A Study of Subjective Assessment: Hybrid Lighting with Automatic Control or Traditional Lighting with Manual Control?

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ABSTRACT

In order to compare a hybrid lighting system with automatic control to a traditional lighting system with manual control, a subjective assessment study was carried out in two rooms at the Technical University of Istanbul. In the test room, a light shelf system equipped with automatic control was installed and in the reference room, a manually controlled traditional lighting system was installed. The rooms were occupied by 20 subjects for specific periods of time, at the end of which, paper-based questionnaires were introduced. The questionnaires contained questions concerning visual comfort, satisfaction and the subject's opinion on lighting systems with automatic control. The results of the questionnaires show an increase in the lighting satisfaction from the traditional lighting system to the hybrid lighting system, and a positive opinion of lighting systems with automatic control.

KEYWORDS

Light shelf, subjective assessment, lighting satisfaction, automatic control system

1. INTRODUCTION

Subjective assessment has been the method for many studies conducted in the field of lighting. The reason for this is that even though electric lighting should be designed to meet certain levels of illuminance, it should also be designed considering the visual perception of the users. Unfortunately, it is not possible to set out specific rules and regulations for the satisfaction of the users, however an optimum approach can be obtained through the assessment of lighting solutions with the help of questionnaires and user evaluations. User evaluation studies do not only bring solutions to the electric lighting design but also give important clues about the utilization of daylight and automatic control.

Daylight can create difficulties in lighting design because of its changeability and intensity. In addition to that, even though automatic control systems are advantageous energy-wise, users of these systems tend to have negative feelings towards control systems because of the fact that they intervene in the lighting preferences of the users. Therefore careful consideration should be given in the utilization of daylight and control systems in work environments (Osterhaus, 2005).

This study aims at the subjective evaluation of a hybrid lighting system that has been previously examined energy-wise in an experiment performed in the scope of a joint project between Istanbul Technical University and Berlin Technical University. For this aim, a subjective assessment study was carried out in order to compare a light

shelf system (LSS) equipped with automatic control to a traditional lighting system with manual control, in two office rooms set up at the Technical University of Istanbul.

2. DATA COLLECTION

The data collection was performed in two adjacent offices situated in Istanbul, facing 10° west of due south.

2.1 Description of Test and Reference Rooms

In the test room, a hybrid lighting system, which is a LSS including electric lighting equipped with automatic control was installed and in the reference room, a manually controlled traditional lighting system with fluorescent lamps was preserved. Figures 1 and 2 show interior views of these offices. The LSS has been mounted in the test room in the upper part of the window system. As the ceiling is a part of the LSS, the test room has been renovated in order to use the ceiling as a secondary diffuser of the LSS. The reference room has been kept in its original structure, since it has the structure of a typical office room in the faculty building (Cetegen et al, 2005).

Figure 1: General view of the test room

Figure 2: General view of the reference room

The LSS consists of daylight and electric light reflectors. Daylight reflectors reflect the daylight coming from the upper part of the window system to the ceiling and the reflected daylight, reaches the inner parts of the room. The electric light sources in the LSS illuminate the room, reflecting the electric light to the ceiling in a similar way. In this project European Instabus (EIB) Integral Type automatic control system has been used. In both of the rooms, the design illuminance measured at night under full electric lighting is 500 lx.

2.2 Subjective Assessment

The subjective assessment study was carried out in June, July, November 2004 and March 2005. A total of 20 users, with ages ranging from 20-40, were asked to complete 2 different paper-based questionnaires following a 90 minute time period in the test and reference rooms. The first questionnaire, prepared for the reference room, consisted of 29 questions, mainly concerning lighting satisfaction, visual comfort and illuminance levels. The second questionnaire, prepared for the test

room, had 4 extra questions about the LSS equipped with automatic control. The experiment was repeated twice, with users using the rooms both in the morning hours and in the afternoon hours. The users were not assigned specific tasks and were left free to decide what they wanted to do with their time. While most of them chose to read and write, some users watched a movie from a desktop computer.

3. RESULTS

The data obtained from the questionnaires have been presented in the paper as average responses and have been evaluated using paired samples t-tests with a confidence interval of 95 %.

3.1 Lighting Satisfaction

The answers given to the question concerning lighting satisfaction in the test and reference rooms can be seen in the figures 3-6. The satisfaction ratings are on a 5 point scale that ranges from 1: not satisfied to 5: satisfied. If Figure 3 and 4 are compared, it is easy to see that the number of satisfied users in the test room is greater than those in the reference room. The same dominance is also present in the data of the afternoon hours (Figures 5 - 6).

