

THE EFFECT OF TASK LIGHTING  
IN A VIDEO DISPLAY UNIT WORKSTATION

by

Bryan D. Miller

B. S., Kansas State University, 1982

---

A MASTER'S THESIS

submitted in partial fulfillment of the  
requirements for the degree

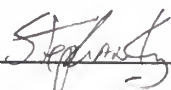
MASTER OF SCIENCE

DEPARTMENT OF INDUSTRIAL ENGINEERING

KANSAS STATE UNIVERSITY  
Manhattan, Kansas

1985

Approved by:

  
Major Professor

LD  
2668  
.T4  
1985  
M54

ACKNOWLEDGEMENTS

A11202 645289

2.2 Appreciation is extended to the IBM Corporation for their contributions to the video display unit and lighting laboratory at Kansas State University and for their grants toward such research; to Dr. Stephan Konz for all of his consulting; and to my parents, Darrel and Karen Miller for their support throughout the years.

## TABLE OF CONTENTS

	<u>Page</u>
Introduction .....	1
Method-	
Task .....	3
Subjects .....	3
Procedure .....	4
Measurement .....	5
Results .....	7
Discussion .....	15
References .....	27
Appendices .....	28

## LIST OF FIGURES AND TABLES

	<u>Page</u>
Figure 1 .....	24
Table 1 .....	6
Table 2 .....	8
Table 3 .....	9
Table 4 .....	10
Table 5 .....	11
Table 6 .....	12
Table 7 .....	13
Table 8 .....	14
Table 9 .....	16
Table 10 .....	17
Table 11 .....	18
Table 12 .....	19
Table 13 .....	20
Table 14 .....	21
Table 15 .....	22
Table 16 .....	23

## INTRODUCTION AND PROBLEM

In recent years, considerable attention has been given to video display unit (VDU) workstations. It is estimated that during the year 1985 over 75% of all office jobs will involve computers in some way, thus making the VDU commonplace (Shaffer, 1981). With the elements of the traditional office changing in this manner, the adequacy of traditional office equipment, furniture, and design must be reexamined to consider the computerized office system (Springer, 1980). Complaints from workers who interact with VDUs on a daily basis typically involve problems of visual fatigue accompanied by other physical symptoms (Dainoff, Happ, and Crane, 1981). Although health considerations and VDU workstation design have received considerable attention, little of the work done to improve VDU workstations has been in the areas of illumination and glare.

Engineers have long recognized substantial losses in visibility and visual performance due to veiling reflectance and reflected glare (Kaufman, 1966). Reflected glare may be a result of office walls, windows, posters, telephones, work surface color, or even a VDU user's white shirt (Christensen, 1981). Most of such problems may be eliminated through proper workstation layout and design.

Louvered luminaires are widely accepted as an aid in reducing reflected glare (Christensen, 1981). Although reflected glare is most noticeable and obvious, Kaufman (1966) points out that veiling reflectance may be

undetectable by the naked eye and, in some cases, is almost unmeasurable by instruments. Veiling reflectance caused by luminaires may be reduced by correct orientation of the worker and the task (Kaufman, 1966). Louvered luminaires also are used to reduce veiling reflectance. The "mirror test" (Lighting Design and Application, 1981) is widely practiced to reveal offending sources of veiling reflectance in the VDU workplace.

The source and intensity of light in the traditional paper handling office is detrimental to VDU use. Because VDUs generally present information with light characters on a dark background, less light is recommended for optimum viewing (Springer, 1981). The standard level of illumination for paper handling offices is about 400-500 lux (Oestberg, 1974) but 150 lux is recommended for combined VDU and paper handling (Stocker, 1964, 1966) and only 50 lux is recommended for pure VDU use (Dunn, 1972). The Illuminating Engineering Society lighting handbook recommends 700-100 lux for general office lighting, and only 300-325 lux in areas of VDU operation. This leads to the prospect that (a) less general light be used for optimum VDU viewing, and (b) that task lighting be used for proper illumination of source documents.

In dealing with such task lighting, reflected glare and veiling reflectance should be given proper consideration. Consequently, tests were done in order to determine the effect of task lighting in a VDU workstation. Side task lighting (transmitted from the side of a document

holder) and top task lighting (transmitted from the top of a document holder) were tested at a VDU work station. Results were compared to general lighting (transmitted from the ceiling luminaires).

#### METHOD

Task The experiment was conducted under controlled conditions in the video display unit laboratory at Kansas State University. Subjects entered "words" comprised of 6 randomly generated letters (see Appendix I) from a document into an IBM model PCXT personal computer. Each letter was generated at equal probability with the constraint that the same letters would not appear consecutively. A single string of 6 letters shall hereafter be referred to as a "word". Each subject entered words for 20 minutes, then rested for 10 minutes. After resting, each subject then repeated this process using another lighting scheme. This completed one trial. There were three trials conducted on each subject. One trial tested both the side and top task lighting; a second trial tested the side task lighting and the general room lighting; and a third trial tested the top task lighting and the general room lighting. The three trials were run sequentially. The total number of words entered and the total number of errors was recorded for each condition and each trial. Upon completing all trials, the subjects were given a semantic-differential vote (see Appendix II).

Subjects There were 16 young adult subjects, 8

male and 8 female. All subjects had corrected 20-20 vision checked on a Titmus vision tester (Appendix III).

Computing and typing skills varied among subjects.

