CONTRAST SENSITIVITY OF THE HUMAN EYE TO VARIOUS DISPLAY PHOSPHOR TYPES

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Observer threshold performance data was obtained using sine wave and tactical vehicle imagery displayed on television monitors, each with a different phosphor screen. Display performance was measured using sine waves and a scanning spectroradiometer.

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CONTRAST SENSTIVITY OF THE HUMAN EYE TO VARIOUS DISPLAY PHOSPHOR TYPES

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INTRODUCTION

The cathode ray tube (CRT) display continues to be a popular device for conveying visual information to aircraft crewmembers. Sophisticated electronic and electro-optical sensors on modern reconnaissance/strike aircraft provide day/night pilotage, navigation, target acquisition, and fire control information to the crewmembers using CRT displays. Alphanumeric, graphic, and pictorial information may be presented sequentially or simultaneously on either virtual image or direct view CRT displays.

The CRT display is versatile, reliable, and economical; new designs are constantly being generated to further improve the technical characteristics of the CRT display. However, is *sufficient consideration* being given to the individual who is required to view the display for hours in an aircraft environment and extract information from it? The individual viewing the display is not in an immaculate laboratory but rather a vibrating, noisy, tense, and generally uncomfortable environment.

This study is the first in a series designed to medically assess the effects of various display characteristics on the human visual system. Although the main thrust of these studies are aimed at aircraft display systems, the results will be generalizable to most CRT display systems. These assessments will consider visual performance, visual fatigue, dark adaptation rates after exposure, and visual contrast sensitivity. The first pilot study discussed here analyzes the visual contrast sensitivity to three display phosphors.

Purpose

The purpose of this study is to investigate the contrast sensitivity of the human eye to various display phosphors. The phosphors used in this study have the unusual characteristic of emitting a large portion of their light output in narrow spectral bands. This unique characteristic enables display manufacturers to obtain very high contrast ratios even in high ambient lighting environments with spectral filters. The amount of contrast necessary for the human eye to distinguish detail on the display has not been studied for the case of narrow spectral emission phosphors; the effects of the narrow band emissions on the human visual system, in general, are unknown.

Literature Review

Green[1] reported that studies of visual acuity as a function of target color indicates that fine detail can be seen equally well in monochromatic light of equal luminance with possible exceptions in the blue portion of the spectrum. This opinion is supported by Campbell, Van Nes, and Bouman[2,3]. However, the exact spectral distribution of the stimuli in the studies used to reach the above conclusions is not known.

METHODS

The spatial frequency response of the eye can be assessed by presenting a sine wave pattern to an observer to determine the visual threshold. The luminance of the pattern varies in a sinusoidal matter as a function of distance across the display; the peaks and troughs of the sinusoid correspond to the maximum and minimum luminances of the display, respectively. The modulation contrast is then defined as the modulation at threshold divided by the mean luminance [$M_c = (B_{max} - B_{min})/(B_{max} + B_{min})$]. By sampling several frequencies, one can establish a transfer function which defines the modulation needed to reach threshold for each spatial frequency. The contrast sensitivity is defined as the reciprocal of the contrast threshold.

The sine wave stimuli were generated with a Tektronix FG 504 function generator and a Visual Information Institute 1406 pedestal generator; the video output of the stimuli generator being fed to the CRT display was monitored with an oscilloscope. The experimenter was able to change the spatial frequency by simply changing the frequency of the function generator; the frequency setting of the function generator was displayed on a frequency counter. The subject was able to adjust the output amplitude of the function generator with an attenuator connnected between the function generator and the pedestal generator.

Three one-inch miniature Ferranti CRTs, type 02D/128, with fiber-optic faceplates were used to present the stimuli to the subjects. The CRTs were driven by a Honeywell display electronic unit (DEU). Each CRT had a different type phosphor screen. The phosphors were: P-45 (white), P-43 (green), and P-22 (red). The sine wave response (SWR) and the spectral output of each tube were measured. The SWR for the three tubes are shown in Figure 1, and the spectral output curves are essentially those shown in the JEDEC Publication 16-C[4].

A Gamma Scientific GSS10 spatial and spectrum radiometer/photometer was used to measure the light output from the CRTs. The microscope optics of the GSS10 served two functions. First, it enabled the subject to comfortably view the small CRT with 25X magnification and simultaneously it enabled the experimenter to spatially scan the image seen by the subject without interrupting the physical configuration of the subject, viewing optics and CRT display to obtain photometric contrast measurements. Prior to acquiring data, the DEU brightness and contrast controls were set using a 10-step gray scale and the photometric microscope. The peak brightness of the display was set at 10 $\pm$ 1 footlambert (fL) and a minimum brightness was set at about 0.1 fL. The contrast sensitivity data was obtained with the display operating in a linear range. All data were collected with the room lights extinguished.

The experimenters set the spatial frequency to be viewed by the subject, starting with the lowest frequencies, and insured the modulation on the display was set at a minimum. The subject (shown in figure 2) sitting with his chin in adjustable chin rest, viewed the display through a microscope; the image subtended a visual angle of 43.8°. He adjusted the attenuator until the sine wave luminance pattern was just visible on the display. When the subject had completed the threshold adjustment, a contrast measurement was obtained through the same optical path used by the subject. The effective 0.0004 X 0.025 inch slit was scanned from the left side of the field to the right side of the field, a distance of 10 mm. The analog output of the photometer, representing the intensity pattern of the display, was fed to a calibrated strip chart recorder. The next spatial frequency was then set by the experimenter and the same procedures were followed until data were recorded at each of 14 frequencies. The maximum and minimum luminance values were obtained from the strip chart data for each spatial frequency; the modulation contrast was then calculated from these values for each frequency. The reciprocal of the modulation contrast was then plotted as a function of spatial frequencies to obtain the contrast sensitivity for each of the display phosphor types.

