

# Effects of Different Lighting Types on Visual Performance

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*This study investigates whether different lighting types have an effect on the visual performance of office workers. Wall washing, cove lighting and uplighting were tested as they are the most widely used lighting types in offices, after general lighting. The lighting level chosen was 275 lx. The experiments were conducted in a controlled environment with different lighting types. Ninety participants took part in three groups of thirty. The performance measurements for each group were done in different lighting sequences. The data collected were statistically analysed. The effects of age, gender and eye deficiency of the participants on performance were also investigated.*

## Introduction

It is known that the lighting level has a significant effect on human performance. Another widely observed fact is that in today's offices, in addition to general lighting, cove lighting, wall washing and uplighting applications are increasing. There are many investigations and experimental studies on the relation between lighting levels and human performance [1, 2, 3, 4, 5, 6, 7, 8, 9, 10] and on the relation between lighting types and space perception [11, 12, 13, 14, 15, 16, 17, 18]. The literature survey conducted in this study did not find any concrete research on the relation between lighting types and human performance. In order to fill this gap, this study investigates human visual performance under different lighting types.

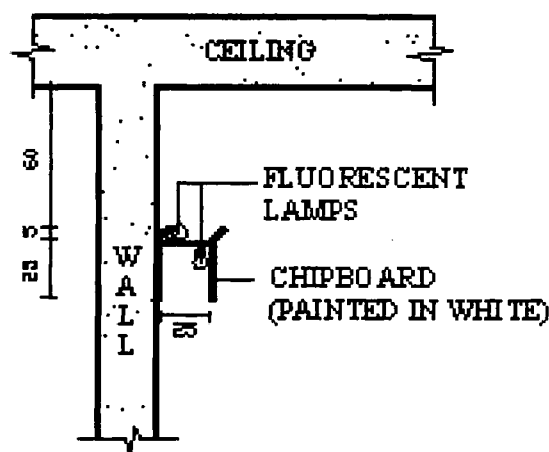


Figure 1. Cove lighting and wall washing lamp installations.

## Experimental Design

The study took place in a specially prepared room at the Faculty of Art, Design and Architecture in the Bilkent University. The room has a nearly square floor, of dimensions 4.10 m x 4.18 m and an area of 17.138 m<sup>2</sup>. The height of the room is 3.84 m. It has no windows, thus, the effect of daylight has been completely eliminated. The walls and the ceiling are painted matte white with a Munsell value of N 9 and 79% reflectance. The floor is covered with light grey terrazzo tiles with a Munsell value of N 7.5 and 51% reflectance.

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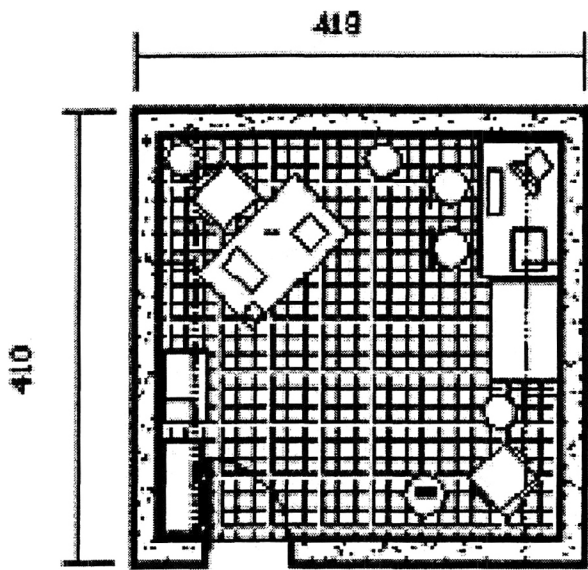
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For the experimental study, three types of lighting, namely cove lighting, wall washing and uplighting, were chosen. Cove lighting and wall washing were designed and installed in one unit with lamps at the upper and lower sides of the cornice. The detail of the installation is given in figure 1. In both types of lighting, Philips TL 54 fluorescent lamps, having 6200 K colour temperature (CT) and 72 % colour rendering index (CRI) values were used and the intensity of light output was controlled with Osram electronic dimmers and ballasts.

