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COMPARISON OF CRT ANTIREFLECTION FILTERS

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16. Abstract This report describes two experiments examining the effects of various CRT screen treatments on reflectance and user performance. In the first experiment, physical measurements were taken of the light emitted and reflected from the screen of a popular video terminal. Measurements were taken for both normal and reverse polarity when the tube face was bare. Similarly, measurements were taken when the screen was covered with either a micromesh or plastic filter. Measurements were taken at the center and upper-right corner of the screen.

At the center point there were no significant differences in reflectance due to polarity, but differences due to screen filters were significant. (The micromesh filter was particularly effective in reducing reflectance.) For the corner point there were no significant differences in reflectance due to either polarity or filter.

The second experiment was a human performance test concerning the same six treatment conditions and terminal as were used in the first experiment. Six university students were asked to count how often the character-pair "3W" occurred within a block of text shown on the screen.

Except for normal polarity leading to shorter search times, neither the filter nor polarity changes had statistically significant effects on search times or errors. There was, however, a tendency for the plastic filter to lead to poorer performance (longer search times, more errors).

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FOREWORD

This research was performed at the University of Michigan as part of the requirements for two courses: Architecture 545, (Advanced Lighting Design--Henry Kowalewski, Instructor) and Industrial & Operations Engineering 433 (Human Performance--Paul Green, Instructor). It was conceived as a pilot study to explore issues of VDT hardware design, the selection of antireflection filters, and operator performance.

We thank Mr. Hoy Ying Chang (Vice President--Engineering, Zenith Data Systems, Zenith Radio Corp.) and Mr. David Fillion (engineering staff, Zenith) for providing the terminal used in this study and important technical data on the screen filters evaluated.

We also thank Mr. James Benya, formerly of Smith, Hinchman, and Grylls of Detroit, Michigan, for his advice.

BACKGROUND

The use of the cathode ray tube (CRT) display, also called a video display terminal (VDT) or video display unit (VDU), is becoming more and more widespread in homes, offices, farms, and factories. In 1980 there were 5 to 10 million VDT's and more than 7 million operators in the U.S. (Center for Disease Control, 1980). This number is predicted to double every 2 to 4 years. Because of the large number of people exposed to and using VDT's, health and safety questions and human performance issues have become important areas of study.

Glare and screen reflections are often cited as problems experienced by computer users (Brown, Dismukes, and Rinalducci, 1982; Cakir, Hart, and Stewart, 1979; Dainoff, Happ, and Crane, 1981). The reflections, often of light sources or even the viewer, tend to mask the image. To reduce specular reflections and improve the contrast ratio, screen filters are often employed. Unfortunately, filters sometimes reduce image quality (Snyder, 1983).

Several studies have examined the effect of filter type on user performance. Habinek, Jacobson, Miller, and Suther (1982) had 32 people read aloud arrays of characters while speed and accuracy were recorded. Each person saw the characters at three different screen locations: upper left, center, lower right. Test displays included (1) a standard phosphor tube with a polished glass surface; (2) the same tube covered with a Sun-Flex nylon micromesh filter; (3) the same tube covered with an Optical Coating Laboratory Inc. (OCLI) quarter-wavelength bonded filter, or (4) the same tube covered with a directly etched faceplate. Half of the participants viewed the characters under positive contrast (also called normal video or positive polarity--light characters on dark background). The other half viewed the characters under negative contrast (also called reverse video or negative polarity--dark characters on light background). All participants viewed arrays under both good and poor lighting conditions.

Under good viewing conditions there were no differences in correct reading rate due to either contrast direction or filter type. Under poor conditions, there were significant differences due to filter type. (Micromesh was best, followed by quarter wavelength and etched screen, and lastly by none at all.) The effect of contrast direction was unclear.

Independent of filter questions, two studies have considered a potentially interacting factor: display polarity. Those favoring reverse polarity argue that a computer display should be like the hard copy (paper) displays used with them. Those favoring normal polarity claim it is less annoying, since the flicker threshold is proportional to screen luminous flux, and fewer pixels are illuminated in the normal video mode.

Iseness (1982) filled the screen of a Hazeltine 1510 terminal with rows of the letter "W." He collected ratings of discomfort due to flicker and glare, and measured the detection of peripheral flicker as a function of ambient illumination, video luminance, and display polarity. (Flicker was examined because people are more sensitive to flicker peripherally than when viewed straight on. A common demonstration of this phenomenon is observed at the video section of a department store by viewing the bank of TV sets directly and peripherally.) Iseness found that increasing the video luminance or changing to reverse video both led to increased flicker perception, as predicted by the Ferry-Porter Law (Geldard, 1972).

Bauer and Cavonius (1980) had 23 people enter four-letter nonsense words on a Hazeltine 1500 terminal. On each trial the digit 4 or 6 appeared on a numeric display behind the terminal. (The intent was to force participants to alternate their gaze between the terminal and other work materials.) After subjects pressed a key on the terminal keyboard corresponding to the digit shown, a nonsense word briefly appeared on the terminal CRT. The subject typed in that word. People made fewer errors in using a terminal with reverse video characters at high video luminance than using normal video with either low- or high-luminance characters.

