GRID ARCHITECTURE, PLANNING AND DESIGN JOURNAL
GRİD MİMARLIK, PLANLAMA VE TASARIM DERGİSİ

Vol. 5, No. 2, 2022, 129-143 / Cilt 5, Sayı 2, 2022, 129-143 / DOI: 10.37246/grid.993713

Visual comfort assessment of OLED lighting in an indoor office environment

Ayşe Nihan AVCI[1], ORCID: 0000-0003-2340-0317
Saadet AKBAY[2], ORCID: 0000-0002-7101-1677

Keywords

Lighting; Oled lighting; Visual comfort; Indoor office environment

Abstract

Visual comfort is one of the significant criteria influencing good-quality lighting in an indoor environment. There are various technologies for delivering illumination in indoor installations; three important milestones are incandescent, fluorescent, and LED lighting. Alternative technologies, such as OLED (organic light-emitting diode) lighting, cannot be disregarded by a thorough examination. Few studies have investigated the influence of OLED lighting on visual comfort in terms of merely illuminance level. To this end, this study investigates the influence of OLED lighting conditions on visual comfort, including general comfort parameters—overall comfort, illuminance, brightness ratio, veiling reflections, colour, flicker effect, overall satisfaction—in an indoor office environment. Twelve members from the Faculty of Architecture, Çankaya University, voluntarily participated in the study. A full-scale indoor office environment was designed for the test environment, which was illuminated by OLED lighting (2900 K). An Office Lighting Survey was adopted to assess the general visual comfort of OLED lighting conditions in an indoor office environment. In contrast to earlier lighting studies, this study did not measure any task performance under the lighting condition. Instead, it focused solely on participants' visual comfort evaluations when exposed to OLED lighting during their everyday routines in an indoor office environment. This study is a preliminary study for further investigations on the doctoral thesis.

Article Information

Received:
10.09.2021

Received in Revised Form:
26.12.2021

Accepted:
18.03.2022

Available Online:
29.07.2022

Article Category

Research Article

Highlights

- OLED lighting conditions are examined by considering the general comfort parameters in the full-scale indoor office environment.
- The influence of OLED lighting conditions is investigated on various visual comfort parameters.
- Evaluating lighting conditions with various parameters helps to provide healthy and comfortable lighting in the indoor environment.

Contact

1. Faculty of Architecture, Çankaya University, Ankara, Turkey
nihanavci@cankaya.edu.tr

2. Faculty of Architecture, Çankaya University, Ankara, Turkey
akbay@cankaya.edu.tr

Avcı, A. N., & Akbay, S. (2022). Visual comfort assessment of OLED lighting in an indoor office environment. *GRID Architecture, Planning and Design Journal*, 5(2), 129-143.

INTRODUCTION

Lighting is one of the several aspects to consider in an indoor office environment that can influence individuals' satisfaction, well-being, and productivity. The lighting in an office environment should be sufficient for visual performance regarding the task concerned. Studies on lighting have revealed the lighting quality required in an office environment to provide high levels of visual comfort (Al Horr et al., 2016). Studies indicate that one of the purposes of lighting is to reduce visual fatigue and improve performance (Summers, 1989). Boyce (2014) found that lighting quality influences visual performance and behaviour outcomes. Besides visual performance, lighting quality also influences task and behavioural performances, social interactions, mood, health and safety, and aesthetic judgements (Veitch & Newsham, 1996). According to Boyce et al. (2003), in terms of visual comfort, five factors that influence visual performance should be considered while producing good-quality lighting in an indoor office environment: visual size, luminance contrast, colour difference, retinal image quality, and retinal illuminance. These factors are crucial in determining the visual system's ability to perceive and recognise stimuli (Van den Wymelenberg, 2012).