For uplighting, three torcheres were used, each with 500 W double-ended flood tungsten halogen lamps having 2900 KCT and approximately 100% CRI.

The experimental room was furnished as an office. As can be seen in figure 2, there is a table at one corner of the room, where all performance measurements took place. The height of the table is 0.75 m above the floor level. With the help of dimmers, all three types of lighting were controlled in order to provide a lighting level of 275 lx at the centre of the study table and on the test sheet that was used to measure the performance of the participants. 275 lx was chosen as the illuminance level as it is approximately the illuminance level required for simple office tasks like reading of printer outputs, ball-point hand-written or 8-10 point type printed documents, newsprint, typed originals, etc. [19]. 275 lx illuminance level also confirms with the required lighting level for general offices (250-300 lx) in Turkey [20]. Participants were chosen from the undergraduate student body of Bilkent University. 90 students, 52 male and 38 female, were randomly selected from all classes. Information on their age and gender, and presence of any eye correction wear were also collected as personal data.



The Performance Test

The test used for measuring performance was a matching test composed of two columns, each column having 25 items. Each item was composed of combinations of the letters 'B' and 'P' and the numbers '5', '6', and '9'. These letters and numbers were selected because of their circular and hook type characteristics and the similarity in their appearance. A copy of the test sheet is given in figure 3.

The first column is the reference column and the second column is the matching column. The order of items in the reference column has been kept same, but in the test sheets provided in each experiment, the order

<u>1</u>	<u>2</u>
A. PB596	<input type="checkbox"/> PB699
B. BP996	<input type="checkbox"/> BP656
C. PB956	<input type="checkbox"/> PB556
D. BP669	<input type="checkbox"/> BP559
E. PB566	<input type="checkbox"/> PB966
F. PB569	<input type="checkbox"/> BP965
G. PB966	<input type="checkbox"/> BP596
H. BP956	<input type="checkbox"/> BP569
I. PB659	<input type="checkbox"/> BP566
J. BP656	<input type="checkbox"/> PB566
K. BP695	<input type="checkbox"/> PB659
L. BP559	<input type="checkbox"/> PB595
M. PB695	<input type="checkbox"/> BP996
N. PB699	<input type="checkbox"/> PB656
P. BP596	<input type="checkbox"/> BP659
Q. PB556	<input type="checkbox"/> PB596
R. PB655	<input type="checkbox"/> PB965
S. BP965	<input type="checkbox"/> BP655
T. BP566	<input type="checkbox"/> PB655
U. PB656	<input type="checkbox"/> PB569
V. BP569	<input type="checkbox"/> PB956
W. BP659	<input type="checkbox"/> BP695
X. BP655	<input checked="" type="checkbox"/> BP956
Y. PB595	<input type="checkbox"/> PB695
Z. BP965	<input type="checkbox"/> BP669

Figure 3. A sample of the matching test.

of items in the second column was altered randomly. When the participants were taken into the room one at a time, the room was illuminated with two fluorescent tubes producing general lighting (figure 4). This lighting was only used when the subjects were admitted and was not used as part of the experimental set-up.

The participants were seated at the test table with a test sheet and under one of the three types of lighting they were asked to fill in the sheet. When the participant filled in one test sheet, the type of lighting was changed and a second test sheet was supplied. The same procedure was also repeated for the third type of lighting. Each session lasted for approximately 20 minutes. The lighting levels were the same throughout the experiment. Adaptation time to lighting conditions for each type of lighting was not considered a problem as adaptation is mainly affected by lighting levels which were the same for all three lighting types used.

