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RESEARCH INTO THE EFFECT OF PHOTOMETRIC FLICKER EVENT ON THE PERCEPTION OF OFFICE WORKERS

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ABSTRACT

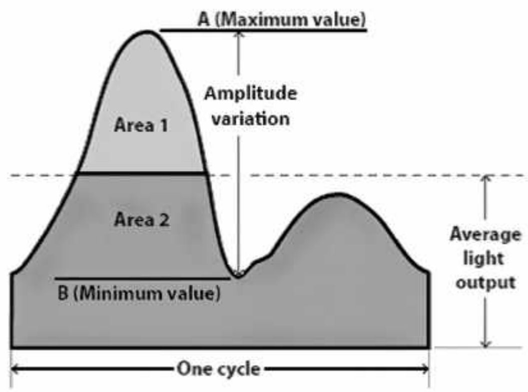
Today the number of office workers has reached to an enormous number due to the fast-growing technology. Most of these office workers spend long hours in enclosed spaces with little/no daylight penetration. The lack of daylight causes physiological and psychological problems with the workers. At this point lighting systems become prominent as the source and the solution of the problem. Photometric flicker event which arises in the lighting systems can sometimes become visible and brings a lot of issues with it. In this paper, an experimental work has been done to investigate the effect of flicker. For this purpose, the flicker values of 3 different experiment rooms for different lighting conditions and scenarios have been measured and a questionnaire study has been carried out in the experiment rooms with 30 participants. In conclusion, the effect of the flicker event on the volunteers have been classified and some methods have been proposed not to experience flicker effects.

Keywords: photometric flicker, indoor lighting, lighting scenarios, dimming

1. INTRODUCTION

The latest developments in the computer technology and the related technologies have increased the number of office workers and the working hours in enclosed spaces. A lot of different jobs, which requires different attention and concentration levels, have been done at desks in offices. There are some studies investigating the physiological and psychological conditions of the office workers who utilize little/no daylight during their shift [1–3]. These studies show that the effects vary from workforce loss to making critical mistakes.

A qualified lighting system requires a proper design with the light spreading internal volume continuously. Photometric flicker event causes physical impairments like eye strain, headache and finally desire to leave the place because of breaking this continuity, both under and over 60 Hz frequencies,



$$\text{Percent Flicker} = 100\% \times \frac{A - B}{A + B} \qquad \text{Flicker Index} = \frac{\text{Area 1}}{\text{Area 1} + \text{Area 2}}$$

Fig. 1. Photometric flicker percentage and index calculation [9]

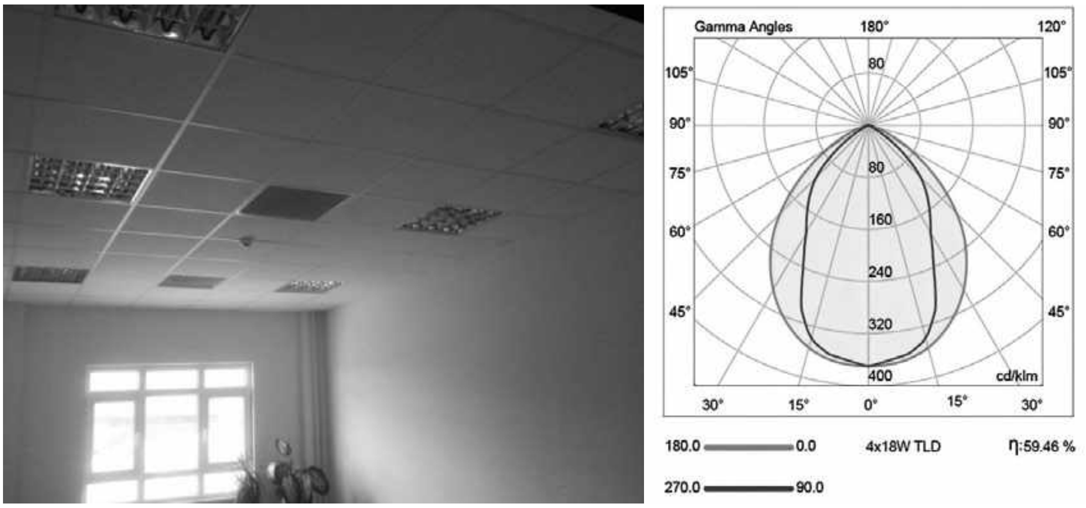


Fig. 2. Lighting system and light distribution curve of luminaires in Test Rooms 1, 2

even over 60 Hz light flicker is not possible to recognize by human eye [4–8].

