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Wallace M. Kojima
Pacific University

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Factors affecting accommodative response while viewing a video display terminal

Abstract

The purpose of this study was to determine if accommodative responses to positive and negative contrast video displays differ significantly under two different levels of ambient illumination. The accommodative responses of 20 optometry students were measured (using a vernier Badal optometer) while characters on a video display terminal (VDT) were viewed binocularly under different screen and surround illumination conditions. Results showed no significant difference in accommodative response between negative and positive contrast VDT screens, but did reveal statistically significant differences ($p < .05$) for two levels of ambient illumination. For both negative and positive contrast conditions, the lower ambient level was associated with a decreased accommodative response (greater lag of accommodation).

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**FACTORS AFFECTING ACCOMMODATIVE RESPONSE WHILE VIEWING A
VIDEO DISPLAY TERMINAL**

Wallace M. Kojima

**In Partial Fulfillment of the
Requirements for the Degree of
Doctor of Optometry**

Pacific University College of Optometry

May 1986

Advisors:

Niles Roth, O.D.

Paul Kohl, O.D.

Robert Yolton, O.D., PhD., FAAO

Handwritten signatures of the three advisors: Niles Roth, Paul Kohl, and Robert Yolton. The signatures are written in black ink and are positioned to the right of their respective printed names.

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ABSTRACT

The purpose of this study was to determine if accommodative responses to positive and negative contrast video displays differ significantly under two different levels of ambient illumination. The accommodative responses of 20 optometry students were measured (using a vernier Badal optometer) while characters on a video display terminal (VDT) were viewed binocularly under different screen and surround illumination conditions.

Results showed no significant difference in accommodative response between negative and positive contrast VDT screens, but did reveal statistically significant differences ($p < .05$) for two levels of ambient illumination. For both negative and positive contrast conditions, the lower ambient level was associated with a decreased accommodative response (greater lag of accommodation).

INTRODUCTION

The rapid introduction of video display terminals (VDTs) has caused a revolution in today's office workplace. The VDT operator population in the United States, now at ten million, is expected to double by 1990.¹ The introduction of VDTs into the workplace has not been without drawbacks, however. Surveys of VDT operators indicates that difficulties with vision and complaints of ocular discomfort are fairly common.^{2,3,4,5,6,7} Ocular symptoms include blurring of vision, sensations of pain or fatigue involving the eyes, irritant-like effects (itchy, dry, gritty, stinging, and/or watery eyes), and headaches. The frequency of these problems has caused much concern and a number of studies have been conducted to find possible causes of these complaints. Collins⁶ concluded that convergence difficulties were the major cause of visual symptoms in 36% of VDT operators complaining of asthenopia. Low fusional reserves were thought to be the primary cause of symptoms in 22%. Gunnarson and Soderberg⁹ determined that visual strain in VDT workers was in some way connected with changes in near point of convergence. Giles¹⁰ found heterophoria and poor fusion as contributory factors to visual discomfort of VDT workers.

Ostberg¹¹, utilizing a laser optometer to measure accommodative posture while viewing a VDT, found decreasing accommodative accuracy with prolonged, concentrated VDT use. Subjects became temporarily myopic for far targets and more hyperopic for near targets. Murch¹², also using a laser optometer found that with decreasing visibility of the VDT, accommodative posture drifts towards the resting point of accommodation (RPA). In these two separate studies, Ostberg¹¹ and Murch¹² demonstrated that the visual system does not

accommodate as accurately to VDT images as to printed copy images; while viewing VDT images, the accommodative lag was greater than with printed copy. More recently, Apodaca and Johnson¹³ confirmed these findings utilizing a retinoscope and beam splitter technique.

The study of specific factors affecting visual problems of VDT operators is difficult because of the many variables involved with VDT use in different working environments. Some of these variables include postural considerations, lighting and reflectance, display design and image quality, and the diverse nature of VDT work. These factors along with the difficulty of defining the physiological correlates of visual fatigue combine to leave the causal factors underlying visual effects of VDT use largely undetermined.