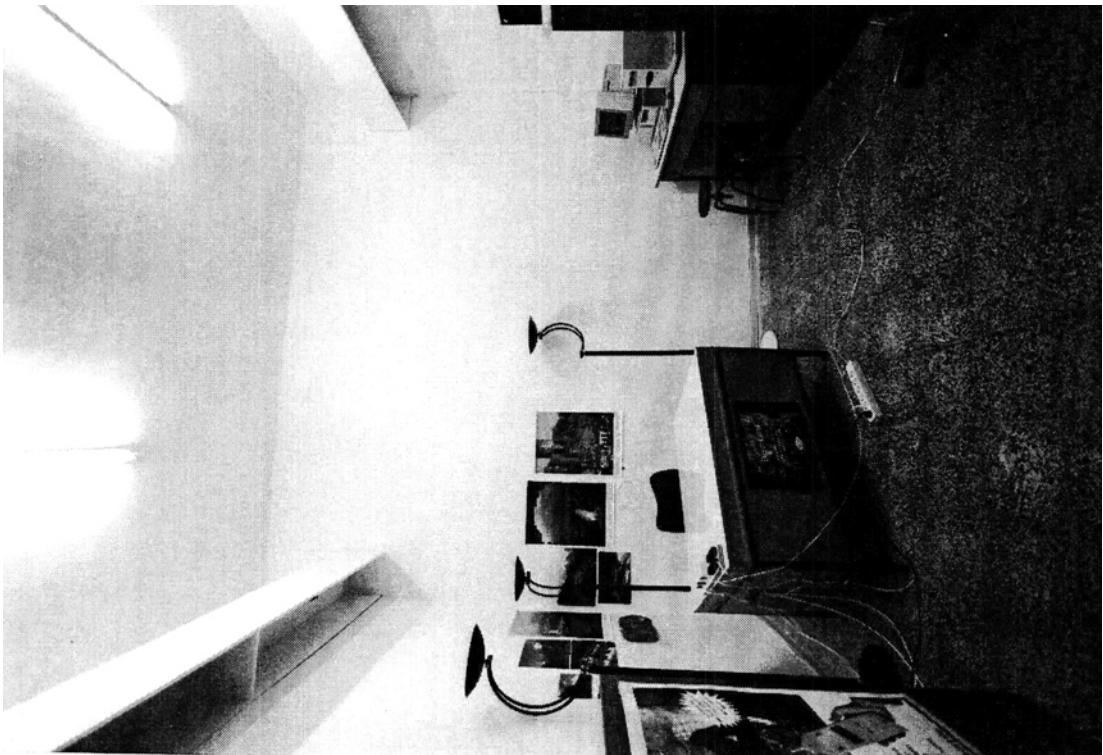
The experiment was carried out on three groups with thirty subjects in each group. In each group, the sequence of lighting types was altered as shown in Table 1 (figures 5, 6, 7). The reason for forming three groups and changing the sequence of lighting types was to eliminate the effects of adaptation of the participants to the test.

Table 1: Sequence of lighting types per group.

	1st Lighting	2nd Lighting	3rd Lighting
1st group	Uplighting	Wall washing	Cove lighting
2nd group	Wall washing	Cove lighting	Uplighting
3rd group	Cove lighting	Uplighting	Wall washing



