity of the photometer resulted in the reading of 1% high (fig. 1). For the spectral transmittance of the red filter (Wratten F-29), the photometer reading was 2.3% high (fig. 2).

The 0.1 ft.-L. luminance level was selected to simulate the luminance level of an aircraft cockpit. Actual cockpit luminance measurements taken during night flights showed that 0.1 ft.-L. would be a relatively bright cockpit for normal night flight conditions (6).

III. RESULTS

Figure 3 shows data for a typical subject (35 years old) who exhibited better visual acuity under 0.1 ft.-L. of white light than under 0.1 ft.-L. of red light. At the 20/50 visual acuity demand the subject was able to correctly identify all 10 letters under white light, but under red light he made only 7 correct identifications. At the 20/40 level he had 7 correct identifications under white light and only 4 correct responses under red light. At the 20/30 level he made 4 correct identifications under white light and no correct identifications under red light.

Figure 4 gives the number of subjects with more correct responses under white or red light at each visual acuity demand. At the 20/30 level 10 subjects had more correct responses

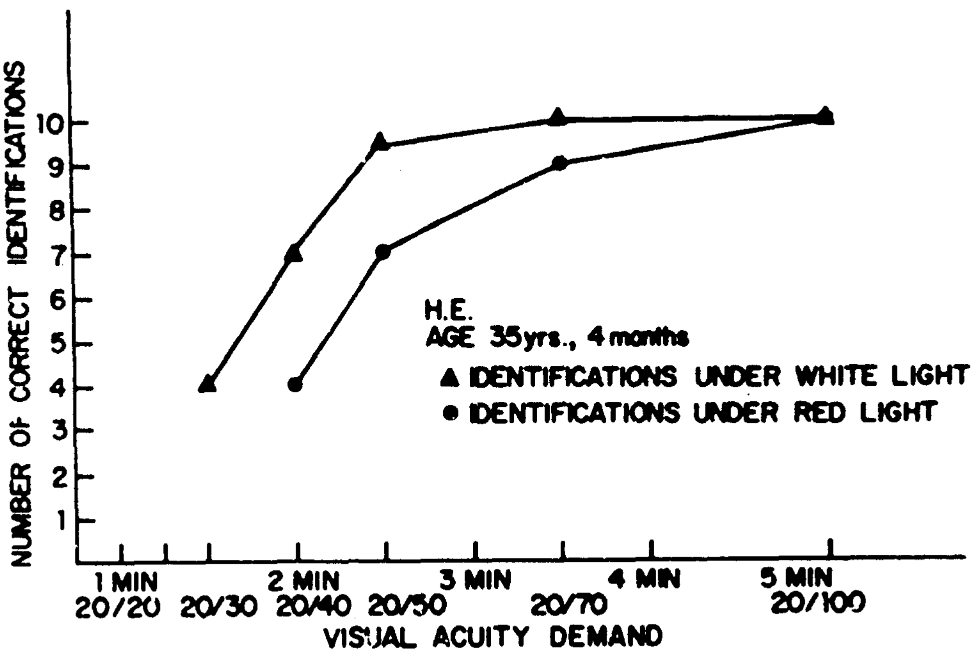

FIGURE 3

The near visual acuity under 0.1 ft.-L. of red light and white light was graphed for a typical subject.