In a second experiment, four-letter nonsense words were briefly presented to 19 observers on a CRT. Their task was to find the identical word in a typed list of 100. For reverse video, search times were about 1 second less, and error rates were about 8% less, than with normal video.

A somewhat less obvious reason for fitting terminals with a screen filter is to reduce the intensity of the electrostatic field generated by the tube face. While the levels of non-ionizing radiation and ionizing radiation are so low that they are barely measurable (Maloney, 1981; Murray, Moss, Parr, and Cox, 1981), it has been suggested that the electrostatic field generated by a video display may be a health hazard. It has been inferred that this field causes imbalances in several biochemical families, resulting in headaches, nausea, dizziness, and changes in mood (Toh, Pooley, Galla, and Berrier, 1981; Wallach, 1982). Measurements have shown that some production video displays generate high levels of positive ions (Moore, 1982). It is commonly felt that uncharged fields (ones with negative ions) are desired over charged fields. Some manufacturers claim their filters do provide electrostatic protection. (This, in fact, has been used to sell atmospheric ion generators.)

To provide additional evidence concerning the benefits of filters, a study was conducted. Specifically, the objective of this pilot study was to analyze effects of varied CRT screen treatments on (1) specular reflectance, and (2) user performance. The first experiment dealt with measurements of screen reflectance of a popular "dumb" computer terminal with various screen treatments. The second experiment concerned user performance in a search task under a fixed illumination level for various screen treatments.

OBJECTIVE MEASUREMENTS OF SCREEN REFLECTANCE, EXPERIMENT 1.

Test Plan

Experimental Measures

Reflectance, reflectance factor, and luminance factors are all measurements of the amount of light reflected by a surface. All three were candidates for use in the first experiment. Reflectance is the ratio of total luminous flux reflected from a surface to the total luminous flux incident on it, and varies between 0 and 1. It is of little value in evaluating non-diffuse surfaces.

The reflectance factor is the ratio of the luminance flux reflected in directions defined by a given cone, to that reflected in the same directions by a perfectly reflecting, perfectly white, uniform diffusing surface. It, too, was rejected, because of interest in the effect on a point (the user), not an area.

The luminance factor is defined as the ratio of the luminance of a reflecting surface (in this case a non-diffusing CRT surface), viewed in a given direction, to that of a perfectly reflecting, perfectly white uniform diffusing surface (a 90% reflective Kodak white card) under the same illumination. It may have any value from zero to numbers approaching infinity. For practical purposes it is equal to the luminance (candela/meter^2 or ft.-L.) divided by illuminance (lumens/meter^2 or ft.-C). See the IES Lighting Handbook for a further explanation (Illuminating Engineering

Society, 1981). The luminance factor was one of the dependent variables in the first experiment.

<u>Equipment</u>

A Zenith model Z-19-CN cathode ray tube computer terminal served as the test display. The terminal had a 30.5 cm (12 in.) diagonal tube with a P-39 green phosphor screen.

The light source was a Kodak model 650H 35mm slide projector modified by installing an aluminum plate with a 0.32 cm (1/8 in.) diameter hole in place of a slide. The projector was mounted on a heavy-duty tripod.

Light was reflected either directly off the untreated polished glass surface of the tube or the combined surface of the filter and tube. There were two test filters: a SunFlex model 45HT (Heathkit part number HCA-4) black nylon, micromesh filter and a Panelgraphic model 12025B-16L (Heathkit part number HCA-3) solid tinted, plastic convex filter. Latitude and longitude settings were made using a custom-made wooden scale (in essence, a giant protractor).

Luminance measurements were taken with a Photo Research model 502 1-degree spot-photometer, which when positioned read an area of approximately 0.635 cm (1/4 in.) diameter on the screen. (To reduce measurement error the photometer was rigidly mounted to a rod securely fastened to the measurement plane.)

Illuminance measurements were taken with a LI-COR model LI-185B incident light meter, with a .635 cm (1/4 in.)

sensor. The arrangement of equipment and test display for this experiment are shown in Figures 1 and 2.