Subjects were required to have some typing skill, although the level of skill was not tested. The subjects were paid at a rate of \$2.00 per hour for each hour of participation, and a bonus of \$7.00 was paid to all subjects who completed the requirements. The total time required by each subject did not exceed 3.5 hours.

Procedure and Experimental Design Each testing session was composed of three trials with two conditions per trial. The conditions for each trial differed in the manner in which the room and source document were illuminated. Condition A used the side illuminated document holder with a low level of indirect general light, Condition B used the top illuminated document holder with a low level of indirect general light, and Condition C used a high level of general room light and no task lighting. Four testing sequences were used, with each one used to test four subjects (see Appendix IV).

Subjects first were tested for 20-20 corrected vision with a Titmus vision tester (see Appendix III). The VDU workstation then was adjusted to fit the subject (see Appendix V). Subjects then were given a series of words to enter (see Appendix VI) as an exercise to familiarize them with the VDU terminal and keyboard. Each subject then began testing. Each condition was tested for 20 minutes separated by 10 minutes of rest. Trials were run



consecutively, allowing for 10 minutes of rest between any two conditions. A pilot run was conducted on two subjects prior to taking data.

All experiments were performed in the VDU laboratory at a constant temperature of 72° F. The indirect room lighting was provided by three kiosk floor lamps for task light testing (Conditions A and B), the direct room lighting was from louvered ceiling panels for Condition C testing (see Appendix VII). Lighting measurements for all conditions are shown in Table 1. An average of 21 fc over the keyboard and 18 fc over the screen was measured by a Topcom IM-2D lightmeter for Conditions A and B. For Condition C the values were 95 fc over the keyboard and 94 over the screen. Illumination provided by the document light measured on the document ranged from 182 to 519 fc for Condition A, 115 to 393 fc for Condition B, and 61 to 88 fc for Condition C.

Necessary equipment included an adjustable illuminated document holder (see Appendix VIII), an adjustable table and chair (see Appendix V), an IBM model PCXT personal computer (see Appendix IX), a stopwatch, and the document holder with task light which was designed and constructed in the Industrial Engineering department at Kansas State University. Each subject read a subject orientation statement (see Appendix X) and signed an agreement and release form (see Appendix XI) prior to participation.

Measurement and Instrumentation A Spellstar software package was used to total data entry and determine

TABLE 1

Light intensity measurements (footcandles)  
for the keyboard, screen, and on the document  
for Conditions A, B, and C.  
Light on the document was measured at 12 points  
as described for each condition.

	<u>CONDITION A</u> (Side)				<u>CONDITION B</u> (Top)				<u>CONDITION C</u> (Ceiling)			
KEYBOARD	21				21				95			
SCREEN	18				18				94			
DOCUMENT (AVG)	313				227				71			
COLUMNS:	1	2	3	4	1	2	3	4	1	2	3	4
Line:												
10	193	262	346	397	295	343	393	365	61	61	62	70
30	224	313	425	519	183	212	221	212	82	73	69	68
50	182	238	297	355	115	128	130	123	88	80	73	68

errors. This allowed the words entered by the subject to be counted and compared to a dictionary for accuracy. One error was assigned to each word even if 2 or 3 letters were wrong. The number of words entered and the number of errors were totaled for each condition in each trial. This data then was compared and tested by sign and Wilcoxon tests for significant differences. The semantic-differential vote (see Appendix II) was used to determine subject preference.

## RESULTS

Table 2 shows that the overall mean of data entered was 9.61 words per minute (103.1%) for Condition A, 9.76 words per minute (104.7%) for Condition B, and 9.32 words per minute (100%) for Condition C. Condition A was 3.1 % better than Condition C and Condition B was 4.7 % better than Condition C. However the differences were not statistically significant. In addition there is no significant difference between side (9.61) and top (9.76) task lighting. Sign and Wilcoxon test analysis of these results are found in Tables 3, 4 and 5.

The mean errors (see Table 2) in data entry was 5.8 % (97.5%) for Condition A, 5.97 % (100.3%) for Condition B, and 5.95 % (100%) for Condition C. No significant differences were found between any two conditions. Sign and Wilcoxon test analysis of these results are found in Tables 6, 7 and 8.

Tables 9 shows test data for all subjects by trial and

TABLE 2

Overall mean Words  
and percent errors by condition.

	<u>CONDITION A</u> (Side)	<u>CONDITION B</u> (Top)	<u>CONDITION C</u> (Ceiling)
Words/Min:	9.61	9.76	9.32
Percent:	103.1%	104.7%	100 %
<hr/>			
% Error:	5.80	5.97	5.95
Percent:	97.5 %	100.3 %	100 %

TABLE 3

Sign & Wilcoxon Test Data For Conditions A vs. B  
Amount of Data Entered per 20 Minute Period.

Sub.	Words (2 trial avg) Condition A	Words (2 trial avg) Condition B	A - B	Rank
1	192.0	236.0	-44.0	16
2	122.5	124.0	- 1.5	1
3	227.5	221.5	6.0	4
4	249.5	223.0	26.5	11
5	83.0	94.5	-11.5	5
6	117.0	135.0	-18.0	7
7	288.5	262.0	26.5	11
8	196.0	170.0	26.0	9
9	185.5	222.0	-36.5	15
10	230.5	257.0	-26.5	11
11	121.5	101.5	20.0	8
12	137.0	142.5	- 5.5	3
13	151.5	178.5	-27.0	13
14	231.0	228.5	2.5	2
15	272.5	242.5	30.0	14
16	269.5	286.0	-16.5	6
Mean	192.2	195.3	- 3.1	

Sign Test :  $\alpha = .05$  critical value = 4

There are 7 positive values and 9 negative values.