There are common approaches worldwide to provide healthy lighting in an office environment by harvesting daylighting as much as possible like daylight responsive lighting control systems, dynamic lighting control systems and dimmable lighting control systems. However, flicker event occurs in all these lighting control systems especially in dimmable lighting control systems.

Flicker event can be explained in numbers by the graphic and the equations in Fig. 1. Flicker percentage and flicker index determines the qualification class of the lighting system. Flicker index takes a value between 0 and 1 while the flicker percentage between 0 % and 100 %.

Fluorescent lamps, a common type of discharge lamps, reaches to a 100 % flicker percentage with their electromagnetic ballast while this percentage decreases to 70 % with electronic ballasts depending on the specifications and brand of the ballast.

In this paper office workers are asked to do specific jobs in three different office rooms with different lighting scenarios. Then a questionnaire consist of 10 questions is made to the volunteer test participants about their psychological state during the period spent in the rooms. The lighting systems of the rooms are as follows: fluorescent lamps with electromagnetic ballasts for Room 1, fluorescent lamps with electronic ballasts for Room 2, LED lamps for Room 3. Five different lighting scenarios are applied in each room with 30 participants with clear vision: 15 female and 15 male aged between 18 and 40.

2. METHODS, MATERIALS AND RESULTS

Test rooms are office rooms on the third floor of M6 building in Engineering Faculty of Sakarya University. The coordinates of the rooms are 40º 74´ North latitude and 30 º 33´ East longitude. The surface areas of the rooms are 24 m^2 and each room have a window oriented to the northwest. The artificial lighting systems of Room 1 and Room 2 consist of six 4x18 fluorescent lamps and double parabolic mirror louver luminaries with the next characteristics (Fig.2):

Φ_v=3150 lm, *CCT*=4000 K, *CRI*=82, *UGR*=12÷15.

The only difference of the systems are the ballasts that luminaries have: electromagnetic ballasts in Room 1 and electronic ballasts in Room 2. In Room 3 six 1x41W, 60cmx60cm mid-class LED panels are used (Fig.3). All panels characteristics are the next:

Φ_v=4150 lm, *CCT*=4000K, *CRI*=84, *UGR*=12.7÷13.6.

The panels are connected to the dimmable DALI ballasts (92 % eff, pf=0.95). (All of the given data are provided by the supplier companies and verified by measurements)

The experiment begins with Visual Burdon Tests which takes 2 minutes of time. Burdon tests are frequently used to determine the attention and perception level of children and teenagers by demanding to point out a specific letter or image from mixed arrays. The participants are subjected to these tests after they spend 10 minutes of free time in the rooms. The tests are performed under 100 % operating con-

Table 1. Test Room Conditions

Room	Room 1	Room 2	Room 3		
Dimming	**100 %**	**100 %**	**100 %**	**75 %**	**50 %**
Illumination level (lx)	226	228	427	241	130
Flicker percentage	%91	%66	%9	%24	%62
Flicker index	0.49	0.21	0.02	0.07	0.19

Table 2. Burdon Test Results of the Test Rooms at Approximate Illumination Level

Room	Room 1	Room 2	Room 3
Dimming	**100 %**	**100 %**	**75 %**
Male Burdon Test Success	81 %	84 %	90 %
Female Burdon Test Success	83 %	85 %	92 %

ditions for Room 1 and Room 2 while 100 %, 75 % and 50 % for Room 3. After the tests are completed, the participants are asked to do an additional questionnaire to determine the effects of the test rooms on their psychological states. This questionnaire is prepared using Likert Scale like in previous similar studies [10]. As an effective attitude scale, Likert Scale uses a 5-scale response parameter set to questions as Strongly agree, Agree, Neutral, Disagree and Strongly disagree. Every single response has a numerical equivalent. As a widespread scale of attitude measurement, Likert Scale is a reliable scale preferred in a lot of scientific studies recently.