RESULTS

The preliminary results indicate no differences exist in the contrast sensitivity of the human eye when viewing the P-43 (green), P-45 (white), or P-22 (red) display phosphors with an average screen luminance of 7 fL from 0.09 to 1.00 cycle per degree. At 0.05 cycle/degree there were contrast sensitivity differences but the differences were not consistent across all four subjects. The contrast sensitivity as a function of spatial frequency found in this study follows the data published by Van Nes and Bouman[3].

DISCUSSION

When presenting visual psychophysical data obtained with CRTs, precise control of the stimuli parameters must be emphasized. The luminance variability across the CRT face due to electronic noise and phosphor nonuniformity tend to contaminate the periodic stimuli luminance variations. The variability of the stimuli generator, DEU, CRT's, photometric equipment, and chart recorder make it virtually impossible to acquire data from signal input device and later correlate these data with photometric threshold modulation measurements. The photometric measurements have to be taken immediately after the subject sets the threshold modulation for each frequency to obtain reliable results.

As stated earlier, the scanning photometric microscope permitted immediate measuring capability without disrupting the physical configuration of the observer, CRT, or instrumentation. However, the penalty incurred was the limitation of the stimuli spatial frequency range. The optics in the microscope permitted a minimum magnification of 2.5X to the scanning slit aperture and 25X through the 10X eyepiece to the observer. Only 25% of the CRT surface area could be viewed by the observer. The eye is so sensitive from one to ten cycles per degree that even though the response of the CRTs and DEU were sufficient to obtain contrast threshold data, the noise inherent in the instrumentation made the data collected unreliable at these frequencies. If the magnification of the CRT image is reduced, the effective slit width increases, resulting also in a degraded modulation measurement capability.

CONCLUSION

The results, in the frequency range measured in this experiment, are consistent with that published by other investigators without regard to the spectral anomalies of the stimulus source. The amount of contrast necessary for the human eye to distinguish detail on CRT's with narrow spectral emission characteristics seem to be consistent with those of broad spectral emission.

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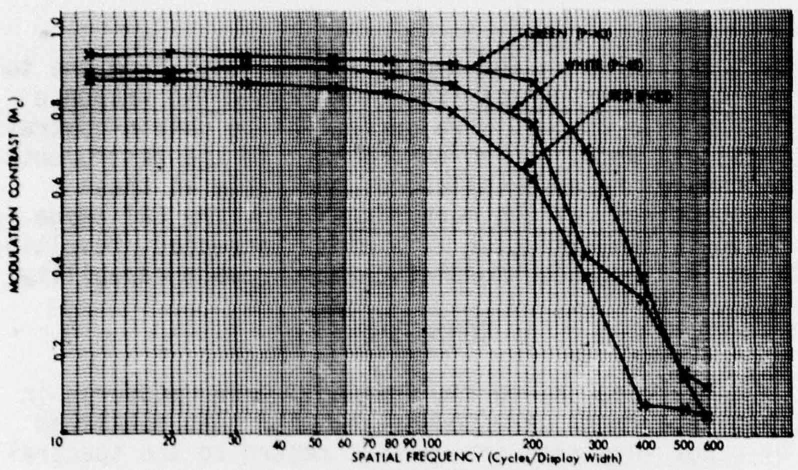

FIGURE 1. Sine Wave Response (SWR) of Three Miniature 1" Ferranti Cathode Ray Tubes Driven by A Honeywell, Inc. Display Electronics Unit. Display Luminances were 50 fL.

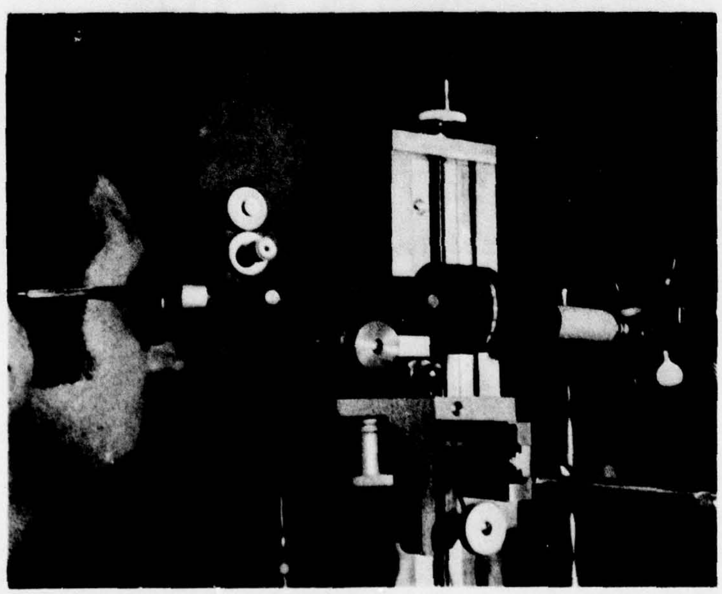

FIGURE 2. Subject Views Miniature Cathode Ray Tube Through Gamma Scientific Scanning Photometric Microscope While Adjusting Attenuator for Threshold Modulation.