$\therefore 7 > 4$  No significant difference is determined.

Wilcoxon Test :  $\alpha = .05$  critical value = 30

$R^+ = 59$   $R^- = 77$

$\therefore 59 > 30$  No significant difference is determined.

TABLE 4

Sign & Wilcoxon Test Data For Conditions A vs. C  
Amount of Data Entered per 20 Minute Period.

Sub.	Words (2 trial avg) Condition A	Words (2 trial avg) Condition C	A - C	Rank
1	192.0	235.5	-43.5	15
2	122.5	108.0	14.5	8
3	227.5	208.0	19.5	10
4	249.5	219.5	30.0	13
5	83.0	94.0	-11.0	3
6	117.0	104.5	12.5	4
7	288.5	267.5	21.0	11
8	196.0	154.5	41.5	14
9	185.5	200.0	-14.5	8
10	230.5	226.5	4.0	1
11	121.5	113.0	8.5	2
12	137.0	123.0	14.0	6
13	151.5	209.0	-57.5	16
14	231.0	216.5	14.5	8
15	272.5	259.5	13.0	5
16	269.5	243.0	26.5	12
Mean	192.2	186.4	5.8	

Sign Test :  $\alpha = .05$  critical value = 4

There are 12 positive values and 4 negative values.

$\therefore 4 = 4$  No significant difference is determined.

Wilcoxon Test :  $\alpha = .05$  critical value = 30

$R^+ = 94$   $R^- = 42$

$\therefore 42 > 30$  No significant difference is determined.

TABLE 5

Sign & Wilcoxon Test Data For Conditions B vs. C  
Amount of Data Entered per 20 Minute Period.

Sub.	Words (2 trial avg) Condition B	Words (2 trial avg) Condition C	B - C	Rank
1	236.0	235.5	0.5	1.5
2	124.0	108.0	16.0	9
3	221.5	208.0	13.5	7
4	223.0	219.5	3.5	3
5	94.5	94.0	0.5	1.5
6	135.0	104.5	30.5	14
7	262.0	267.5	- 5.5	4
8	170.0	154.5	15.5	8
9	222.0	200.0	22.0	12
10	257.0	226.5	30.5	14
11	101.5	113.0	-11.5	5
12	142.5	123.0	19.5	11
13	178.5	209.0	-30.5	14
14	228.5	216.5	12.0	6
15	242.5	259.5	-17.0	10
16	286.0	243.0	43.0	16
Mean	195.3	186.4	8.9	

Sign Test :  $\alpha = .05$  critical value = 4

There are 12 positive values and 4 negative values.

$\therefore 4 = 4$  No significant difference is determined.

Wilcoxon Test :  $\alpha = .05$  critical value = 30

$R^+ = 103$   $R^- = 33$

$\therefore 33 > 30$  No significant difference is determined.

TABLE 6  
Sign & Wilcoxon Test Data For Conditions A vs. B  
Percent of Errors/Data Entered

Sub.	% Errors (2 trial avg) Condition A	% Errors (2 trial avg) Condition B	A - B	Rank
1	5.99	6.78	- 4.5	13
2	3.67	3.63	0.0	1.5
3	3.74	3.39	1.0	5.5
4	8.42	6.73	6.0	14
5	10.84	9.52	0.0	1.5
6	3.85	2.96	0.5	3.5
7	4.51	4.20	2.0	9
8	5.87	5.59	2.0	9
9	8.89	9.68	- 5.0	15
10	7.38	9.14	- 6.5	16
11	5.35	8.87	- 2.5	11
12	3.65	3.16	0.5	3.5
13	3.63	5.04	- 3.5	12
14	5.84	5.03	2.0	9
15	5.14	5.36	1.0	5.5
16	5.75	5.94	- 1.5	7
Mean	5.80	5.97	- 0.5	

Sign Test :  $\alpha = .05$  critical value = 4

There are 10 positive values and 6 negative values.

$\therefore 6 > 4$  No significant difference is determined.

Wilcoxon Test :  $\alpha = .05$  critical value = 30

$R^+ = 62$        $R^- = 74$

$\therefore 62 > 30$  No significant difference is determined.



TABLE 7

Sign & Wilcoxon Test Data For Conditions A vs. C  
Percent of Errors/Data Entered

Sub.	% Errors (2 trial avg) Condition A	% Errors (2 trial avg) Condition C	A - C	Rank
1	5.99	8.49	- 8.5	15
2	3.67	6.48	- 2.5	8
3	3.74	3.37	1.5	5
4	8.42	4.33	11.5	16
5	10.84	4.79	4.5	12
6	3.85	6.22	- 2.0	7
7	4.51	5.05	- 0.5	1.5
8	5.87	5.50	3.0	10
9	8.89	5.50	5.5	13
10	7.38	8.83	- 3.0	10
11	5.35	4.42	1.5	5
12	3.65	6.50	- 3.0	10
13	3.63	3.11	- 1.0	3
14	5.84	6.47	- 0.5	1.5
15	5.14	7.71	- 6.0	14
16	5.75	6.99	- 1.5	5
Mean	5.80	5.95	- 0.1	

Sign Test :  $\alpha = .05$  critical value = 4

There are 6 positive values and 10 negative values.

$\therefore 6 > 4$  No significant difference is determined.