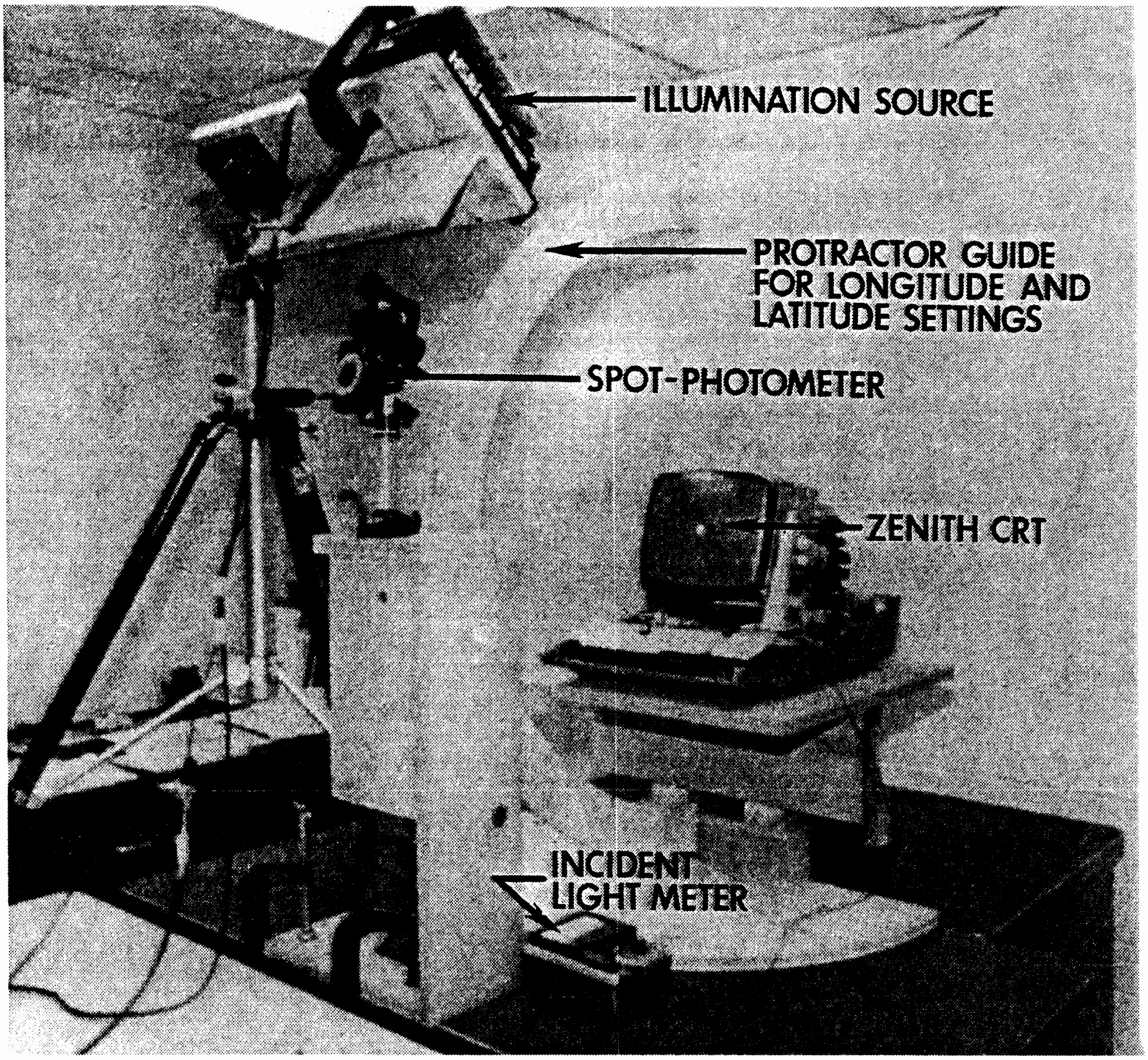

Figure 1. Test equipment arrangement

Figure 2. CRT test display (Note luminous dot at center).

Test Activities

In this experiment physical measurements were taken of the amount of light emitted and reflected by the display face of a Zenith Z-19-CN terminal. The purpose was to look at directional reflectance from the CRT under various screen treatments and screen polarities.

Readings were taken at the center and upper right corner of the display. Three screen treatments were tested (no filter, micromesh filter, and plastic filter) along with two video conditions (normal video and reverse video). (The contrast direction was controlled via DIP switches inside the terminal.) To take the luminance measurements (the light emitted by and reflected from the screen), a photometer was used. It was placed 60.9 cm (24.0 in.) from the screen, 20 degrees below horizontal (the position of a viewer's eyes when the terminal is used in an ergonomically proper position (Cakir, Stewart and Hart, 1980)), and aimed at one of the two screen measurement points.

For the center point, measurements for each filter/ video polarity combination were taken every 10 degrees on the longitude (horizontal) and latitude (vertical). There were 9 longitude measurements (range of 0 to 80 degrees) and 6 latitude measurements (range of 20 to 70 degrees). Readings were double checked for accuracy once every 10 degrees latitude. Some points could not be measured due to physical interference of the measurement scale (which determined longitude and latitude degree points).

For the upper-right corner point, measurements were spaced less regularly because of interference with the measurement apparatus. There were six longitude measurements (range of 10 to 55 degrees) and three latitude measurements (range of 20 to 40). A total of 420 readings were taken. The other equivalent corners (upper left, lower left, and lower right) were assumed to be identical because of symmetry of the CRT face.

Results

Of interest in this experiment was how screen treatment affected specular reflectance at two measured screen points. Shown in Tables 1 and 2 are Mean and Range Luminance Factor values for center and upper-right corner points. As shown in these tables, there were no large differences in the mean values between the two points, but the range of corner values was double that for the center values. However, a direct statistical comparison of the two points is inappropriate, because measurements were made at noncomparable longitude and latitude pairs.

A four-way ANOVA of the center point luminances revealed no significant differences due to polarity ($\underline{F}'<1$) or the Filter by Polarity Interaction ($\underline{F}'<1$). However, filter differences were significant ($\underline{F}''(2.1,22.2)=17.70$, $\underline{p}<.001$). For the corner point, the Polarity ($\underline{F}''(2.1,2.6)=1.28$, $\underline{p}>.05$), Filter ($\underline{F}''(10,6,34.2)=1.56$, $\underline{p}>.05$), and Filter by Polarity effects were not significant.