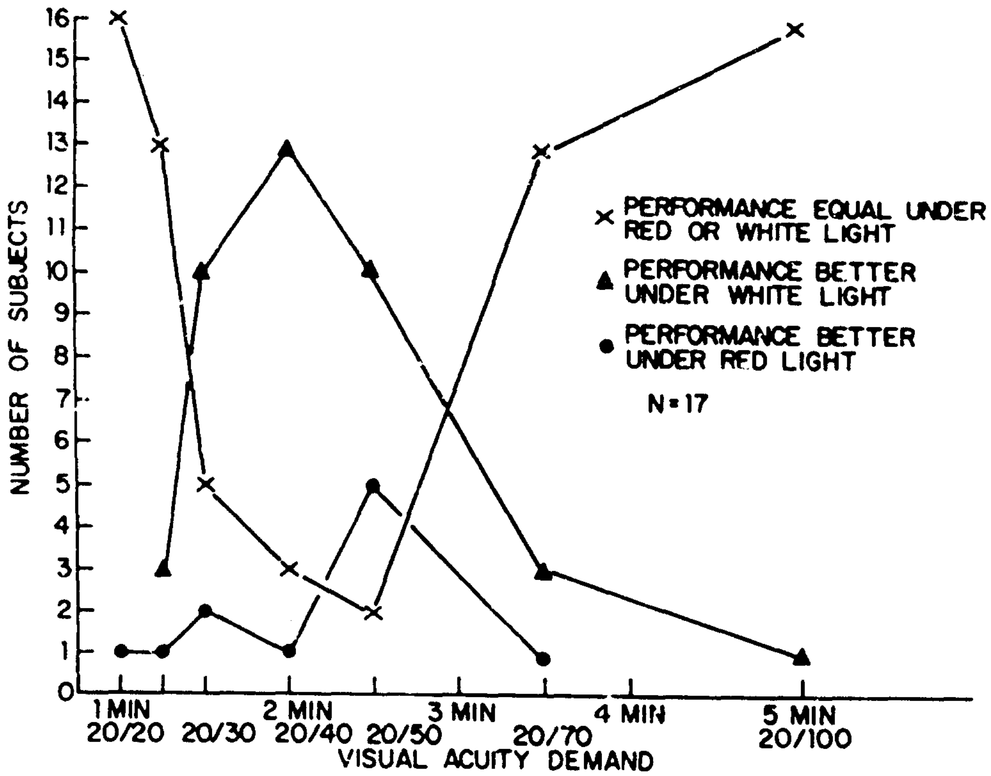

FIGURE 4

For each near visual acuity demand, the number of subjects with better or equal acuity under red light or white light was graphed.

under white light and only 2 subjects had more correct responses under red light; 5 subjects had the same number of correct responses under red or white light. At the 20/40 level 13 subjects responded better under white light while 1 subject responded better under red light; 3 subjects had the same number of correct responses under red or white light. At the 20/50 level 10 subjects did better under white light and 5 subjects did better under red light; 2 subjects had equal responses under red and white light.

The total number of correct responses for all subjects at each visual acuity demand under red and white light is illustrated in figure 5. There were 170 correct responses possible at each visual acuity demand; there were 17 subjects and 10 "tumble E's" for each acuity demand. Very few correct identifications were given for visual acuity demands greater than 20/30, and almost all were correctly identified above the 20/70 level.

At each visual acuity demand given in figure 6 the differences between the total number of correct responses under red and white light are illustrated. For a specific near visual acuity demand, the increased number of correct responses under white light is represented above the dashed line. At the 20/30 level there were 30 more correct responses for white light than for red light. At all the visual acuity demands between 20/30 and 20/70 there were more correct responses under white light than under red light.

The raw data for 2 color-deficient subjects not included in the group data are given in figures 7 and 8. Each subject showed a