Wilcoxon Test :  $\alpha = .05$  critical value = 30

$R^+ = 61$        $R^- = 75$

$\therefore 61 > 30$  No significant difference is determined.

TABLE 8

Sign & Wilcoxon Test Data For Conditions B vs. C  
Percent of Errors/Data Entered

Sub.	% Errors (2 trial avg) Condition B	% Errors (2 trial avg) Condition C	B - C	Rank
1	6.78	8.49	- 4.0	11.5
2	3.63	6.48	- 2.5	6
3	3.39	3.37	0.5	2
4	6.73	4.33	5.5	14
5	9.52	4.79	4.5	13
6	2.96	6.22	- 2.5	6
7	4.20	5.05	- 2.5	6
8	5.59	5.50	1.0	3
9	9.68	5.50	10.5	16
10	9.14	8.83	3.5	9.5
11	8.87	4.42	4.0	11.5
12	3.16	6.50	- 3.5	9.5
13	5.04	3.11	2.5	6
14	5.03	6.47	- 2.5	6
15	5.36	7.71	- 7.0	15
16	5.94	6.99	0.0	1
Mean	5.97	5.95	0.5	

Sign Test :  $\alpha = .05$  critical value = 4

There are 9 positive values and 7 negative values.

$\therefore 7 > 4$  No significant difference is determined.

Wilcoxon Test :  $\alpha = .05$  critical value = 30

$R^+ = 76$        $R^- = 60$

$\therefore 60 > 30$  No significant difference is determined.

by condition. By considering the means at the bottom of Table 9 it is apparent that learning occurred. The effect of learning was minimized by subtracting subject data from the respective means. This also was done for error rate (see Table 10). Sign and Wilcoxon test (Tables 11-16) were used to analyze the data further. No significant differences were found.

The semantic-differential vote illustrated a preference for task lighting, and for top task lighting (Condition B) in particular. Questions 2,3,5, and 6 of the test give analysis of test conditions. A score of 5 was considered no preference for all questions. Subjects preferred task lighting by margins of 2.5 and 2 in questions number 2 and 5 respectively. Subjects favored top task lighting by a margin of 1 in both questions 3 and 6. The tally and average score for each question of the semantic-differential vote are located in Figure 1.

#### DISCUSSION

The two pilot tests went well. From this preliminary testing no apparent change in experimental design was considered necessary. There appeared to be very little learning by the subjects, and results seemed to point to the expected. However, upon testing all subjects, a greater learning effect became apparent (see Table 9). The warm up exercise and testing sequence were part of the testing procedure as an effort to reduce the effect of learning. It is suggested that further testing include a

TABLE 9

Test data for subjects by trial and conditions.

Number of Words Entered

Trial:	1		2		3	
Condition:	A	B	A	C	B	C
Subject:						
1	160	229	224	219	243	252
5	83	87	83	88	102	100
9	167	216	204	192	228	208
13	148	170	155	197	187	221
Condition:	C	A	B	A	C	B
Subject:						
2	91	116	122	129	125	126
6	77	113	125	121	132	145
10	194	195	248	266	259	266
14	203	239	231	223	230	226
Condition:	B	C	A	B	A	C
Subject:						
3	200	195	225	243	230	221
7	236	265	299	288	278	270
11	91	91	116	112	127	135
15	205	251	267	280	278	268
Condition:	C	B	C	A	B	A
Subject:						
4	190	215	249	255	231	244
8	135	164	174	200	176	192
12	100	136	146	130	149	144
16	217	271	269	254	301	285
Mean:	156.1	184.6	196.1	199.8	204.8	206.4

TABLE 10

Test data for subjects by trial and conditions.  
Percent of Errors

Trial:	1		2		3	
Condition:	A	B	A	C	B	C
Subject:						
1	5.0	8.3	6.7	9.1	5.4	7.9
5	12.1	11.5	9.6	10.2	7.8	3.0
9	10.8	12.0	7.4	5.7	7.5	5.3
13	2.7	4.7	4.5	2.0	5.4	4.1
Condition:	C	A	B	A	C	B
Subject:						
2	6.6	4.3	3.3	3.1	6.4	4.0
6	9.1	5.3	1.6	2.5	4.6	4.1
10	9.3	8.2	8.9	6.8	8.5	9.4
14	4.9	5.9	5.2	5.8	7.8	4.9
Condition:	B	C	A	B	A	C
Subject:						
3	4.0	3.6	3.1	2.9	4.4	3.2
7	4.7	3.4	5.0	3.8	4.0	6.7
11	12.1	5.5	5.2	6.3	5.5	3.7
15	5.9	8.4	6.0	5.0	4.3	7.1
Condition:	C	B	C	A	B	A
Subject:						
4	4.7	6.1	4.0	5.5	7.4	11.5
8	2.2	4.3	8.1	6.0	6.8	5.7
12	11.0	1.5	3.4	3.9	4.7	3.5
16	7.8	7.4	6.3	6.7	4.7	4.9
Mean:	7.1	6.3	5.5	5.3	6.0	5.6

TABLE 11

Sign & Wilcoxon Test Data For Conditions A vs. B  
After Minimizing the Effect of Learning

Amount of Data Entered per 20 Minute Period.