The percent luminance reduction provided by filters is shown in Table 3. While these differences were statistically significant at only one point, they were of considerable magnitude for both points, especially for the micromesh filter.

TABLE 1

MEAN AND RANGE LUMINANCE FACTOR VALUES FOR
CENTER SCREEN POINT

	No Filter	Micromesh Filter	Plastic Filter	Mean & Range
Normal Polarity				
Mean	2.5	1.2	1.4	1.7
Range	(5.7)	(2.7)	(16.1)	(16.2)
Reverse Polarity				
Mean	2.6	1.2	1.4	1.7
Range	(6.7)	(2.6)	(18.7)	(18.1)
Mean	2.6	1.2	1.4	
Range	(6.9)	(2.7)	(18.1)	

TABLE 2

MEAN AND RANGE LUMINANCE FACTOR VALUES FOR
UPPER-RIGHT CORNER SCREEN POINT

	No Filter	Micromesh Filter	Plastic Filter	Mean & Range
Normal Polarity				
Mean	2.0	0.6	3.1	1.9
Range	(19.9)	(4.3)	(21.5)	(21.5)
Reverse Polarity				
Mean	3.6	0.6	2.2	2.1
Range	(30.3)	(5.5)	(15.1)	(30.5)
Mean	2.9	0.6	2.6	
Range	(30.3)	(5.5)	(21.5)	

TABLE 3

LUMINANCE REDUCTION FACTORS

Screen Treatment	Percent (%) Luminance Reduction	
	Center of Screen	Right Corner of Screen
None (polished glass)	0	0
Micromesh Filter	54	88
Plastic Filter	46	10

HUMAN PERFORMANCE WITH VARIOUS FILTERS, EXPERIMENT 2

Test Plan

The purpose of this experiment was to determine how screen polarity and filter choices (none, plastic, micromesh) affected how well people were able to search text shown on a CRT terminal. Their performance was assessed by how long they took and how many mistakes they made.

Participants

Six male University of Michigan (Ann Arbor) students volunteered to take part in the study. Participants ranged in age from 18 to 22 years old. All had 20/20 vision (uncorrected). Five of the six participants had previously viewed text or data on a video terminal. Three of the six categorized themselves as regular CRT users (more than twice a week), and two others were infrequent users (once every 3 months).

Test Equipment and Materials

This experiment was conducted in a typically lighted office in the Space Physics Research Laboratory at The University of Michigan. The computer terminal, two filters, photometer, and illumination meter from the first experiment were also used here. The computer terminal was placed on a standard desk .76 meters (30 in.) above the floor. It was positioned on the desk top so that a reflection of the overhead lighting was visible at the center of the screen. Across subjects, the viewer/screen relationship was relatively consistent, with people looking down 20^{o} along a

61 cm (24 in.) line of sight to the display. The average ambient illumination on the almost vertical CRT face was about 570 lx (53 ft-c). The workplace was not optimized, in the sense that subjects did not have a well-designed workplace with respect to human factors.

The task instructions and six test arrays were stored in an Amdahl 5860 computer operating under MTS (Michigan Terminal System). The Amdahl was linked to the terminal via a 300 baud dial-up line. At the time of the study the system load was low and responses to commands were immediate.

The test arrays consisted of 10 rows of 52 randomly sequenced digits and upper case letters. The characters were 0.51 cm (0.2 in.) high and 0.254 cm (0.1 in.) wide. Characters were formed from a 5 x 7 dot matrix in an 8 x 10 dot box. Figure 4 shows one of the six test stimuli. (See Appendix B for all the test arrays.) In each array there were 10 quasirandom occurrences of the string "3W". (It never began a line.)

Number/Letter to Locate - 3W

```
PAHJDYKJ3MSMWOW3KMLOPHJDUYQPNVCBHU3WJSKIUEI3WKSKNW3K
BNEYW3SJNWSJJ3JSKMNSJUWUSJ3WJSJ3MXNKHPOUEIUM3IAWSN3I
MNCHUEKABNCVUYEWHGIO3SKJWJJ3WJSJBNCUJISOOPNXMHSJTYSH
3MNJHWSHJW3SJJHJ3WSHJUIROPNCXMJUISHYRKJJKAL3DSJ3SKKW
NMXYUUSJ3KLLWSHJ3SK33KLJKWL3WSHUIONMCBGAJQOPURIICNWM
WM3MCXHUSJEOPPWUEINXMJHDJYUEJHJALKL3LSL3LWLSLALL3WLS
RYUUWNMCN3SKSKWAAOO3MMCNNISKW3SKKW3KSKKMJK3IKDIOPMCN
8SKK3WSKKNXMUUSJQPOALKJDMYETTSNMCHJAI3IWISAKSKK3K3MN
KBCBUDJJ3NSJWSJHN3WSJMW3SUIDJHHKSKHJDUWNCXVQUJSHTYE3
3MSHJW3SJ3JSJWSIKJJWJJ3WJSKMNCJIIPQPAJJ3OSJJWSKMNXCK
```

Figure 4. The ten-row/fifty-two-column alphanumeric test stimulus.