*Figure 5. Experimental room with uplighting.*



*Figure 4. Experimental room with general lighting.*

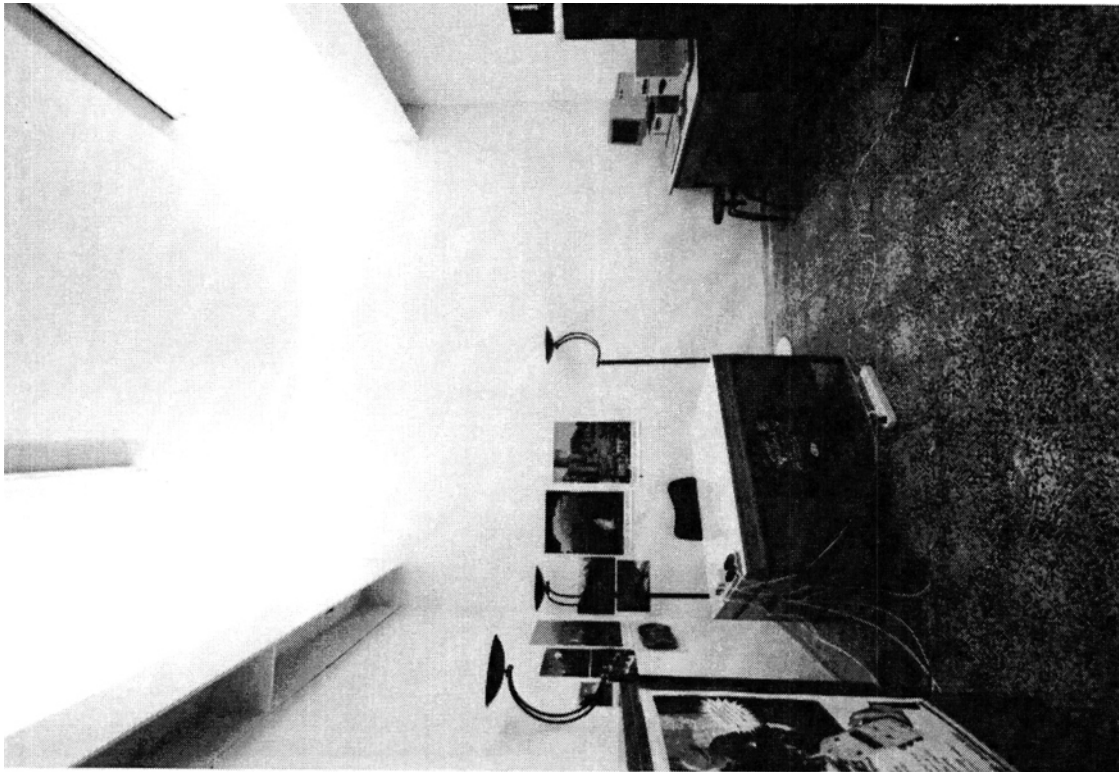


Figure 7. Experimental room with cove lighting.