Sub.	Words (2 trial avg) Condition A	Words (2 trial avg) Condition B	A - B	Rank
1	15.90	41.30	-25.40	16
2	-69.70	-77.25	7.55	4.5
3	27.05	43.55	-16.50	10
4	46.40	28.30	18.10	14
5	-93.10	-100.20	7.10	3
6	-75.20	-66.25	- 8.95	7
7	88.05	84.05	4.00	2
8	- 7.10	-24.70	17.60	12
9	9.40	27.30	-17.90	13
10	38.30	55.75	-17.45	11
11	-78.95	-76.45	- 2.50	1
12	-66.10	-52.20	-13.90	9
13	-24.60	-16.20	- 8.40	6
14	38.80	27.25	11.55	8
15	72.05	64.55	7.55	4.5
16	66.40	91.30	-24.90	15
Mean	- 0.78	3.13	- 3.91	

Sign Test :  $\alpha = .05$  critical value = 4

There are 7 positive values and 9 negative values.

$\therefore 7 > 4$  No significant difference is determined.

Wilcoxon Test :  $\alpha = .05$  critical value = 30

$R^+ = 48$   $R^- = 88$

$\therefore 48 > 30$  No significant difference is determined.

TABLE 12

Sign & Wilcoxon Test Data For Conditions A vs. C  
After Minimizing the Effect of Learning

Amount of Data Entered per 20 Minute Period.

Sub.	Words (2 trial avg) Condition A	Words (2 trial avg) Condition C	A - C	Rank
1	15.90	32.40	-16.50	15
32	289.50	422.50	142.50	123.5
4	46.40	43.40	3.00	5
5	-93.10	-109.10	16.00	13
6	-75.20	-75.95	0.75	2
7	88.05	72.00	16.05	14
8	-7.10	-21.60	14.50	11
9	9.40	-3.10	12.50	9
10	38.30	46.05	-7.75	7
11	-78.95	-82.50	3.55	6
12	-66.10	-53.10	-13.00	10
13	-24.60	5.90	-30.50	16
14	38.80	36.05	2.75	3.5
15	72.05	64.00	8.05	8
16	66.40	66.90	-0.50	1
Mean	-0.78	-2.41	-3.91	

Sign Test :  $\alpha = .05$  critical value = 4

There are 11 positive values and 5 negative values.

$\therefore 5 > 4$  No significant difference is determined.

Wilcoxon Test :  $\alpha = .05$  critical value = 30

$R^+ = 87$   $R^- = 49$

$\therefore 49 > 30$  No significant difference is determined.

TABLE 13

Sign & Wilcoxon Test Data For Conditions B vs. C  
After Minimizing the Effect of Learning

Amount of Data Entered per 20 Minute Period.

Sub.	Words (2 trial avg) Condition B	Words (2 trial avg) Condition C	B - C	Rank
1	41.30	32.40	8.90	6.5
2	-77.25	-72.45	- 4.80	4
3	43.55	12.50	31.05	15
4	28.30	43.40	-15.10	12
5	-100.20	-109.10	8.90	6.5
6	-66.25	-75.95	9.70	9.5
7	84.05	72.00	12.05	11
8	-24.70	-21.60	- 3.10	3
9	27.30	- 3.10	30.40	16
10	55.75	46.05	9.70	9.5
11	-76.45	-82.50	6.05	5
12	-52.20	-53.10	0.90	2
13	-16.20	5.90	-22.10	13
14	27.25	36.05	- 8.80	8
15	64.55	64.00	0.55	1
16	91.30	66.90	24.40	14
Mean	3.13	- 2.41	5.54	

Sign Test :  $\alpha = .05$  critical value = 4

There are 11 positive values and 5 negative values.

$\therefore 5 > 4$  No significant difference is determined.

Wilcoxon Test :  $\alpha = .05$  critical value = 30

$R^+ = 96$   $R^- = 40$

$\therefore 40 > 30$  No significant difference is determined.



TABLE 14

Sign & Wilcoxon Test Data For Conditions A vs. B  
After Minimizing the Effect of Learning

Percent of Errors/Data Entered

Sub.	% Errors (2 trial avg) Condition A	% Errors (2 trial avg) Condition B	A - B	Rank
1	-0.45	0.70	-1.15	11
2	-2.10	-1.90	-0.20	2
3	-2.00	-2.75	0.75	5
4	3.05	0.60	2.45	15
5	4.55	3.50	1.05	10
6	-1.90	-2.70	0.80	6.5
7	-1.25	-1.95	0.70	4
8	0.40	-0.60	1.00	9
9	2.80	3.60	-0.80	6.5
10	1.70	3.60	-1.90	13
11	-0.40	3.00	-3.40	16
12	-0.65	-3.05	2.40	14
13	-2.70	-1.10	-1.60	12
14	0.05	0.95	-0.90	8
15	-0.60	-0.75	0.15	1
16	0.35	-0.10	0.45	3
Mean	0.05	0.07	-0.01	

Sign Test :  $\alpha = .05$  critical value = 4

There are 9 positive values and 7 negative values.

$\therefore 7 > 4$  No significant difference is determined.

Wilcoxon Test :  $\alpha = .05$  critical value = 30

$R^+ = 67.5$   $R^- = 68.5$

$\therefore 67.5 > 30$  No significant difference is determined.