Test Activities and Their Sequence

Participants were tested one at a time. Prior to the test, participants were shown a sample screen of characters and permitted to adjust the display intensity to a comfortable level. The brightness level selected (arbitrarily defined as 1-6, where 6 = brightest luminance level) was recorded by the experimenter. (The consequent contrast ratio was typically 6:1, 1:6 or 7:1, 1:7, depending on whether normal or reverse video mode was being tested.) Participants were also encouraged to adjust their seats to maximize comfort and screen visibility. Instructions for the experiment were then displayed on the screen by the experimenter. The participant read the directions and, upon completion, was asked by the experimenter if there were any questions.

Each person was tested under six conditions (2 contrast directions by 3 filter choices [none, plastic, micromesh]). The sequence of text arrays was counterbalanced across subjects. (The complete sequence is shown in Appendix B.) Prior to each condition the screen was covered with a gray card and an array of characters was listed on the screen. The card was then removed and a stop watch was started. The participants' task was to count how often the character string "3W" occurred in each text array. Participants were instructed to search the text line by line, from top to bottom, scanning each line from left to right. Further, they were to search at a natural pace and as accurately as possible. When the participant was done, the experimenter recorded the elapsed time (in seconds) and the number of "3W" pairs found.

Results

Of interest in this experiment was how screen treatment affected human search performance. Shown in Tables 4 and 5 are Mean Number of Errors and Mean Search Times for each condition. The two performance measures were correlated (r=-.37, p <.05) with longer search times being associated with fewer errors, an indication of the speed-accuracy tradeoff.

A three-way ANOVA of the error data revealed that the effects of neither Polarity ($F(1,5)$=.04, p >.1) or Filter ($F(2,10)$=2.79, p >.1) were significant. However, in a three-way ANOVA of the search time data, the effect of Polarity was significant ($F(1,5)$=7.11, p <.05) but not the effect of Filter ($F(2,10)$=2.14, p >.1). (Normal polarity was associated with briefer search times.) For both types

TABLE 4

MEAN NUMBER OF ERRORS
(Number of "3W's" not found out of 10)

	No Filter	Micromesh Filter	Plastic Filter	Mean
Normal Polarity	1.5	1.3	2.8	1.8
Reverse Polarity	2.2	1.5	2.2	1.9
Mean	1.8	1.4	2.5	

TABLE 5

MEAN SEARCH TIMES (in seconds)

	No Filter	Micromesh Filter	Plastic Filter	Mean
Normal Polarity	50.5	41.1	61.6	51.0
Reverse Polarity	51.5	59.1	60.1	56.9
Mean	51.0	50.1	60.9	

of data there was a trend for the plastic filter to lead to poor performance (longer search times, more errors).

CONCLUSIONS

These data suggest that covering a bare VDT face with a micromesh filter may lead to improved user performance. In the first experiment, placing a micromesh filter on a standard CRT substantially reduced reflected light. So, too, did the plastic filter, but to a lesser extent. However, for only one of the two screen locations were the differences statistically significant.

In the second experiment, user performance was best when the display was covered with a micromesh filter, though the differences between it and the bare screen or the plastic filter were not statistically significant. The lack of significance is not surprising, considering the paucity of data collected: 69 errors over 36 timed trials.

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APPENDIX A

OBJECTIVE MEASUREMENTS OF SCREEN REFLECTANCE, EXPERIMENT 1: RAW DATA

LUMINANCE FACTORS FOR NORMAL POLARITY, NO FILTER, POINT AT CENTER SCREEN

Latitude (deg)	Longitude (deg)								
	0	10	20	30	40	50	60	70	80
20	6.0	5.7	4.5	3.6	3.6	2.6	1.8	1.4	.3
30	5.3	5.1	4.6	4.4	3.5	2.6	2.1	1.5	.6
40	4.6	4.8	4.6	4.3	3.2	2.1	2.3	1.2	.8
50	3.6	3.5	3.2	2.8	2.8	2.4	1.9	1.4	.8
60	e	2.8	1.9	1.6	1.9	1.8	1.5	1.0	.7
70	e	1.5	1.5	1.5	1.5	1.3	1.3	1.1	.8

LUMINANCE FACTORS FOR REVERSE POLARITY, NO FILTER, POINT AT CENTER SCREEN

Latitude (deg)	Longitude (deg)								
	0	10	20	30	40	50	60	70	80
20	7.2	5.7	4.4	3.7	3.7	2.8	1.9	1.5	.5
30	5.4	5.2	4.6	4.4	3.5	2.7	1.9	1.3	.6
40	4.6	4.6	4.6	4.3	3.1	1.8	2.1	1.3	.9
50	3.7	3.6	3.4	3.0	2.8	2.4	1.9	1.5	.8
60	e	2.9	1.8	1.8	1.8	1.8	1.5	1.1	.7
70	e	1.5	1.5	1.5	1.5	1.4	1.3	1.1	.8

e = equipment interference, no measurements taken (support wire)