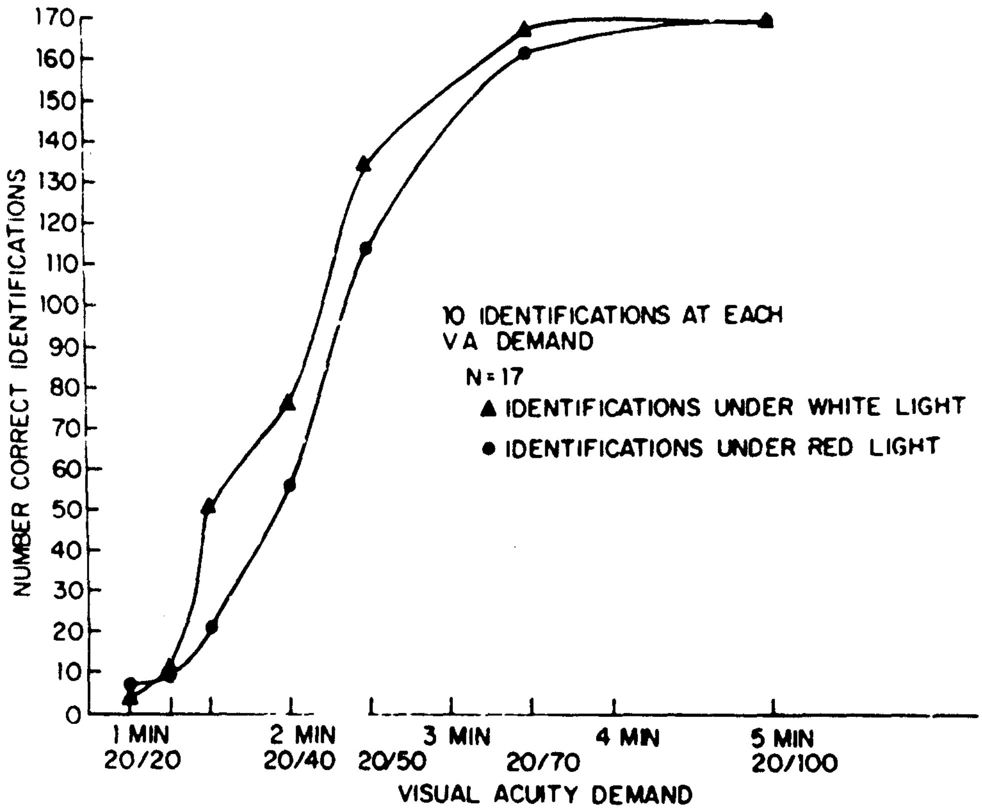

FIGURE 5

The cumulative correct responses for all 17 subjects were graphed for each acuity demand.

marked improvement in visual acuity under white light when compared to red light. Figure 7 presents the data for a 40-year-old protanomalous subject, and figure 8 shows the data for a 19-year-old deuteranope.

The raw data in figure 9 are from a 19-year-old subject with normal color perception. In contrast to the older subjects, he did not exhibit a difference in near visual acuity under red or white light.

IV. DISCUSSION

Red light is often used to replace white light under conditions where the lowest level of dark adaptation is desirable, but it is important to remember that the intensity of light rather than the color of light has the greatest effect on dark adaptation. In fact, the lowest possible level of dark adaptation is obtained by not having any lighting, but complete darkness is not possible in an aircraft cockpit where a pilot must read instruments. Therefore, a pilot should have only the minimum amount of light necessary to read instruments so that he will experience a minimal loss of dark adaptation. A small change in intensity of low-level light markedly affects both the level of dark adaptation and the visual acuity. Therefore, it would be desirable to have cockpit lights which provide the best dark adaptation and also the best visual acuity. Since near visual acuity appears to be reduced under red light for subjects between 35 and 45 years of age, the questionably better dark adaptation provided by red light