TABLE 15

Sign & Wilcoxon Test Data For Conditions A vs. C  
After Minimizing the Effect of Learning

Percent of Errors/Data Entered

Sub.	% Errors (2 trial avg) Condition A	% Errors (2 trial avg) Condition C	A - C	Rank
1	-0.45	3.05	-3.50	15
2	-2.10	-0.05	-2.05	10
3	-2.00	-2.55	0.55	5
4	3.05	-1.95	5.00	16
5	4.55	1.15	3.40	14
6	-1.90	0.30	-2.20	11
7	-1.25	-0.90	-0.35	3
8	0.40	-1.15	1.55	8.5
9	2.80	0.05	2.75	13
10	1.70	2.35	-0.65	6
11	-0.40	-1.35	0.95	7
12	-0.65	0.90	-1.55	8.5
13	-2.70	-2.40	-0.30	2
14	0.05	-0.20	0.25	1
15	-0.60	1.80	-2.40	12
16	0.35	0.75	-0.40	4
Mean	0.05	-0.01	0.07	

Sign Test :  $\alpha = .05$  critical value = 4

There are 7 positive values and 9 negative values.

$\therefore 7 > 4$  No significant difference is determined.

Wilcoxon Test :  $\alpha = .05$  critical value = 30

$R^+ = 64.5$   $R^- = 71.5$

$\therefore 64.5 > 30$  No significant difference is determined.

TABLE 16

Sign & Wilcoxon Test Data For Conditions B vs. C  
After Minimizing the Effect of Learning

Percent of Errors/Data Entered

Sub.	% Errors (2 trial avg) Condition B	% Errors (2 trial avg) Condition C	B - C	Rank
1	0.70	3.05	-2.35	10.5
2	-1.90	-0.05	-1.85	9
3	-2.75	-2.55	-0.20	1
4	0.60	-1.95	2.55	12.5
5	3.50	1.15	2.35	10.5
6	-2.70	0.30	-0.30	2
7	-1.95	-0.90	-1.05	5
8	-0.60	-1.15	0.55	3
9	3.60	0.05	3.55	14
10	3.60	2.35	1.25	7
11	3.00	-1.35	4.35	16
12	-3.05	0.90	-3.95	15
13	-1.10	-2.40	1.30	8
14	0.95	-0.20	1.15	6
15	-0.75	1.80	-2.55	12.5
16	-0.10	0.75	-0.85	4
Mean	0.07	-0.01	0.25	

Sign Test :  $\alpha = .05$  critical value = 4

There are 8 positive values and 8 negative values.

$\therefore 8 > 4$  No significant difference is determined.

Wilcoxon Test :  $\alpha = .05$  critical value = 30

$R^+ = 77$   $R^- = 59$

$\therefore 59 > 30$  No significant difference is determined.

## Semantic-Differential Vote

A tally and average value are illustrated for each question. Questions number 2,3,5 and 6 give analysis of test conditions.

1. I use computers AVG = 6.5 .  
 1 || 2 3 || 4 5 | 6 7 || 8 || 9 ||| |  
 very often very seldom
2. I liked the lighted document holder AVG = 7.44 .  
 1 2 3 4 5 || 6 ||| 7 ||| 8 || 9 ||| |  
 very little very much
3. I liked the document light on the side best. AVG = 5.94  
 1 || 2 | 3 | 4 | 5 || 6 7 ||| 8 | 9 |||  
 very true very false
4. My typing ability is AVG = 5.0 .  
 1 2 | 3 || 4 || 5 ||| 6 ||| 7 ||| 8 9  
 very poor very good
5. I thought no document light was best. AVG = 6.94  
 1 || 2 3 4 5 || 6 | 7 || 8 || 9 ||| ||  
 very true very false
6. I liked the document light on the top best. AVG = 6.0  
 1 || 2 3 || 4 || 5 6 7 ||| 8 || 9 |||  
 very false very true

Figure 1. Tally & Analysis for Semantic-Differential Vote.

longer warm up exercise, or perhaps experienced data entry personell as subjects. Test data for subjects by trial and condition is found in Table 9.

Another problem may possibly have been the nonuniform light distribution of task lighting on the document. As was illustrated Table 1, the light varied to great extent ( $\bar{V}=97$  fc for Cond. A and  $\bar{V}=96$  fc for Cond. B vs.  $\bar{V}=8$  fc for Cond. C) on the document under the two task lighting schemes (Conditions A and B). Maximum to minimum ratios were 2.3:1 for Condition A 3.4:1 for Condition B vs. 1.4:1 for Condition C. It is suggested that the task light extend at least 2 inches on either side beyond the width or height (whichever be the case) of the document. This should aid in delivering a more uniform light distribution on the document. In addition a lens designed to wash light more uniformly across the document would be desirable to prevent the intensity from dropping at the far edges of the document.

As illustrated in Table 4 and Table 5, the sign and Wilcoxon tests for Conditions A vs. B and Conditions B vs. C are close to significant. It is my feeling that through the above modifications of the test design a significant difference could be found for a task lighting situation vs. a general overhead lighting situation. Because the differences are so very delicate, I believe that a larger pool of subjects would need to be tested for a greater length of time in order to determine a difference in side vs. top task lighting (Condition A vs. B).

The percent of errors favored Condition A over all others although all values were nearly the same and there were no significant differences. I am not convinced that error rates can be measured accurately in such testing considering the wide range of circumstances that could lead to an entry error. It is my suggestion that the error rate be used as a check for reliable subject data and concern be focused on the amount of data entered.

The semantic-differential vote favoring Condition A and B over Condition C was as expected. I feel that these results give a strong indication that further testing of this nature should be conducted.