LUMINANCE FACTORS FOR NORMAL POLARITY, MICROMESH FILTER, POINT AT CENTER SCREEN

Latitude (deg)	Longitude (deg)								
	0	10	20	30	40	50	60	70	80
20	2.3	1.7	1.4	1.3	1.7	.7	.9	.5	.4
30	2.4	1.6	1.5	1.4	2.1	.8	.7	.5	.5
40	2.1	1.6	1.5	1.4	1.8	1.7	.9	2.3	1.5
50	1.8	1.5	1.3	1.4	2.8	2.8	2.5	.8	.1
60	e	1.9	1.1	.7	.7	.7	1.2	1.9	.4
70	e	.6	.8	.7	.5	.5	.5	.5	.7

LUMINANCE FACTORS FOR REVERSE POLARITY, MICROMESH NO FILTER, POINT AT CENTER SCREEN

Latitude (deg)	Longitude (deg)								
	0	10	20	30	40	50	60	70	80
20	2.2	1.7	1.3	1.3	1.7	.8	.8	.5	.4
30	2.4	1.6	1.5	1.5	2.2	.8	.5	.4	.5
40	2.1	1.6	1.5	1.4	1.7	1.5	.7	2.4	1.5
50	1.8	1.5	1.4	1.4	1.8	2.8	2.4	.7	.2
60	e	1.9	1.1	.8	.7	.7	1.2	1.9	.4
70	e	.6	.8	.7	.5	.5	.5	.5	.7

e = equipment interference, no measurements taken (support wire)

LUMINANCE FACTORS FOR NORMAL POLARITY, PLASTIC FILTER, POINT AT CENTER SCREEN

Latitude (deg)	Longitude (deg)								
	0	10	20	30	40	50	60	70	80
20	16.3	7.1	2.5	1.4	1.3	.9	.6	.4	.2
30	4.3	3.6	2.4	1.7	1.3	.9	.6	.4	.2
40	2.2	2.1	1.9	1.7	1.1	.8	.7	.4	.2
50	1.4	1.3	1.2	1.1	1.0	.8	.6	.4	.2
60	e	1.0	.7	.6	.6	.6	.5	.3	.2
70	e	.5	.5	.5	.5	.4	.4	.3	.2

LUMINANCE FACTORS FOR REVERSE POLARITY, PLASTIC FILTER, POINT AT CENTER SCREEN

Latitude (deg)	Longitude (deg)								
	0	10	20	30	40	50	60	70	80
20	18.3	8.2	2.6	1.5	1.3	1.0	.6	.2	.2
30	4.6	3.5	2.3	1.8	1.3	.9	.5	.3	.2
40	2.2	1.8	1.8	1.6	1.1	.6	.5	.4	.3
50	1.4	1.3	1.2	1.1	1.0	.8	.6	.4	.2
60	e	1.0	.7	.7	.6	.6	.5	.3	.2
70	e	.5	.5	.5	.4	.4	.4	.3	.2

e = equipment interference, no measurements taken (support wire)

LUMINANCE FACTORS FOR NORMAL POLARITY, NO FILTER, POINT AT CORNER OF SCREEN

Latitude (deg)	Longitude (deg)					
	10	18	25	35	45	55
20	.5	.7	.6	.5	.5	.4
32	.8	2.6	.8	.5	.4	.3
40	4.0	20.2	1.6	.6	.4	.4

LUMINANCE FACTORS FOR REVERSE POLARITY, NO FILTER, POINT AT CORNER OF SCREEN

Latitude (deg)	Longitude (deg)					
	10	18	25	35	45	55
20	.5	.7	.6	.4	.5	.4
32	.8	30.6	.8	.5	.4	.3
40	5.0	19.9	1.6	.6	.4	.4

LUMINANCE FACTORS FOR NORMAL POLARITY, MICROMESH FILTER, POINT AT CORNER OF SCREEN

Latitude (deg)	Longitude (deg)					
	10	18	25	35	45	55
20	.1	.3	.2	.1	.1	.1
32	.2	4.4	.2	.1	.1	.1
40	1.0	2.3	.3	.2	.1	.2

LUMINANCE FACTORS FOR REVERSE POLARITY, MICROMESH FILTER, POINT AT CORNER OF SCREEN

Latitude (deg)	Longitude (deg)					
	10	18	25	35	45	55
20	.1	.2	.2	.1	.2	.1
32	.2	5.6	.2	.1	.1	.1
40	1.1	2.3	.3	.1	.1	.2

LUMINANCE FACTORS FOR NORMAL POLARITY, PLASTIC FILTER, POINT AT CORNER OF SCREEN

Latitude (deg)	Longitude (deg)					
	10	18	25	35	45	55
20	.4	.2	.6	.2	.2	.1
32	2.4	21.6	1.7	.3	.2	.1
40	9.0	15.7	2.7	.3	.2	.1

LUMINANCE FACTORS FOR REVERSE POLARITY, PLASTIC FILTER, POINT AT CORNER OF SCREEN

Latitude (deg)	Longitude (deg)					
	10	18	25	35	45	55
20	.4	.2	.6	.2	.2	.1
32	2.4	5.6	1.7	.3	.2	.1
40	9.8	15.2	2.8	.3	.2	.1