Field and laboratory studies, as well as surveys, have been conducted in an attempt to understand and determine conditions which are most preferred for VDT viewing. These studies and surveys have explored such areas as lighting, reflection, glare, flicker, character size, color, and body posture.^{4,14,15} One area of VDT viewing which has been explored through laboratory studies has been the comparison between negative and positive contrast conditions.* Bauer and Cavonius¹⁶ examined the effects of positive and negative contrast screens on performance of a letter identification task. They found that the error rate was lowest for the negative contrast screen (black letters on a white background) and highest for the positive contrast screen (white letters on a black background). In another study, Bauer and Cavonius¹⁶ compared the effect of negative versus positive contrast VDT screens in detecting discrepancies between a VDT screen and a typewritten page. Once again, the negative contrast screen produced fewer errors, faster times, and was most preferred by the subjects. In addition, they found that a higher luminance negative contrast screen yielded both greater subjective preference and improved

visual performance than a lower luminance negative contrast screen. Snyder and Taylor¹⁷ demonstrated that increased character luminance significantly increased character legibility. Shurtleff¹⁸ supported this by demonstrating that increased character/background contrast resulted in increased character legibility.

In a study by Radl¹⁹, it was found, once again, that negative contrast screens yielded greater legibility than positive contrast screens. Radl also compared the effects of positive and negative contrast on visual comfort and performance when subjects transcribed letters from a VDT screen to a paper sheet. The subjects rated the negative contrast screen as more comfortable and performance was also found to be better with this presentation.

Although there have been many reports of different visual effects when comparing negative to positive contrast VDT screens, little has been done to investigate possible physiological reasons to account for the differences. Therefore, this study was designed to explore this effect. The question investigated was whether there was any difference in accommodative posture between viewing positive and negative contrast VDT screens. An additional question was whether different peripheral surrounds (black or white) have an effect on accommodative posture while viewing a VDT.

* In this report, the U.S. convention of calling light characters on black background positive contrast and calling dark characters on light background negative contrast will be employed.

METHODS

Subjects

Twenty students at the Pacific University College of Optometry were selected for this study (ages 22 to 31, mean=25.31). All had corrected visual acuities of at least 20/20 at both near and far distances, no evidence of ocular pathology, and stereoacuities of at least 30 arcseconds, as determined with the Randot 3-ball stereotest. Spherical refractive errors of the subjects' right eyes ranged from 8.75 diopters of myopia to 1.00 diopters of hyperopia (mean=2.12 diopters of myopia, S.D.=2.50 diopters), astigmatism ranged from 0.00 to 2.25 diopters (mean=0.50 diopters, S.D.=0.62 diopters), and anisometropia (spherical equivalent) was no greater than 1.75 diopters (mean=0.37 diopters, S.D.=0.37 diopters).

Methods and Materials

Subjects were seated and viewed an Amdek Color-I VDT screen binocularly through the beam splitter of a vernier Badal optometer²⁰. The VDT was placed 50 centimeters from the subject's eyes with characters corresponding to 6/57 (20/190) Snellen acuity (9.5 arcminute vertical detail subtense). Screen dimensions were 28.3 cm by 21.3 cm and a 40 column display format was used. The target presented was a passage in which some words were spelled incorrectly. These inaccuracies were included in an attempt to maintain the subject's attention on the screen. The words were generated by a Commodore 64 computer and remained constant throughout the study. Contrast modes were changed readily with the computer.

Subjects were supplied with the most plus (least minus) lenses for best distance visual acuity as determined by prior clinical examination.

Corrective lenses were placed in the lens cells of the optometer. In order to minimize stray light on the screen area, the VDT was enclosed in an open-ended box constructed from poster board and the peripheral surround was illuminated with a 60 W fluorescent bulb placed directly behind the VDT. Two boxes were used for the purpose of creating two separate ambient environmental conditions. One box was constructed with white poster board and the other with black. The dimensions of the boxes and the experimental setup are illustrated in Figure 1.