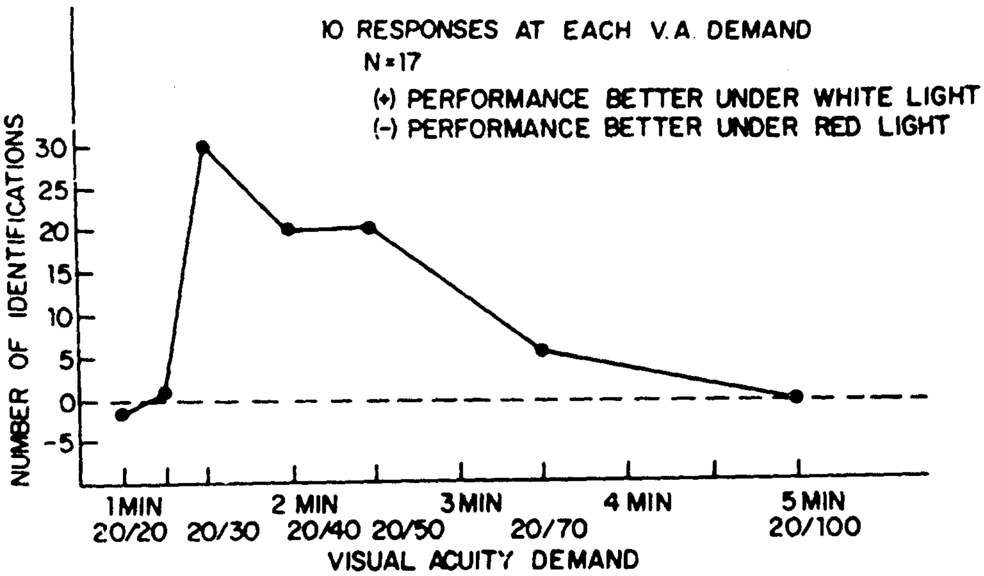

FIGURE 6

The difference between the number of cumulative correct responses under red light and the number of cumulative correct responses under white light was graphed for 17 subjects at each visual acuity demand.

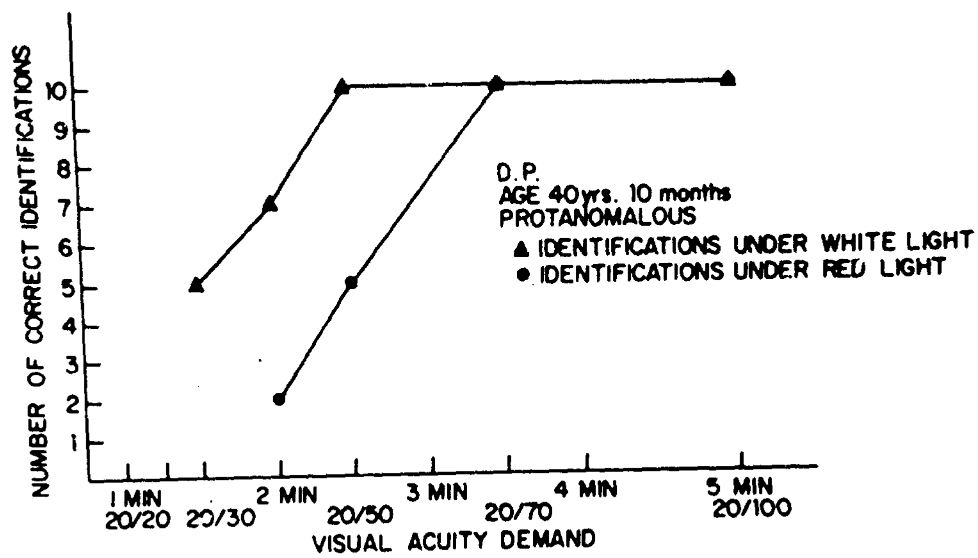

FIGURE 7

Visual acuity was recorded for a 40-year-old protanomalous subject, but it was not included with the group data.