APPENDIX B

HUMAN PERFORMANCE WITH VARIOUS FILTERS, EXPERIMENT 2: ORDER OF TEST CONDITIONS AND PARTICIPANT INSTRUCTIONS

ORDER OF TEST CONDITIONS

Participant	Conditions (filter type, direction of contrast, array number)					
	1	2	3	4	5	6
1	None pos 6	None neg 1	M'mesh pos 2	M'mesh neg 3	Plastic pos 4	Plastic neg 5
2	None neg 5	M'mesh pos 6	M'mesh neg 1	Plastic pos 2	Plastic neg 3	None pos 4
3	M'mesh pos 4	M'mesh neg 5	Plastic pos 6	Plastic neg 1	None pos 2	None neg 3
4	M'mesh neg 3	Plastic pos 4	Plastic neg 5	None pos 6	None neg 1	M'mesh pos 2
5	Plastic pos 2	Plastic neg 3	None pos 4	None neg 5	M'mesh pos 6	M'mesh neg 1
6	Plastic neg 1	None pos 2	None neg 3	M'mesh pos 4	M'mesh neg 5	Plastic pos 6

INSTRUCTIONS AND TEST ARRAYS FOR
HUMAN PERFORMANCE EXPERIMENT

T H E   U N I V E R S I T Y   O F   M I C H I G A N

ZENITH VIDEO DISPLAY TERMINAL:
VISUAL PERFORMANCE EXPERIMENT

This experiment is being conducted as part of the academic requirements for Industrial Operations Engineering 433 (Human Performance) and Architecture 545 (Advanced Lighting Design) at the University of Michigan.

Its purpose is to collect performance data on people using a Zenith Video Display Terminal (VDT), under six video display conditions.

EXPERIMENT INSTRUCTIONS:

One block of text will be shown on the computer screen. You will count how many times the number/letter combination of "3W" occurs in the text block. When you are done, tell the experimenter how many times the combination occurred. Count-up the combinations once at your natural pace. You will perform this task for six video display conditions the experimenter will inform you of the condition that is being tested before each one starts. Start each condition upon instruction from the experimenter.

ZENITH VDT PERFORMANCE TASK

CONDITION 1

PAHJDYKJ3MSMWOW3KMLOPHJDUYQPNVCBHU3WJSKIUEI3WKSKNW3K
BNEYW3SJNWSJJ3JSKMNSJUWUSJ3WJSJ3MXNKHPOUEIUM3IAWSN3I
MNCHUEKABNCVUYEWHGIO3SKJWJJ3WJSJBNCUJISOOPNXMHSJTYSH
3MNJHWSHJW3SJJHJ3WSHJUIROPNCXMJUISHYRKJJKAL3DSJ3SKKW
NMXYUUSJ3KLLWSHJ3SK33KLJKWL3WSHUIONMCBGAJQOPURIICNWM
WM3MCXHUSJEOPPWUEINXMJHDJYUEJHJALKL3LSL3LWLSLALL3WLS
RYUUWNMCN3SKSKWAAOO3MMCNNISKW3SKKW3KSKKMJK3IKDIOPMCN
8SKK3WSKKNXMUUSJQPOALKJDMYETTSNMCHJAI3IWISAKSKK3K3MN
KBCBUDJJ3NSJWSJHN3WSJMW3SUIDJHHKSKHJDUWNCXVQUJSHTYE3
3MSHJW3SJ3JSJWSIKJJWJJ3WJSKMNCJIIPQPAJJ3OSJJWSKMNXCK

ZENITH VDT PERFORMANCE TASK

CONDITION 2

8SKK3WSKKNXMUUSJQPOALKJDMYETTSNMCHJAI3IWISAKSKK3K3MN
RYUUWNMCN3SKSKWAAOO3MMCNNISKW3SKKW3KSKKMJK3IKDIOPMCN
KBCBUDJJ3NSJWSJHN3WSJMW3SUIDJHHKSKHJDUWNCXVQUJSHTYE3
MNCHUEKABNCVUYEWHGIO3SKJWJJ3WJSJBNCUJISOOPNXMHSJTYSH
NMXYUUSJ3KLLWSHJ3SK33KLJKWL3WSHUIONMCBGAJQOPURIICNWM
PAHJDYKJ3MSMWOW3KMLOPHJDUYQPNVCBHU3WJSKIUEI3WKSKNW3K
3MNJHWSHJW3SJJHJ3WSHJUIROPNCXMJUISHYRKJJKAL3DSJ3SKKW
3MSHJW3SJ3JSJWSIKJJWJJ3WJSKMNCJIIPQPAJJ3OSJJWSKMNXCK
WM3MCXHUSJEOPPWUEINXMJHDJYUEJHJALKL3LSL3LWLSLALL3WLS
BNEYW3SJNWSJJ3JSKMNSJUWUSJ3WJSJ3MXNKHPOUEIUM3IAWSN3I