Table 1 shows that the illumination levels of Room 1 and Room 2 under 100 % operating conditions are approximate to the level of room 3 under 75 % operating conditions. Thus the Burdon test results of these conditions are evaluated separately. In Table 1, the illumination levels are measured values at working plane of 80 cm height by TES1336A luxmeter and flicker percentage and flicker index are the result of the measured values by UPRTEK MK350 tool.

As it is seen from Table 1, the worst flicker percentage and flicker index are arisen by electromagnetic ballast application while the best values are observed by LED panels with DALI ballast application at 100 % operating condition (no dimming condition). DALI ballast is also an electronic driving circuit which corrects the power factor. This specification of DALI ballasts and the LED panels working at DC voltage together decrease the flicker values and at 100 % operating give the best results.

In Room 3 the flicker percentage increased from 9 % to 24 % at 75 % operating and to 62 % at 50 % operating while the flicker index increased from 0.02 to 0.07 at 75 % operating and 0.19 at 50 % operating (Table 1). Since DALI ballasts drive by PWM modulation, the DC voltage waveform is clipped in proportion to the dimming. Thus, the

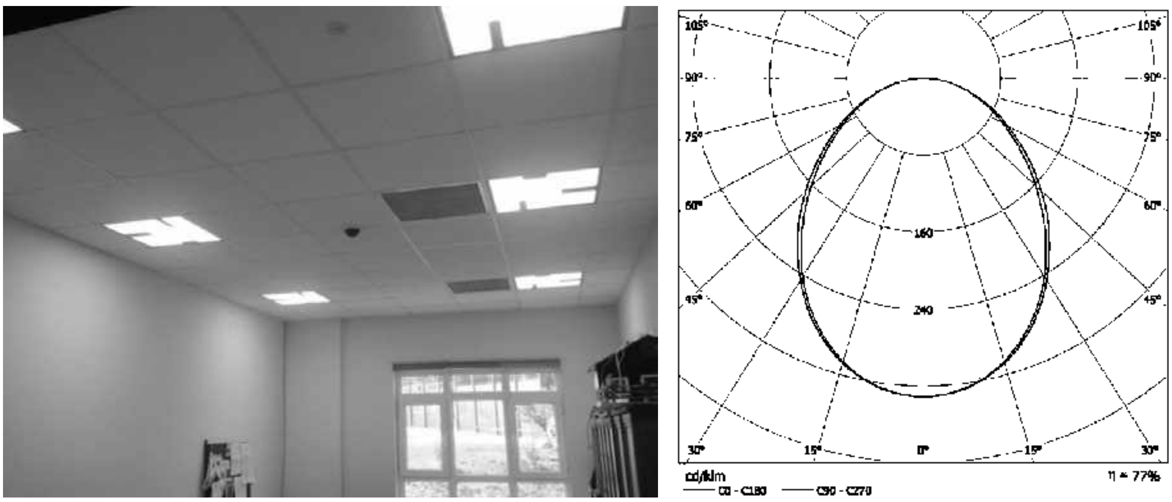


Fig. 3. Lighting system and light distribution curve of luminaires in Test Room 3

Table 3. Burdon Test Results for Room 3 at Different Illumination level

Room	Room 3	Room 3
Dimming	**100 %**	**50 %**
Male Burdon Test Success	92 %	87 %
Female Burdon Test Success	93 %	86 %

flicker values change by dimming conditions. In fact, the flicker values would be measured at higher levels, if the application is performed by an electronic ballast with no dimming property.

The Burdon tests and questionnaires are performed in dark hours when there is no daylighting effect. Table 2 gives the results of Burdon tests for the three test rooms at approximate illumination level and Table 3 gives the results for Room 3 at different dimming conditions.

Table 2 and Table 3 shows that the success in attention test in Room 1 and Room 2, where the flicker percentage and flicker index are high, are less than the success in Room 3 at the lowest illumination level. The success in Room 3 also decreases when the operating conditions are changed to 50 % with higher flicker values. Participants who should find and underline specific letters in the given texts performed more mistakes every time the lighting was dimmed. Those mistakes are not only made at the end of the Burdon Tests given but also at the top of the text. Participants could not perform the same success in the same tests in different tries under dimming and different light conditions. Thus, it can be concluded that the rise in flicker values causes perceptual disorder and distractibility even people are familiar to the work they are handling.