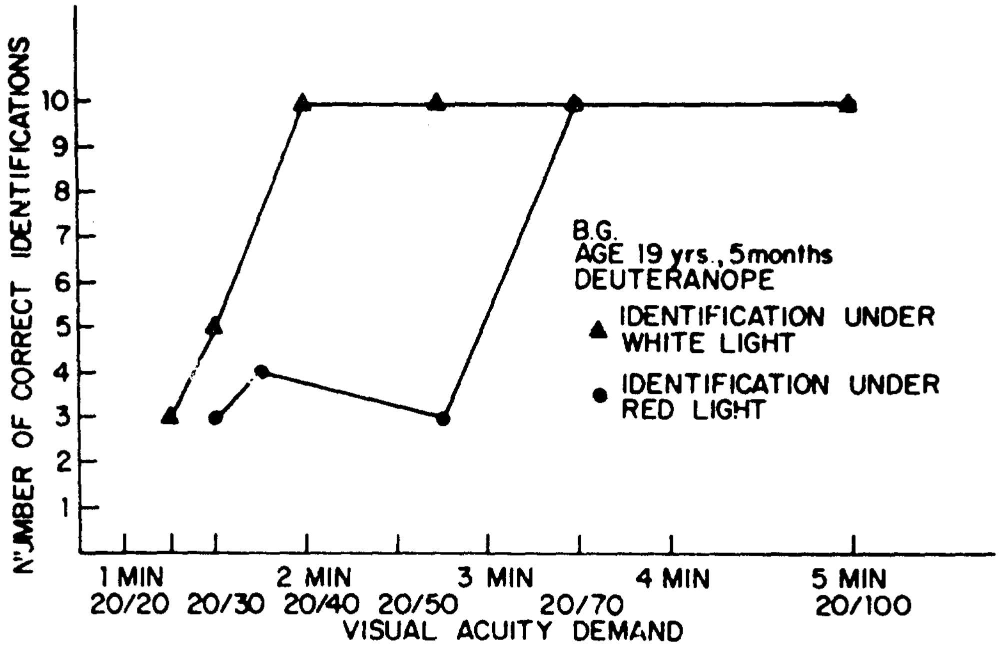

FIGURE 8

The near visual acuity was graphed for a 19-year-old deuteranope, but his data were not included with the group data.

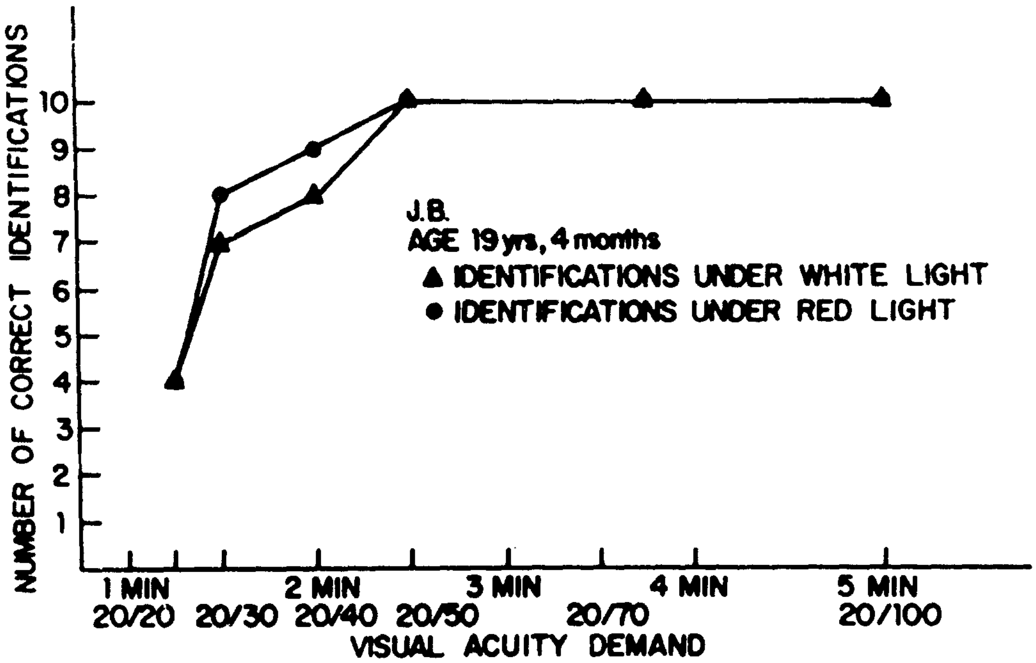

FIGURE 9

The near visual acuity of a 19-year-old subject with normal color perception was illustrated, but it was not included in the group data.

compared to white light may be negated by the decrement in near visual acuity.

V. CONCLUSION

The 35- to 45-year-old subjects had significantly ($P < .05$) better near visual acuity under 0.1 ft.-L. of white versus red light for acuity demands of 20/30, 20/40, and 20/50. When near visual acuity demands approached 20/20, the visual acuity was very poor under both red and white light. As the near visual acuity demand approached 20/70, the subjects' visual acuity was nearly 100% under both red and white light of 0.1 ft.-L.

Since near visual acuity is reduced under red light and it is questionable if low-level red light provides better dark adaptation (7, 8), it is recommended that white light be used in aircraft cockpits for optimum visual performance.

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