## REFERENCES

- Christensen, M., Lighting Prescription for Areas Containing CRT Displays, Lighting Design and Application , May 1981, 23-27.
- Dainoff, M.J., Happ, A., and Crane, P., Visual Fatigue and Occupational Stress in VDT Operators, Human Factors , 1981, 23(4), 421-438.
- Dunn, R.F.H., Lighting in Radar Rooms, Lighting and Design , 1972, 65, 6-9.
- Kaufman, J. E., 1966, I.E.S. Lighting Handbook , Fourth Edition, Illuminating Engineering Society, NY, NY.
- Lighting for CRT Areas., Lighting Design and Application , Feb., 1981, 19-21.
- Oestrberg, O., Fatigue in clerical work with CRT computer terminals. Presented at Manniskor och Datoren, Stockholm, Sweden: November 28-29, 1974.
- Shaffer, H., Growing Concern Over the VDT, Administrative Management , June 1981, 42(6), 24-27.
- Springer, T.J., Visual Display Units in Office Environments, Proceeding of Symposium , Tufts University, May 1980.
- Stocker, A.C., Displays, Papers and Lighting, Information Display , 1964, 1(1), 16-26.
- Stocker, A.C., The Size and Contrast of Hard Copy Symbols, Information Display , 1966, 3(5), 36-42.

## APPENDIX I

Document used by subjects for testing.

Reduced 74 %

1	KHQUFM	HWTJFQ	ZBUGAE	LXQVEP
2	ZULTSP	ARSEZP	TQVAXR	SYNYHC
3	XQTHQS	RZAUEM	QIQENY	ZFYSIQ
4	TCWBOJ	BCHLKS	FJWISR	UROWFW
5	NKTNZY	NEBJLV	TPDOEB	VUPNHF
6	HWIEPE	RKPAHV	KRFLCP	NRHGVM
7	JWGBHW	BINJLJ	GQIWXB	YKANSJ
8	BAEOMR	XCUYGM	WXGVUB	NVZTUM
9	ATDKEV	XSHCRT	IJYZWO	HOCLXW
10	ZVEPLR	KZPYBO	DHDUDF	QEQSTS
11	IFERLU	UXHXYP	KYUXYB	NBUDUG
12	QFDCMG	CELPMZ	NDFELP	MKJBLC
13	PJUHX T	LDZPAW	GOMNXN	UHPRGX
14	QTJBLO	XYBKLH	LWOUZH	BXSREX
15	LKCFYT	OYCSVS	BUMGGK	TSWUQH
16	SAKRDN	ZCBXJR	QEZPME	QWNGNG
17	LEWYHV	MENKXZ	OKHXFI	IZGNCR
18	BDHQKL	GJSYSE	UXQXNU	KIWOQJ
19	RBNKLB	ZXRIQW	LEHBEQ	RWRLEW
20	GWJZXA	UEBJKY	ULXKYJ	KOVZSH
21	NJAVMJ	ELFTXI	QSCGDW	FERQXW
22	EQXYJV	YJHACK	JOVWMT	OTGIGP
23	MXNBVK	QFIKWP	AVJCRE	MDSLJF
24	GERXCO	RTOHYB	FBFVNH	LQHSAF
25	LPCAHY	XLXFPC	KFIURY	UAPVBO
26	BFLAOW	UDLQBX	EWXMDM	DVYKEJ
27	YNRPOM	INLQEQ	ELZJHB	YEFKYJ
28	CTRUWF	MSBCBJ	IEZLVC	NOHGTI
29	MFCFPD	FADNOS	XEXFKS	VUHWXA
30	YEYAPM	ZUSTGL	WMHRCV	IKRSVY
31	YISMIM	HNIDVR	RKRQHA	RZNCNL
32	CATPKT	ARQNPR	INMLCX	KFIUPZ
33	ZIQMEX	MAPUBX	PFPSSE	UTLJQC
34	LSYJUT	TWGPEG	JGNGJN	PMBYCA
35	IWDZYS	REXEPN	PLQSQY	LJCNLD
36	YIGILA	ZMWHIP	LRJZBC	ULKJYG
37	KOLANX	WODRDG	LXDRJR	TIMNOK
38	HAROBBS	ATRF CZ	QZIKIV	GLIKAN
39	GPYRXV	NOHNAQ	KXQXSU	KSCCKY
40	AXVBOE	LUPCNG	VPNAWX	TFHSFD
41	VEMFYL	YMUYSL	RHERAO	JWKRSL
42	PVDQSH	BPMNTY	CMYUUY	FQIJQB
43	XRCVAW	EHUYJR	QXSUTV	EBEPCV
44	ZPHXRQ	JQPJQG	QDNHLU	WXQQWC
45	PMZNSG	LZBVOK	YPZPRD	PRJSWL
46	MOGCSM	FGRJSI	PRNWK	OTQWGN
47	JKQLWX	JYKBGX	MJGLXT	GDUMYE
48	KFSAXL	CGUOAS	BPSCBS	XLHFGN
49	EDNLIP	BDHIJM	MQSCAF	JAUFNT
50	BAYRBY	JFGOSM	KOBBJI	JGQJSX



## APPENDIX II

## Semantic-Differential Vote

Circle a Number

Subject Number \_\_\_\_\_

1. I use computers \_\_\_\_\_ .  

1	2	3	4	5	6	7	8	9
very often						very seldom		
  
2. I liked the lighted document holder \_\_\_\_\_ .  

1	2	3	4	5	6	7	8	9
very little						very much		
  
3. I liked the document light on the side best.  

1	2	3	4	5	6	7	8	9
very true						very false		
  
4. My typing ability is \_\_\_\_\_ .  

1	2	3	4	5	6	7	8	9
very poor						very good		
  
5. I thought no document light was best.  

1	2	3	4	5	6	7	8	9
very true						very false		
  
6. I liked the document light on the top best.  

1	2	3	4	5	6	7	8	9
very false						very true		

APPENDIX III

Titmus vision tester used in testing subjects.