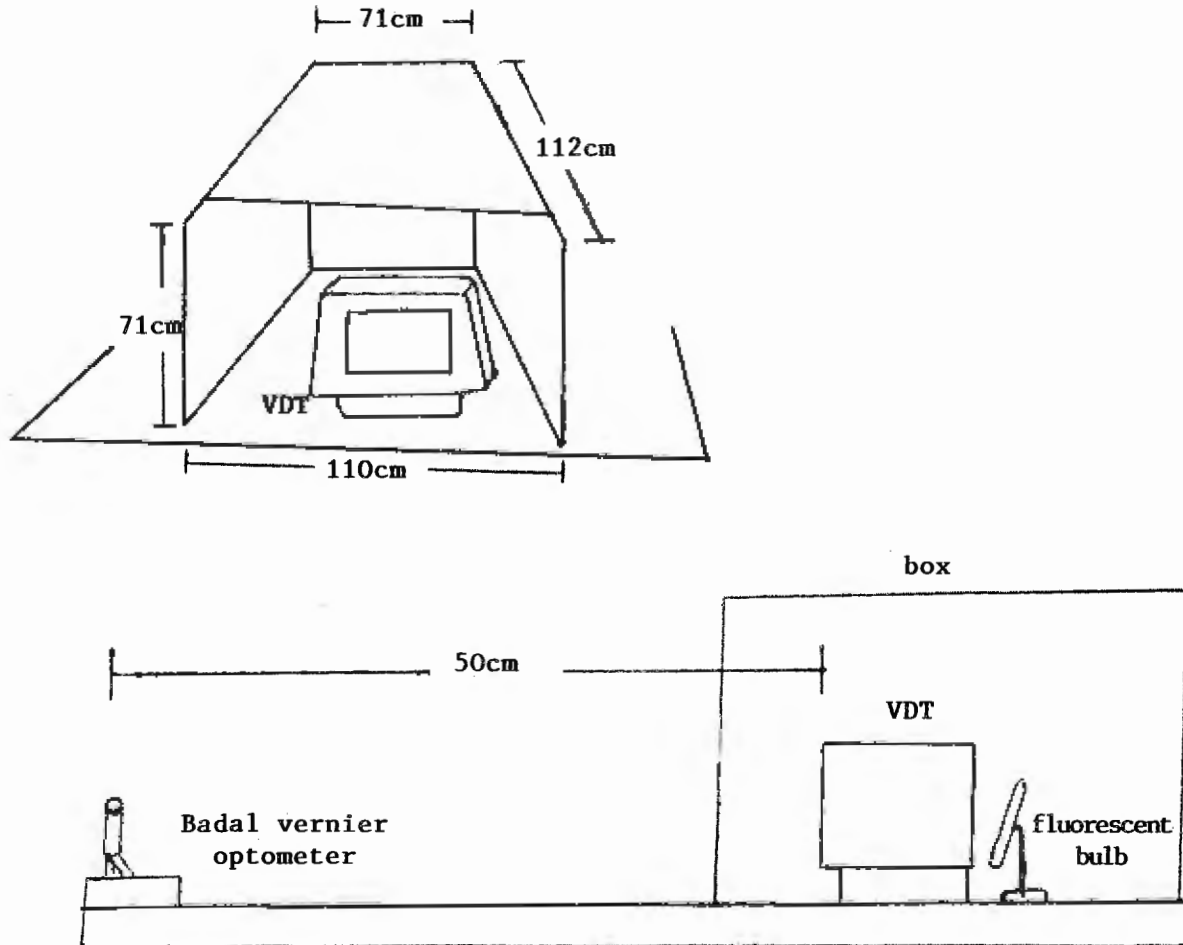


Figure 1. Dimensions of box (top) and setup of experiment (bottom).

Overhead 34 W fluorescent lights remained on throughout the study.

Four conditions were used:

Condition 1--white peripheral surround, negative contrast screen.

Condition 2--white peripheral surround, positive contrast screen.

Condition 3--black peripheral surround, negative contrast screen.

Condition 4--black peripheral surround, positive contrast screen.

In each condition, subjects were instructed to read the passage of words on the VDT screen, and at instructed times, to view a specific word. At this time, the accommodative status of each subject's right eye was measured. Measurements were made initially and then every twenty seconds for two minutes.

Subjects viewed the VDT through a beam splitter that was part of a vernier Badal optometer. A chin-rest and forehead-rest were used throughout the study to maintain a constant reading distance. Each accommodative datum was the average of two optometer readings (ascending/descending method of limits). The optometer's vernier lines were exposed for half-second intervals and adjusted until the subjects reported alignment.

In order to compensate for any trend effects, the twenty subjects were divided randomly into four groups of five subjects and the order of presentations were counterbalanced with respect to the various test conditions.

There was a two minute rest period between each condition at which time subjects were instructed not to view any near object.