The results of questionnaires which evaluates the effects of the test rooms on the participants' psychological states are given in Table 4. The participants are asked eight questions in three main topics. All of the data entered to SPSS14.0 software and following tables are re-organized in the following form to create a better view to understand the results gathered by the questionnaire (Table 4).

As it is seen from Table 4, the number of participants with complaints of "feeling uncomfortable" and "being unable to focus" dramatically increases in rooms with higher flicker percentage and index values. In Room 3 the decreasing illumination level at 50 % operating condition also contributes the distractibility. The number of participants who are unwilling to work in the current lighting conditions supports the fact that the flicker values have significant effects on office workers' performance.

Table 4. The Feelings of the Participants in Different Lighting Conditions

Room	Room 1	Room 2	Room 3		
Dimming	**100 %**	**100 %**	**100 %**	**75 %**	**50 %**
Feeling uncomfortable in the room	11 participants (36.7 %)	7 participants (23.3 %)	1 participant (3.3 %)	1 participant (3.3 %)	3 participants (10 %)
Being unable to focus	10 participants (33.3 %)	8 participants (26.7 %)	1 participant (3.3 %)	1 participant (3.3 %)	5 participants (16.7 %)
Being unwilling to work in the room for a long time	13 participants (43.3 %)	10 participants (33.3 %)	1 participant (3.3 %)	1 participant (3.3 %)	5 participants (16.7 %)

Table 5. Participant Satisfaction Levels about the Visual Conditions in the Room "Q4. I am satisfied with the visual conditions of the Room"

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree Disagree	0 5	0,0 16,7	0,0 16,7	0,0 16,7
	Neutral	10	33,3	33,3	50,0
	Agree	9	30,0	30,0	80,0
	Strongly Agree	6	20,0	20,0	100,0
	Total	30	100,0	100,0	

Table 6. Total Median Values of Responses Given to the Questionnaire

Question	Q 1	Q 2	Q 3	Q4	Q 5
Median	4,00	3,96	3,62	3,82	3,72
Question	**Q 6**	**Q 7**	**Q 8**	**Q 9**	**Q 10**
Median	3,50	3,54	3,86	3,26	3,44

Table 7. Reliability Evaluation of the Questionnaire Reliability Statistics

Cronbach's Alpha	N of Items
,869	10

Looking at results obtained in Room 3, even under relatively high flicker conditions just 16.7 % of the participants have focusing problems and want to get out of the Room in a short time. Responses given to Questionnaire Question 4 is given in Table 5 as an example to understand the evaluations in a better way.

To investigate the total reliability of the questionnaire applied median values (Table 6) and Cronbach's Alpha (Table 7) should be investigated. As seen in Table 7, reliability of the questionnaire is 86.9 % according to the responses given by the participants. That indicates applied questionnaire to measure the psychological situations of the participants is a proper one.

3. CONCLUSION

In this paper the flicker effect on office workers is investigated by evaluating the Burdon tests and questionnaires performed with 30 participants who are asked to work under varying lighting conditions in three different test rooms. The results obtained from the tests and questionnaires show that people working in environment with high flicker percentage and index suffers from perceptual disorder, focusing problems and unwillingness to work for long hours in current conditions. It is found out that dimming at all levels also contributes the perception and attention issues. Thus, the lighting systems of an office environment should be selected to be able to provide high illumination levels with low flicker percentage and index. Some methods to decrease the flicker effect can be given as follows:

- Using LED panels instead of fluorescent lamps;
- Using ballasts and drives with high power factors;
- Using drives with current control methods instead of the ones with PWM modulation for dimming;
- If possible, determining the required illumination levels in designing stage so that no dimming scenarios are required and applied.