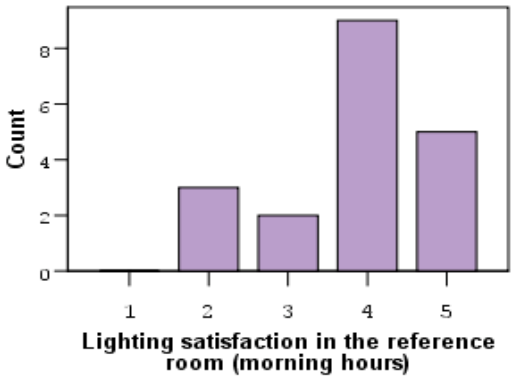

Figure 3

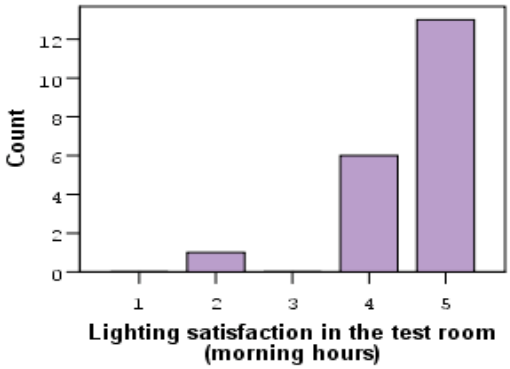

Figure 4

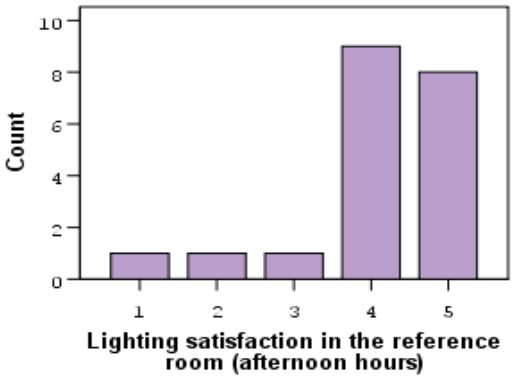

Figure 5

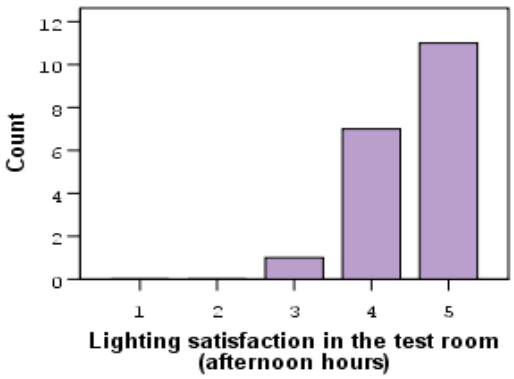

Figure 6

In the following tables, the reference room and the test room in the morning hours are presented by R1 and T1; the reference room and the test room in the afternoon hours are presented by R2 and T2, respectively. A better understanding of lighting satisfaction can be obtained through observing the average responses of the users,

given in Table 1. Especially in the morning hours, the satisfaction level in the reference room is low with a mean value of 3.84 compared to that of the test room with a mean value of 4.55. The t-test shows that the data gathered in the morning hours are statistically significantly different ($p<0.05$)[1] from each other. The data for the afternoon hours do not show a statistically significant difference; however, considering the responses in Figures 5 - 6, it is possible to say that the users rate the test room with higher levels of satisfaction also in the afternoon hours.

TABLE 1
Average responses given to the question relating to lighting satisfaction

Assessment of lighting satisfaction (1 = Not satisfied, 5 = Satisfied)	
R1	3.84
T1	4.55
R2	4.1
T2	4.53

3.2 Illuminance Levels

TABLE 2
Average responses given to questions relating to illuminance levels

Assessment of illuminance levels (1 = Low, 3 = High)					
	General	Work plane	VDU	Wall across desk	Door wall
R1	1.9	2.10	2.06	1.90	1.35
T1	1.85	1.85	1.89	2.05	1.90
R2	1.95	2.20	2.13	2.05	1.40
T2	1.95	1.85	2.00	1.90	1.85

The mean values of illuminance levels, as observed by the users can be seen in Table 2. Except for the illuminance level on the door wall, which is the wall that is furthest from the window, all the other illuminance level assessments do not show extensive differences from the reference room to the test room. The t-test shows that the data for illuminance level on the door wall of the two rooms are statistically significantly different both in the morning and in the afternoon hours ($p<0.05$). The reason for this can be explained as follows: The reflectors in the LSS reflect the daylight coming from the upper part of the window system to the ceiling, enabling it to reach the inner parts of the room. Therefore the users have found the door wall to have a higher illuminance level with the ratings having a mean value of 1.90 in the morning and 1.85 in the afternoon. Therefore it is possible to say that this hybrid lighting system with automatic control provides better illuminance uniformity.