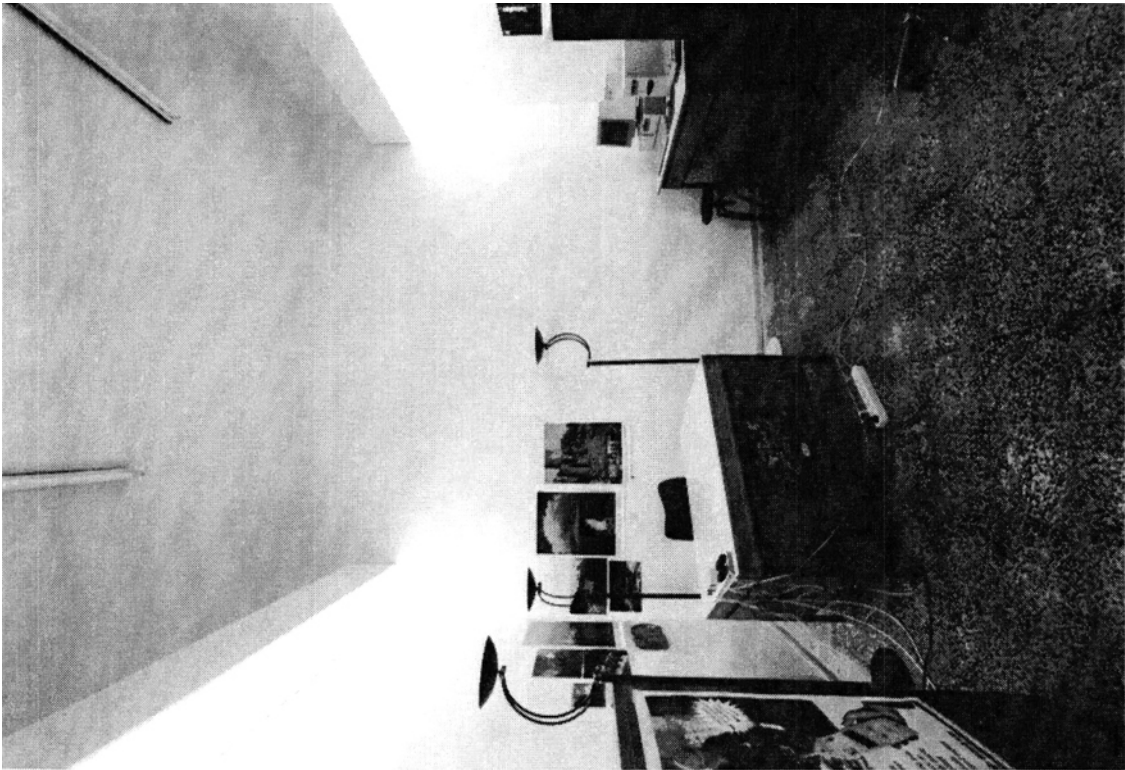


Figure 6. Experimental room with wall washing.

Table 2. Data collected in Group 3, Test 1, cove lighting.

Subject	Age	Gender	Eye Correction	Correct Checks	Wrong Checks	Left Blank	Time (minutes)	Correct checks per minute	Correct, %
1	21	M	NO	24	1	0	6	4	96
2	22	M	NO	25	0	0	8	3	100
3	22	M	YES	25	0	0	4	6	100
4	22	F	YES	17	4	4	7	2	68
5	23	F	NO	22	3	0	4	6	88
6	22	M	NO	25	0	0	4	6	100
7	23	M	NO	21	2	2	7	3	84
8	22	F	NO	25	0	0	6	4	100
9	23	M	NO	25	0	0	5	5	100
10	25	F	YES	20	2	3	6	3	80
11	19	F	NO	25	0	0	7	4	100
12	22	M	YES	24	1	0	7	3	96
13	22	M	YES	25	0	0	6	4	100
14	26	M	YES	21	4	0	6	4	84
15	24	F	NO	25	0	0	4	6	100
16	20	M	YES	17	6	2	8	2	68
17	25	M	NO	23	1	1	4	6	92
18	25	F	YES	25	0	0	5	5	100
19	23	M	NO	25	0	0	5	5	100
20	20	F	YES	25	0	0	8	3	100
21	21	F	NO	19	2	4	8	2	76
22	22	M	NO	25	0	0	6	4	100
23	21	F	NO	17	8	0	8	2	68
24	22	M	YES	23	1	1	5	5	92
25	21	M	NO	25	0	0	4	6	100
26	20	F	YES	25	0	0	5	5	100
27	22	F	NO	22	1	2	5	4	88
28	21	M	YES	24	0	1	5	5	96
29	20	F	NO	23	1	1	6	4	92
30	22	M	YES	24	0	1	4	6	96

Average Age	22	Min. Time	4	True Mean	23
Eye correction %	43	Max. Time	6	False Mean	1
Gender M %	57	Mean Time	6	Empty Mean	1
Gender F %	43	Answer/Minute	4		

Data were collected on the following variables:

- Time spent while filling in each test.
- Maximum and minimum amount of time spent during the tests.
- Ratio between the number of correct answers and the time spent.
- Number of correct answers under each lighting type.
- Ratio between the number of correct answers and the lighting types.
- Percentage of correct answers.
- Relation between participants' age, gender, their eye deficiencies and the number of correct answers they gave under each lighting type.

Data were collected in a data collection sheet, an example of which is given in Table 2.

The overall data collected in the study are given in Tables 3 to 5.

The rounded mean values of all the data collected are given in Table 6.

Discussion and Findings

Three initial hypotheses were formulated at the outset of the experiment:

Hypothesis 1. The performance of the participants will vary under different types of lighting.

Hypothesis 2. The gender of the participants will influence their performances under different types of lighting.

Hypothesis 3. Corrected eye deficiencies will influence the performances of the participants under different types of lighting.