In addition, indoor lighting standards of the International Commission on Illumination (CIE) define the following criteria for visual comfort: glare, veiling reflections, illuminance levels, luminance ratios and uniformity, colour rendering index (CRI), correlated colour temperature (CCT), and flicker effect (CIE, 1995). This available guidance and these quantitative or qualitative visual comfort criteria are derived from studies conducted mainly using fluorescent lighting. Many studies have been examined to determine whether the same principles still apply to illumination using LED (light-emitting diode) lighting (Iacomussi et al., 2015). Although numerous types of lighting have been utilised in office environments, the most common ones nowadays are fluorescent, incandescent, and LED lamps. Kazemi et al. (2018) state that lighting sources have various physical qualities; nevertheless, few studies have compared the influence of their visual performance and visual comfort on individuals. For instance, Sahin et al. (2014) found that individuals exposed to high colour temperature (i.e., 6500 K) LEDs indicate higher visual comfort and colour recognition than those exposed to fluorescents. Canazei et al. (2017) assert that LED lighting produces less mental fatigue than fluorescent lighting in an office environment. In addition, when compared to conventional white fluorescent light sources, white-light LED light sources perform better in non-visual performances (Okamoto & Nkawaga, 2015). In their study, Avcı and Memikoğlu (2017) aim to investigate the effects of LED lighting conditions on task performance. The study created a test environment with a full-scale cabinet to prevent light absorption and the effect of environmental colour, with dimensions of 1.60 m x 2.60 m x 2.80 m. The cabinet's surfaces were all white, and it was furnished with a white table and a stool. The study reports that the illuminance levels of LED in 500 lx are more visually comfortable in general; however, 200 lx is more visually comfortable in preventing burning eyes while reading. The study's findings show that the standard illuminance level does not address all the visual comfort standards of LED lighting. Additionally, studies indicate that the illumination level on the working surface is significant in office lighting satisfaction. According to the categories in the European Standard EN 12464-1, the most recent average illuminance recommended for offices on the task-based categories is 500 lx (European Standards, 2019). However, it is essential to note that providing only an illuminance level is insufficient to provide comfortable office lighting. The aspects mentioned earlier on lighting setting must also be evaluated to attain appropriate visual comfort levels. In addition to visual comfort levels, some studies also examine space and room appearance, surface brightness and colour, light distribution, and the appearance of light and luminaires for visual comfort appraisals (Iacomussi et al., 2015). Hawes et al. (2012) also claim that fluorescent and other lighting fixtures are commonly used in indoor office environments. Newer technologies such as LED lighting have more advantages than other fixtures, including better visual performance and visual comfort criteria and low power consumption, flexibility in application, and long lifespan. However, Nardelli et al. (2017) assert that when all the essential features of the lighting system are considered, there is no agreement in the lighting literature on the advantages of LED lighting over other technologies.

Although various technologies deliver illumination in indoor installations, three significant milestones are incandescent, fluorescent, and LED lighting. Aside from the benefits of LED lighting, new approaches to improving the performance of traditional methods have been established; nonetheless, Humphry Davy and Michael Faraday have continued the advancement, becoming the starting point of lighting technology. Alternative technologies, on the other hand, such as induction lamps or OLED (organic light-emitting diode), whose influence is still unknown, cannot be disregarded by a thorough examination (Montoya et al., 2017). OLED lighting opens a whole new realm of light-interaction possibilities. OLED is a solid-state lighting (SSL) technology with numerous advantages over conventional choices. In addition to its design (ultra-thin, featherweight, flexible, cool-to-touch, long-life span, and 90+ colour rendering index), the benefits of OLED include health and well-being (no blue light risk, no UV, circadian rhythm friendly, no flicker, naturally diffuse, and glare-free), and sustainability (recyclable, 85% organic and glass materials, does not contain toxic materials, no thermal heat sink, reduced manufacturing footprint, and low power consumption) (Hawes et al., 2012; Why OLED, 2020). Accordingly, in the current study, OLED is considered an interior lighting element as the next stage of solid-state lighting (SSL) technology. Few studies have researched the influence of OLED lighting on visual comfort in terms of merely illuminance level (Avcı, 2017; Avcı & Memikoğlu, 2021). To this end, this study aims to investigate the influence of OLED lighting conditions on visual comfort, including general comfort parameters, in an indoor office environment. In contrast to earlier lighting studies, this study does not include any assessment tools—such as task performance—and instead focuses solely on visual comfort by examining individuals' everyday routines in an indoor office environment while they were exposed to OLED lighting. This study is a preliminary study that provides the basis for doctoral research.