Photometric Readings

Luminance measurements were made with a Tektronix J-16 photometer coupled to a J 6523-2 1° Narrow Angle Luminance Probe. With negative contrast, under both ambient conditions average character luminance was 221 cd/m^2 , while average background luminance was 741 cd/m^2 . In both ambient conditions, average character luminance with positive contrast was 499 cd/m^2 while average

background luminance was 96 cd/m^2 . Figure-ground contrast calculated using Equation 1 for the positive contrast screen was 0.81 while contrast for the

$$\left(1 - \frac{\text{lower luminance}}{\text{higher lumiannce}} \right) \text{ Equation 1.}$$

negative contrast screen was 0.70. The luminance readings and contrast findings are listed in Table 1.

	Luminance (cd/m^2)		Figure-ground contrast
	character	background	
negative contrast	221	741	0.70
positive contrast	499	96	0.81

Table 1. Luminance readings and figure-ground contrast findings.

Illuminance normal to the subject's corneas were measured with a Tektronix J-16 photometer coupled to a J-6511 Illuminance Probe. The readings are summarized in Table 2.

surround condition	white	black
negative contrast	270 lm/m^2	190 lm/m^2
positive contrast	250 lm/m^2	150 lm/m^2

Table 2. Illuminance normal to the subject's corneas.

RESULTS

Although mean accommodative responses for both the white and black surround conditions were greater for the positive contrast than for negative, statistically there was no significant difference (Table 3). A comparison between the two surround conditions does, however, reveal statistically significant differences. Accommodative responses for both negative and positive contrast conditions were less with the black surround (Table 3).

	Surround condition		Comparison between black and white surround
	white	black	
positive contrast	1.806 diopters S.D.=0.565	1.537 diopters S.D.=0.556	t=-2.836 P<0.0103 *
negative contrast	1.779 diopters S.D.=0.578	1.504 diopters S.D.=0.654	t=-3.085 P<0.0060 *
Comparison between positive and negative contrast settings	t=-0.732 P<0.4792	t=-0.950 P<0.3566	

Table 3. Accommodative responses in each condition and statistical results.

* statistically significant (p<0.05).

DISCUSSION

In the present study, accommodative lags were found for each viewing condition. However, there were no statistically significant differences in accommodative lag between positive and negative contrast at either ambient light level. This result is similar to what Murch¹² found using positive and negative contrast raster cathode ray tubes.

Having found no accommodative difference between negative versus positive contrast presentations, factors which may account for the greater preference for and improved performance with negative contrast presentations are;

1. The contrast differential could be less between a negative contrast VDT screen and a printed sheet since most printed sheets are in negative contrast presentations.¹⁹ Thus contrast shifts would be reduced as the operator looked back and forth between the VDT and the page from which she/he was working.
2. Negative contrast is an effective method for reducing the effects of reflections and glare on the VDT screen.¹⁹
3. The higher mean luminance from the negative contrast screen could reduce the operator's pupil diameter, thus decreasing optical distortions and improving depth of field.¹⁶ The latter effect is of considerable importance to those who have lost much of their ability to accommodate.

This study indicates that small differences in illuminance at the eye due to positive versus negative contrast conditions did not significantly affect accommodative accuracy at either ambient light level. However, larger differences in illuminance from the peripheral surround do significantly

affect accommodative accuracy resulting in greater accommodative lag for the lower level in both positive and negative contrast presentations. This is demonstrated when comparing the black to white surround conditions in both positive and negative contrast modes.

Similar findings have been reported in studies of accommodation for printed copy. Johnson²¹, utilizing a laser optometer, showed that errors of accommodation (lags) were comparatively small at higher levels of luminance and progressively increased with successive luminance reductions, indicating that accommodative stimulus becomes less effective in determining the accommodative response as luminance is reduced. Reductions in accommodative accuracy with decreasing luminance have been previously reported by several investigators²² who showed that accommodation drifts towards the resting point of accommodation as luminance levels are decreased. Although the previously mentioned studies were performed using printed copy, findings from this study seem to indicate similar accommodative responses with VDT viewing.

Having found that lower levels of ambient illumination can affect accommodative accuracy (resulting in a greater accommodative lag), it is conceivable that viewing VDTs in low ambient illumination may lead to difficulties with vision, ocular discomfort, decreased performance on visual tasks, and/or be less preferred subjectively. It is recognized, however, that differences in peripheral surround color (black versus white) may also have had contributory effects. The present findings also make evident the importance of controlling illumination in VDT studies.

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