ZENITH VDT PERFORMANCE TASK

CONDITION 3

3MNJHWSHJW3SJJHJ3WSHJUIROPNCXMJUISHYRKJJKAL3DSJ3SKKW
WM3MCXHUSJEOPPWUEINXMJHDJYUEJHJALKL3LSL3LWLSLALL3WLS
BNEYW3SJNWSJJ3JSKMNSJUWUSJ3WJSJ3MXNKHPOUEIUM3IAWSNSI
KBCBUDJJ3NSJWSJHN3WSJMW3SUIDJHHKSKHJDUWNCXVQUJSHTYE3
PAHJDYKJ3MSMWOW3KMLOPHJDUYQPNVCBHU3WJSKIUEI3WKSKNW3K
NMXYUUSJ3KLLWSHJ3SK33KLJKWL3WSHUIONMCBGAJQOPURIICNWM
MNCHUEKABNCVUYEWHGIO3SKJWJJ3WJSJBNCUJISOOPNXMHSJTYSH
3MSHJW3SJ3JSJWSIKJJWJJ3WJSKMNCJIIPQPAJJ3OSJJWSKMNXCK
8SKK3WSKKNXMUUSJQPOALKJDMYETTSNMCHJAI3IWISAKSKK3K3MN
RYUUWNMCN3SKSKWAAOO3MMCNNISKW3SKKW3KSKKMJK3IKDIOPMCN

ZENITH VDT PERFORMANCE TASK

CONDITION 4

MNCHUEKABNCVUYEWHGIO3SKJWJJ3WJSJBNCUJISOOPNXMHSJTYSH
PAHJDYKJ3MSMWOW3KMLOPHJDUYQPNVCBHU3WJSKIUEI3WKSKNW3K
BNEYW3SJNWSJJ3JSKMNSJUWUSJ3WJSJ3MXNKHPOUEIUM3IAWSN3I
3MSHJW3SJ3JSJWSIKJJWJJ3WJSKMNCJIIPQPAJJ3OSJJWSKMNXCK
3MNJHWSHJW3SJJHJ3WSHJUIROPNCXMJUISHYRKJJKAL3DSJ3SKKW
KBCBUDJJ3NSJWSJHN3WSJMW3SUIDJHHKSKHJDUWNCXVQUJSHTYE3
NMXYUUSJ3KLLWSHJ3SK33KLJKWL3WSHUIONMCBGAJQOPURIICNWM
RYUUWNMCN3SKSKWAAOO3MMCNNISKW3SKKW3KSKKMJK3IKDIOPMCN
8SKK3WSKKNXMUUSJQPOALKJDMYETTSNMCHJAI3IWISAKSKK3K3MN
WM3MCXHUSJEOPPWUEINXMJHDJYUEJHJALKL3LSL3LWLSLALL3WLS

ZENITH VDT PERFORMANCE TASK

CONDITION 5

KBCBUDJJ3NSJWSJHN3WSJMW3SUIDJHHKSKHJDUWNCXVQUJSHTYE3
3MNJHWSHJW3SJJHJ3WSHJUIROPNCXMJUISHYRKJJKAL3DSJ3SKKW
NMZYUUSJ3KLLWSHJ3SK33KLJKWL3WSHUIONMCBGAJQOPURIICNWM
RYUUWNMCN3SKSKWAAOO3MMCNNISKW3SKKW3KSKKMJK3IKDIOPMCN

PAHJDYKJ3MSMWOW3KMLOPHJDUYQPNVCBHU3WJSKIUEI3WKSKNW3K
3MSHJW3SJ3JSJWSIKJJWJJ3WJSKMNCJIIPQPAJJ3OSJJWSKMNXCK
BNEYW3SJNWSJJ3JSKMNSJUWUSJ3WJSJ3MXNKHPOUEIUM3IAWSN3I
8SKK3WSKKNXMUUSJQPOALKJDMYETTSNMCHJAI3IWISAKSKK3K3MN
WM3MCXHUSSJEOPPWUEINXMJHDJYUEJHJALK3LSL3LWLSLALL3WLS
MNCHUEKABNCVUYEWHGIO3SKJWJJ3WJSJBNCUJISOOPNXMHSJTYSH

ZENITH VDT PERFORMANCE TASK

CONDITION 6

WM3MCXHUSJEOPPWUEINNXMJHDJYUEJHJALK3LSL3LWLSLALL3WLS
3MSHJW3SJ3JSJWSIKJJWJJ3WJSKMNCJIIPQPAJJ3OSJJWSKMNXCK
3MNJHWSHJW3SJJHJ3WSHJUIROPNCXMJUISHYRKJJKAL3DSJ3SKKW
MNCHUEKABNCVUYEWHGIO3SKJWJJ3WJSJBNCUJISOOPNXMHSJTYSH
RYUUWNMCN3SKSKWAAOO3MMCNNISKW3SKKW3KSKKMJK3IKDIOPMCN
NMXYUUSJ3KLLWSHJ3SK33KLJKWL3WSHUIONMCBGAJQOPURIICNWM
PAHJDYKJ3MSMWOW3KMLOPHJDUYQPNVCBHU3WJSKIUEI3WKSKNW3K
KBCBUDJJ3NSJWSJHN3WSJMW3SUIDJHHKSKHJDUWNCXVQUJSHTYE3
BNEYW3SJNWSJJ3JSKMNSJUWUSJ3WJSJ3MXNKHPOUEIUM3IAWSN3I
8SKK3WSKKNXMUUSJQPOALKJDMYETTSNMCHJAI3IWISAKSKK3K3MN