Vol. 5, No. 2, 2022, 129-143 / Cilt 5, Sayı 2, 2022, 129-143 / DOI: 10.37246/grid.993713

METHOD

Participants

The subject group for the study consisted of 12 participants. They were members from the Faculty of Architecture, Çankaya University, Ankara, Turkey: ten from the Department of Interior Architecture and two from the Department of City and Regional Planning. Their ages ranged from 26 to 32; the mean age was 29. Two of the participants wore glasses, and two utilised contact lenses.

Experimental Setting

The experiment was carried out in a full-scale indoor office environment at Çankaya University, Faculty of Architecture. The office was 15m^2, with one large window in one of the north-facing walls, white-painted walls, white ceiling, red terrazzo ceramic tile on the floor. The office was divided into two with thick white blackout drapes to achieve optimal lighting conditions and prevent natural lighting. After division, the test environment area was approximately 6 m^2 (2.5 m x 2.5 m x 2.8 m). This square meter was designed to provide the required illuminance level for the environment. The furnishing and colour scheme was kept consistent with the same qualities in all faculty staff offices in the full-scale indoor office environment. There were two black-covered bookcases (80 x 35 cm), a black-covered desk (160 cm x 70 cm x 71 cm) with a semi-matt laminated surface, and a blue upholstered office chair. Figure 1 presents the schematic plan and section of the full-scale indoor office environment and the photograph of the test environment.