## APPENDIX IV

## SUBJECT TESTING SEQUENCES

- CONDITION A : Side task lighting with  
low indirect general light.
- CONDITION B : Top task lighting with  
low indirect general light.
- CONDITION C : High level ambient light  
with no task lighting.

TESTING SEQUENCE	SUBJECTS	TRIALS		
		1	2	3
1	1,5,9,13	A B	A C	B C
2	2,6,10,14	C A	B A	C B
4	3,7,11,15	B C	A B	A C
5	4,8,12,16	C B	C A	B A

## APPENDIX V

Adjustable workstation used for testing.



## APPENDIX VI

Task used to familiarize subjects with terminal.

1	VXHX YR	KYUCYB
2	CE LPMZ	NDFELP
3	LDZPAW	GOMNXN
4	XYBKLH	LWOUZH
5	OYCSVS	BUMQ GK
6	ZCBXJR	QEZPME
7	MBNKXZ	OKHXFI
8	GJSYSE	UXQXNU
9	ZXRIGW	ULXKYJ
10	ELFTXY	OSCGDW

## APPENDIX VII

Luminaires used for testing in VDU laboratory.



Figure 1. Louvered ceiling lights.

## APPENDIX VII



Figure 2. Free standing kiosk lights.



## APPENDIX VIII

Illuminated adjustable document holder.



Figure 1. Condition A, Side task lighting.



Figure 2. Condition B, Top task lighting.



APPENDIX IX

IBM model PCXT computer used for testing.



## APPENDIX X

THE EFFECT OF TASK LIGHTING  
IN A VIDEO DISPLAY UNIT WORKSTATION

## SUBJECT ORIENTATION STATEMENT

The purpose of this research is to compare the effect of various lighting schemes with relationship to the computer user's performance. Subjects will enter data from a provided document into a computer terminal for a period of 20 minutes, then take a 10 minute break. Subjects then will enter data under a different lighting scheme for a period of 20 minutes followed by a 10 minute break. This will conclude one (1) trial. Three such trials will be completed by each subject. Prior to the first trial subjects will be given an eye check to ensure corrected 20-20 vision. Any subject not having corrected 20-20 vision will be dismissed from further participation. There will be a brief exercise to familiarize subjects with the computer terminal. A short questionnaire will be given to each subject upon completing all trials. Subjects will be paid at a rate of \$2.00 per hour, and will receive a \$7.00 bonus if all requirements are met, thus resulting in a total maximum payment of \$14.00. Total time required per subject should not exceed 3.5 hours.

## APPENDIX XI

THE EFFECT OF TASK LIGHTING  
IN A VIDEO DISPLAY UNIT WORKSTATION

## AGREEMENT AND RELEASE

1. I, \_\_\_\_\_ volunteer to participate in a project in connection with research studies to be conducted by Kansas State University.
2. I fully understand the purpose of the study as outlined in the orientation statement and test protocol.
3. I understand that I will receive payment at the rate of \$2.00 per hour for each hour I participate, and a \$7.00 bonus upon completing the requirements outlined in the subject orientation statement. I also realize that the maximum payment I may receive is \$14.00 .
4. I understand that I may be observed during my participation and my conduct and/or voice may be recorded by photographic and/or recording devices. I also realize that public reports and articles may be made of the experiments and all of the observations, and I consent to publication of such including the use of photographs if my face is "blanked" out.
5. I understand also that my performance as an individual will be treated as research data and will in no way be associated with me for other than identification purposes, thereby assuring anonymity of my performance and response.
6. I understand that I will be permitted to leave the test at any time and I may discontinue participation without penalty or loss of benefits to which I was otherwise entitled.
7. If I have any questions concerning my rights as a test subject, injuries or emergencies resulting from my participation or any questions concerning the study, I understand that I can contact Bryan Miller at 537-3963 or Dr. Konz at 532-5606.
8. I have read the Subject Orientation and explanation of the Test Protocol statement and signed the herein Agreement and Release, this \_\_\_\_\_ day of \_\_\_\_\_, 19 \_\_\_\_ .

---

Signature

THE EFFECT OF TASK LIGHTING  
IN A VIDEO DISPLAY UNIT WORKSTATION

by

Bryan D. Miller

B. S., Kansas State University, 1982

---

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

DEPARTMENT OF INDUSTRIAL ENGINEERING

KANSAS STATE UNIVERSITY  
Manhattan, Kansas

1985

## ABSTRACT

Side task lighting (transmitted from the the side of a document holder) and top task lighting (transmitted from the top of a document holder) were tested at a VDU workstation. Results were compared to general lighting (transmitted from ceiling luminaires). The task lighting arrangements were used in conjunction with low intensity indirect luminaires.

Sixteen subjects were tested in the video display unit laboratory at Kansas State University. Each subject entered "words" comprised of 6 randomly generated letters into a computer terminal for 20 minutes and then rested for 10 minutes. After resting, each subject then repeated this process using another lighting scheme. This completed one trial. There were three trials conducted on each subject; thus each of the three conditions was tested twice. The order of trials was randomized.

No significant differences were found between any of the three conditions for either quantity of output or quality of output. The semantic-differential vote favored task lighting over general lighting.