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The effect of viewing a laser-scanned display on colour perception and the visual accommodation response

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Abstract

This paper investigated some effects of viewing a laser scanned display (LSD) on visual perception. LSDs potentially provide a high-brightness, monochromatic, image which could have particular effects on the visual system. As a monochromatic image may reduce a potential cue for visual accommodation (chromatic aberration), participants' accommodation was measured while they viewed an image on either a laser-scanned, or video-projected, display. Furthermore, monochromatic diplays may lead to effects on perception as a result of chromatic adaptation. Colour vision was also assessed before and after using the displays. Increased variability of the level of accommodation was found when using the laser-scanned display, but the magnitude of the effect was mediated by how fast elements of the display were moving. The greatest difference in accommodative variance was between a video display with slow-moving elements (0.016 D) and an equivalent laser-scanned display (0.118 D). Viewing of the laser-scanned display also led to measurable changes in colour perception in some participants. Thus, although further research is required, this paper suggests that viewing a laser-scanned display may have some effect on the accommodation response and on colour perception.

Keywords: Visual accommodation; Laser-scanned display; Colour perception; Color vision

1. Introduction

Increasingly, displays such as head-mounted displays (HMDs) and head-up displays (HUDs) are being used to overlay information on the 'real world'. Depending on the environment, one of the major problems with displays of this type can be achieving a sufficiently high display luminance so that the display is visible against a bright background. One class of display that *can* provide the high brightness levels often required of HMDs and HUDs are laser-scanned displays (LSDs) (For a description see Proctor[1]). Laser scanned displays use a rapidly scanned, brightness modulated, laser beam to produce an image either directly on the retina, or via an intermediate screen that is viewed by the user. Apart from the high brightness provided by LSDs, they have negligible persistence and unlike most other displays, are mainly monochromatic. It is possible to produce a colour LSD by using more than one laser of course, but each colour used will still be chromatically narrow-band.

This paper presents a human factors evaluation of a LSD compared with a video-projected display when used to perform a simple tracking task. The human eye does not usually view monochromatic images and one system that may be influenced by viewing such a monochromatic image is the accommodation (focusing) response of the human eye. As the accommodation level of the eye changes, so does the degree of chromatic aberration introduced into the image. A number of studies [2–6] have suggested that chromatic aberration of an image may play an important role in the accommodation response and that some individuals may be more dependent on chromatic aberration cues than others. If a monochromatic display is used, this effectively removes chromatic aberration as a cue to accommodation – and this may make it more difficult to maintain an appropriate focus on the display. Thus

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the accommodation of a number of participants was investigated to ascertain whether they were able to maintain a stable level of accommodation when using a LSD.

Another issue addressed was the effect that a monochromatic display may have on perceived colour as a result of chromatic adaptation to a single wavelength. There is some evidence that exposure to laser light can lead to (reversible) changes in colour perception [7,8]. The possibility that colour perception may be affected by viewing a monochromatic display was also assessed in this study.

2. Methods

2.1. Display description

The display tested was an early production Microvision™ display using a frequency-doubled Neodymium: Yttrium Aluminum Garnet (NdYAG) laser providing light of 532 nm wavelength (green). In this study the optical train was reduced to an image plane comprising a diffusing screen and a 25 mm focal length positive lens, giving a 12 mm exit pupil and an image at an optical distance of 5.9 m (matched to the actual distance of the video-projected display – see below) as shown in Fig. 1.

The overall resolution of the display was VGA (640×480 pixels). The update rate was 60 Hz.

The LSD was compared to a standard (white-light) VGA display, projected onto the wall of the laboratory at a distance of 5.9 m from the participant. The luminance of the bright areas of the LSD was 30 cd m^{-2} (although production LSDs could theoretically be of far higher luminance) and the background was 0.8 cd m^{-2}. The LSD and video-projected displays were matched for apparent brightness using a minimally-distinct-border method.