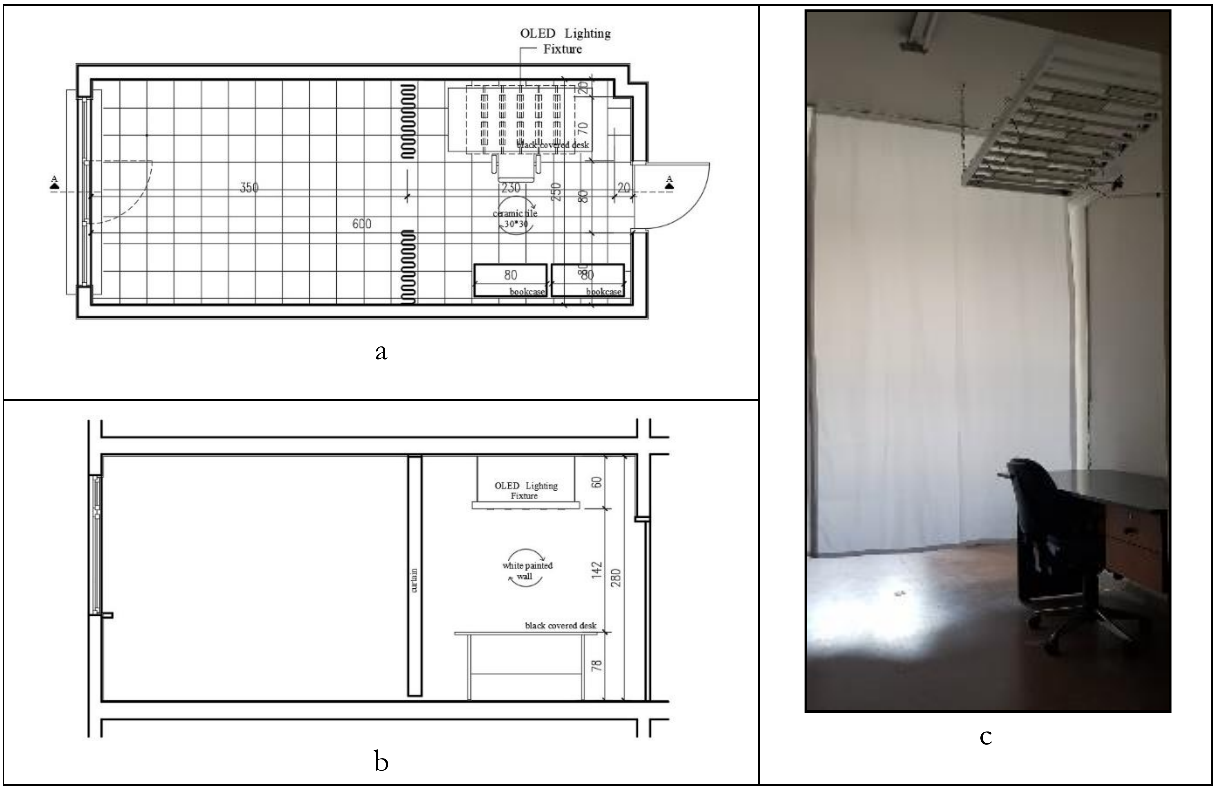

Figure 1 - a) Schematic Plan, b) Section of the Full-Scale Indoor Office Environment (not to scale), and c) A Photograph of the Test Environment (first author's archive).

Lighting Conditions

The OLED lighting was used to illuminate the full-scale indoor office environment. The lighting fixture was mounted on the ceiling, placed roughly above the middle of the desk to provide optimal lighting conditions and avoid glare and reflections on the working area, as suggested by Ferlazzo et al. (2014), Lee et al. (2014), and Avcı (2017). The OLED lighting setup had a white frame that held the suspended lighting equipment, which included ten OLED panels and their drivers. The lighting fixture was suspended by chains from four locations at a height of 2.20 m (Lee et al., 2014) from the floor . Two series-connected electrical systems were designed to illuminate all the panels. A dimmable switch was used to control the OLED displays separately, and two adaptors were used to connect the OLED panels and their drivers. Table 1 shows the technical properties of lighting equipment used in the test environment.

Table 1- Technical Properties of Lighting Equipment used in the Test Environment.

Lighting Equipment	Name	Dimension	Lumen	CCT	CRI	Product
OLED panel	Lumiblade OLED Panel Brite FL300 L WW	24.8 cm x 7 cm	300 lm	2900 K	>90	
OLED panel driver	Driver D024V 10W/0.1-0.4A/28V D/A	5.8 cm x 5 cm				

Although 500 lx is recommended for a convenient illuminance level in an office environment (European Standards, 2019), a study by Avcı and Memikoğlu (2021) found that 200 lx for OLED lighting was visually comfortable, particularly to preventing glare. Illuminance levels were measured at three points on the desk surface; namely, the left, middle, and right (207 lx, 211 lx, and 202 lx) and the illuminance level in the test environment was set to 200 lx as an average. A luminance meter (Konica Minolta CL-70F) was employed to calibrate the illuminance level in the environment. Indoor air temperature and air quality directly impact visual comfort in an indoor environment (Al horr et al., 2016). To obtain further information regarding the office condition, indoor air temperature (Testo 175 T2), sound level (Testo 815), and VOC detection (Toxi RAE Pro Pid) were also measured before each experiment.

Measures and Procedure

Office Lighting Survey (Eklund & Boyce, 1996) was adopted to be used to assess the general visual comfort of OLED lighting conditions in an indoor office environment for the study. Allan et al. (2019) state that the office lighting survey questionnaire evaluates both the board and specific lighting features over the long term. The questionnaire used in this study consisted of 11 questions. The context of the questions includes measuring the visual comfort criteria such as overall comfort (e.g., 'Overall, the lighting is comfortable'), illuminance (e.g., 'The lighting is uncomfortably bright for the tasks that I perform'), brightness ratio (e.g., 'The lighting is poorly distributed here'), veiling reflections (e.g., 'Reflections from the light fixture hinder my work'), colour (e.g., 'My skin is an unnatural tone under light'), flicker effect (e.g., 'The light flicker throughout the day'), comparison with other lighting conditions, and overall satisfaction. In addition to these questions, participants were required to answer whether an additional lighting unit was needed, which was a yes/no question. The others were on a Likert scale, with values ranging from 'one' (strongly disagree) to 'seven' (strongly agree). In contrast to earlier lighting studies, this study did not measure any task performance under the lighting condition and instead focused solely on participants' visual comfort evaluations while they were exposed to OLED lighting during their everyday routines in an indoor office environment. Therefore, the experiment involved a day of the working period for the participants, which lasted a total of seven hours.