3.3 Luminance

The mean values of the luminance differences between the window and the window wall in both of the rooms, as observed by the users, can be seen in Table 3. The

[1] The p value of a sample is the probability of seeing a sample with at least as much evidence in favor of the alternative hypothesis as the sample actually observed. The smaller the p-value, the more evidence there is in favor of the alternative hypothesis. (Albright et al, 2003)

users have rated the luminance difference to be more noticeable in the reference room, as the values are closer to the discomfortable rating of 3. When a t-test is performed on the data, a statistically significant difference can be seen in the data of the afternoon hours, with $p<0.05$. The reason for this is that in the test room, as the LSS is mounted on the upper part of the window, the visible part of the window is smaller than it is in the reference room.

TABLE 3
Average responses given to the question relating to luminance

Luminance difference between the window and the window wall (1 = Unnoticeable, 3 = Discomfortable)	
R1	2.10
T1	1.85
R2	2.25
T2	1.65

3.4 Glare and Reflection

Table 4 shows the mean values of the responses given to questions relating to glare and reflection. The first two data are about the glare caused by sunlight and the light coming from the sky respectively, and the following two are about reflection caused by sunlight and reflection caused by electric light. An overall observation of the data shows that the users did not experience frequent incidences of glare or reflection in neither of the rooms. When a t-test was performed on the data however, 2 afternoon groups showed statistically significant differences; the data concerning the glare from the sky and the data concerning reflection of daylight ($p<0.05$). From this result, it is possible to say that the room with the hybrid lighting has lower rates of glare and reflection incidences in the afternoon hours. The reason is, as the LSS is mounted on the upper side of the window, it partially blocks the view of the sky, and thus diminishes the glare caused by the light coming from the sky. Similarly, as the LSS prevents most of the direct entry of sunlight to the room, it reduces the possibility of reflection caused by sunlight.

TABLE 4
Average responses given to questions relating to glare and reflection

	Assessment of glare (0 = Never, 3 = Frequently)		**Assessment of reflection** (0 = Never, 3 = Frequently)	
	From the Sun	From the Sky	Daylight	Artificial light
R1	0.84	0.70	0.80	0.19
T1	0.70	0.30	0.50	0.20
R2	0.50	0.80	0.70	0.63
T2	0.20	0.45	0.30	0.15

3.5 Automatic Control and the LSS

Table 5 gives the mean values of the responses given to the questions concerning automatic control systems and the hybrid lighting system of interest. Despite the fact

that previous studies (Moore et al, 2005) show that most people resent the utilization of automatic control systems in their lighting preferences, the results of this questionnaire show a positive approach to these systems and to the LSS evaluated in the experiment.

TABLE 5
Average responses given to questions relating to the LSS equipped with automatic control

	T1	T2
How do you evaluate the fact that there isn't a luminaire on the ceiling? (1 = Negative, 3 = Positive)	2.85	2.75
How do you evaluate lighting systems equipped with automatic control? (1 = Negative, 3 = Positive)	2.65	2.65
How do you evaluate the Light Shelf System? (1 = Negative, 3 = Positive)	2.65	2.70
Would you use the present light shelf system equipped with automatic control in your own work environment? (1 = Negative, 3 = Positive)	2.75	2.80

4. CONCLUSION

This subjective assessment study has been carried out in order to compare a hybrid lighting system with automatic control to a traditional lighting system with manual control. The first difference shows itself in the lighting satisfaction data, with the test room having higher rates of satisfaction than the reference room. The second difference appears in the illuminance levels perceived by the users, proving the fact that the LSS provides a better uniformity of illuminance. The luminance difference evaluation is another finding that shows the test room to be more comfortable in terms of lighting, especially in the afternoon hours. In addition to that, the data concerning glare and reflection, which are very important for the comfort of the user, show that the occurrence of glare caused by the sky and reflection caused by electric lighting is lower in the test room than it is in the reference room. The data obtained on these important parameters of lighting, illuminance, luminance, glare and reflection, bring forward the reasons for the users having rated the test room with higher values of lighting satisfaction. Finally the questions about the LSS and automatic control systems in general show that, in spite of the findings of previous work on this issue, the users have rated these systems with positive opinions. Overall, the user evaluations have provided information that shows an increase in the lighting satisfaction from the traditional lighting system with manual control to the hybrid lighting system with automatic control, and a positive opinion of lighting systems with automatic control.

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