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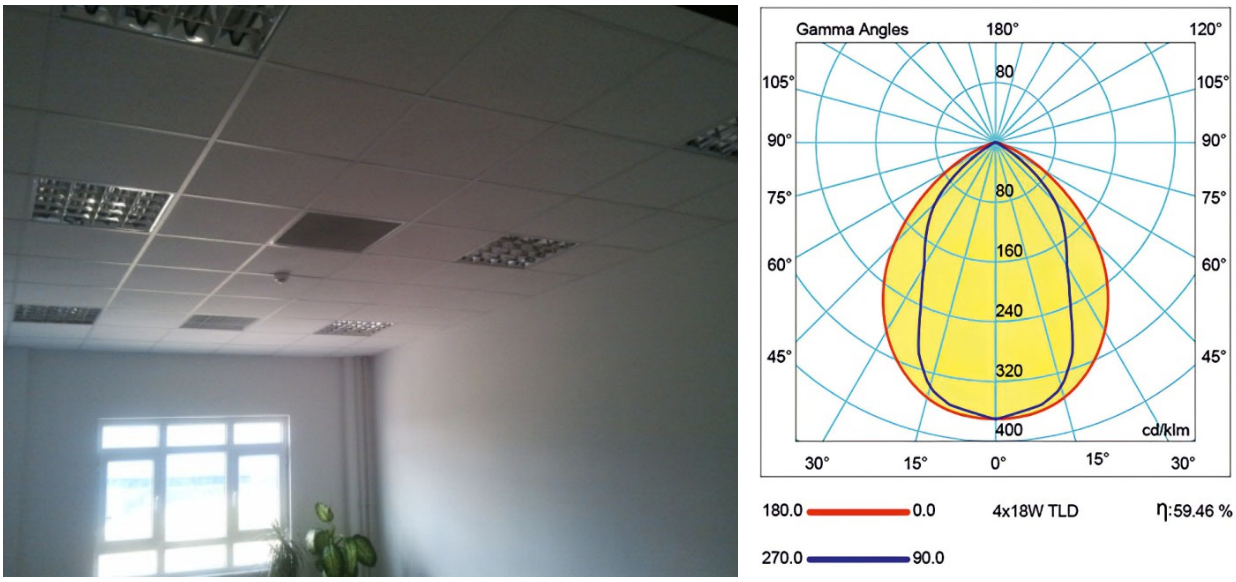

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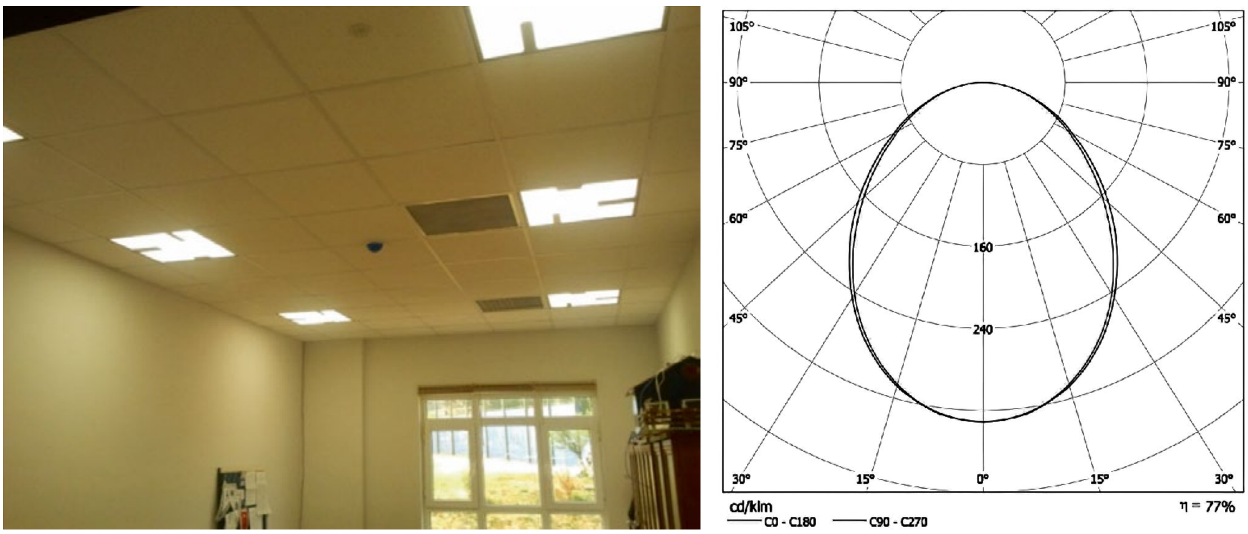

Fig. 3. Lighting system and light distribution curve of luminaires in Test Room 3