2.2. Visual stimulus

The target stimulus was designed to resemble the type of imagery used in a simple aircraft head-up-display (HUD) as shown in Fig. 2. The imagery was designed to be fairly simple and uncluttered. The stimulus image should not, therefore, have been unduly affected by image quality variations between the displays. The LSD was set up so that the image was focussed at the same distance as the video-projected display (5.9 m). It was not possible to match the images for size, but the displays were set-up to produce images that were as

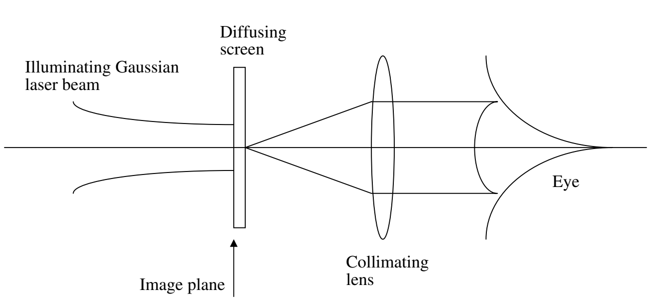

Fig. 1. Simplified display optics

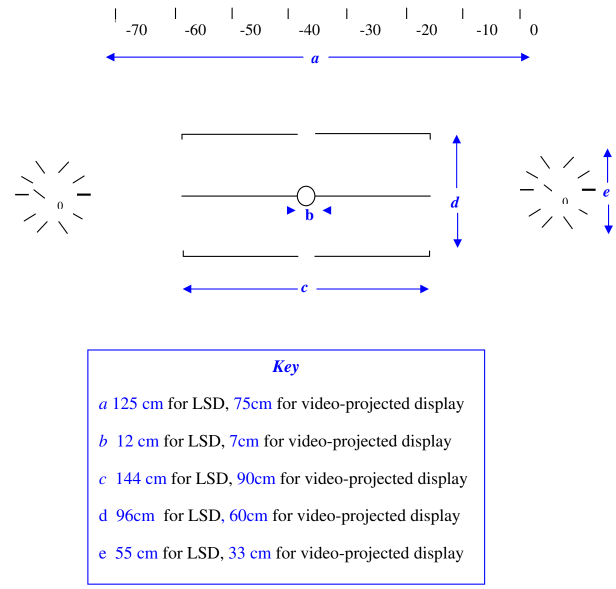

Fig. 2. Stimulus for visual accommodation study. The pitch ladder (the three horizontal lines) moved vertically in a quasi-random fashion. The central circle was static. The participants' task was to use a joystick to try and maintain the alignment of the central line of the pitch ladder with the centre circle (as shown).

similar as possible. Fig. 2 shows the apparent size of the stimulus at 5.9 m for both display types.

For this study the three central bars moved vertically only. The motion of the central bars was driven by a long-period oscillator composed of five sinusoidal harmonics of a specified base period (all phase-shifted by varying degrees). Changing the base period altered the average speed of the oscillation. The subjective appearance of the motion is of a drift of the central bars with apparently random changes in speed and direction. The participants used a joystick (positioned to their left hand side) to perform a tracking task where they were required to keep the central bar in line with the central circle (as shown in Fig. 2). Measures of tracking accuracy (pixel deviation from the centre position) were recorded during the task presentations. There were two levels of task difficulty: *easy*, slow tracking and *difficult*, fast tracking (the base period of the sinusoids was four times that in the slow tracking task). Actual speed of the drift at any one time was determined by a combination of the oscillator and the control inputs from the participant.

2.3. Visual accommodation study

Sixteen participants (Twelve male, four female. Median age: 28. Age range: 20–40) took part in the visual accommodation study. All participants were functional emmetropes[1] and none knew of any colour vision anomalies[2]

[1] The participants did not need visual correction under normal conditions.

[2] One participant was found to be anomalous upon completion of the City University Colour Vision Test and no further testing of their colour vision was conducted during the trials.