Two-sample z statistic was applied for two-sided alternative hypothesis to the data collected. Statistical tests suggest the following:

1. Mean values for correct answer percentage and correct answer per minute, as seen in Table 6, were statistically tested in pairs for each lighting type. The statistical results revealed no significant differences among them (uplighting & wall wash,  $z=0.09$ ,  $p=0.93$ ; uplighting & cove,  $z=0.09$ ,  $p=0.93$ ; wall wash & cove,  $z=0.18$ ,  $p=0.86$ ). The first hypothesis of the experiment is rejected. Performances of the participants do not vary under different types of lighting. A larger sample group may yield different results. Furthermore, if the result of correct answer percentage of wall washing, in comparison to cove lighting and uplighting is considered, a rate of 0.3% over uplighting and 0.6% over cove lighting

Table 3: Test results under uplighting.

	Correct answer, %				Correct answer, per minute			
	1st Group	2nd Group	3rd Group	Avg.	1st Group	2nd Group	3rd Group	Avg.
Male	92	97	97	95	4	5	5	5
Female	90	97	96	94	4	6	5	5
with eye correction	88	96	96	93	4	5	5	5
without eye correction	93	97	97	96	4	5	6	5

Table 4: Test results under wall washing.

	Correct answer, %				Correct answer, per minute			
	1st Group	2nd Group	3rd Group	Avg.	1st Group	2nd Group	3rd Group	Avg.
Male	97	95	95	96	5	4	5	5
Female	96	93	96	95	4	5	5	5
with eye correction	96	91	92	93	5	4	5	5
without eye correction	94	93	99	95	5	4	5	5

Table 5: Test results under cove lighting.

	Correct answer, %				Correct answer, per minute			
	1st Group	2nd Group	3rd Group	Avg.	1st Group	2nd Group	3rd Group	Avg.
Male	97	96	94	96	5	5	5	5
Female	97	94	89	93	5	5	4	5
with eye correction	92	96	91	93	5	5	4	5
without eye correction	99	94	93	95	5	5	4	5

Table 6: Mean values of all collected data.

	Correct answer, %			Correct answer, per minute		
	Uplighting	Wall Washing	Cove Lighting	Uplighting	Wall Washing	Cove Lighting
Male	95	96	96	5	5	5
Female	94	95	93	5	5	5
with eye correction	93	93	93	5	5	5
without eye correction	96	95	95	5	5	5

may signal a trend towards wall washing providing a performance increase in the long term.

2. Mean values of correct answer percentages, as it is indicated in Table 6, were not significantly differentiated from each other for males and females (uplighting,  $z=0.20$ ,  $p=0.84$ ; wall wash,  $z=0.23$ ,  $p=0.82$ ; cove,  $z=0.62$ ,  $p=0.53$ ). Consequently, the second hypothesis is rejected.

3. Mean values of correct answer percentages, as it is indicated in Table 6, were not significantly differentiated from each other for subjects with eye correction and those with healthy eyes (uplighting,  $z=0.61$ ,  $p=0.54$ ; wall wash,  $z=0.39$ ,  $p=0.70$ ; cove,  $z=0.39$ ,  $p=0.70$ ). Consequently, the third hypothesis is also rejected.

## Conclusions

This study aimed to find out whether there is a relationship between different types of lighting and human performance. It also explored the most favourable lighting type for office tasks among wall washing, cove lighting and uplighting. It was found that no such relation exists, but nevertheless a very minor effect was found in favour of wall washing. Gender and eye corrections were found to have no effect on human performance under different lighting types. Veitch and Newsham [21] have done a similar study by conducting typing and proofreading tests under different types of lighting and luminaires with lensed and louvered, or direct and indirect systems. They searched the highest speed and error rate, which they considered to mean the performance of a worker. There are some minor indications parallel to the assessments of Veitch and Newsham [21] in this study even though the results have not shown significant differentiation within the frame of its sample scale.

The participants in this study were almost at the same age, in the young age group (18-23). Further experiments may be done with a larger range of age groups that may result in significant findings. Other performance related factors such as cultural background, education, race, ethnic group, psychological aspects, time of day, etc could also be tested as further steps of this study.

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