Each participant was invited to the full-scale setup office environment according to the pre-scheduled timetable. The participant was then seated at a desk and allowed to place all necessary equipment (laptop, paper, pencil, etc.) in the working area for their daily routine while working. The experiment was started at 10 am and finished at 3 pm, with a one-hour lunch break from 12 am to 1 pm for each participant. During the experiment, the parameters including indoor air temperature, sound level, and VOC detection in the office environment were measured four times (i.e., at 10 am, 12 am, 1 pm, and 3 pm). First, participants were informed about the study's purpose and ethical assurance. The researcher (first author) then asked each participant about their demographic information, such as age, gender, department, and whether they used glasses or contact lenses, and recorded their responses on their forms. A portable OLED lighting fixture was turned on at the office, and the participant was given the Ishihara colour deficiency test to see whether they had normal colour vision. To ensure that the illuminance level was set at 200 lx, a luminance meter was used to measure the degree of illuminance level for each test environment. The participants were then left alone to spend their regular working hours at the office. At the end of the day, each participant was required to complete the office lighting survey questionnaire.

Statistical Analysis

IBM SPSS Statistics 23.0 software was used to perform the statistical analysis of the collected data. The Shapiro-Wilk test was used to evaluate the data for normality. Mean and standard deviation statistics were performed to make some observations about the distribution of the items. A one-way between groups of variances (ANOVA) was conducted to determine which visual comfort criteria differed significantly from the others. The effect size was computed using eta squared (η^2). In addition, a paired sample t-test was utilised to investigate the relationship between the visual comfort criteria of overall comfort, illuminance, brightness ratio, veiling reflections, colour, flicker effect, the comparison to other lighting conditions, and overall satisfaction.

RESULTS AND DISCUSSION

Prior to further discussion of the data results, as previously stated, the quality characteristics of the interior environment were tested four times for each participant throughout the test (at 10 am, 12 am, 1 pm, and 3 pm). The measurement results reveal that the values of factors affecting indoor environmental quality under OLED lighting circumstances are within the requirements' comfort range (ASHRAE, A. 2004; Gazete, 2017). The gathered data were examined for normality, and the Shapiro-Wilk test result shows that the data is normally distrusted (W [12] = 0.910, p = 0.216). To make some observations about the data, the descriptive statistics with mean and standard deviations were calculated. Table 2 presents the frequency distribution of the ten items.

Table 2- Descriptive Statistics of the Data

Items on visual comfort	N	Mean	SD
Overall comfort	12	4.75	1.36
Illuminance (1)	12	2.92	1.38
Illuminance (2)	12	3.50	1.62
Brightness ratio (1)	12	2.92	1.56
Brightness ratio (2)	12	3.25	2.01
Veiling reflection	12	2.33	1.78
Colour	12	2.17	1.19
Flicker effect	12	2.17	1.64
Comparison with other lighting conditions	12	5.00	1.35
Overall satisfaction	12	4.42	1.51

Table 1 shows that the participants used the positive side of the rating scale to evaluate the overall comfort criterion of OLED lighting using. This approach was also valid for the criterion of overall satisfaction with OLED lighting, as participants rated this scale on the higher end of the scale. Furthermore, when participants were asked, 'How does the lighting compare to similar workplaces?', OLED lighting was rated in the higher part of the scale.

ANOVA was conducted to determine which of the visual comfort criteria, including overall comfort, illuminance, brightness ratio, veiling reflection, colour, flicker effect, comparison with other lighting conditions, and overall satisfaction, differed significantly from the others. The results indicate that the visual comfort of OLED lighting differed significantly at the $p < .05$ level in the criteria of illuminance level (F [5, 11] = 5.94, $p = .026$, $\eta^2 = 0.83$) and colour perception (F [5, 11] = 4.68, $p = .044$, $\eta^2 = 0.80$). In addition, a paired samples t-test was used to investigate the differences between the pairs of 11 visual comfort criteria. The results show that there was statistically significant difference (sig. two-tailed, $p < 0.05$) in scores on overall comfort ($M = 4.75$, $SD = 1.36$) with illuminance level ($M = 3.21$, $SD = 0.84$), veiling reflection ($M = 2.22$, $SD = 1.78$), colour perception ($M = 2.17$, $SD = 1.19$), and flicker effect ($M = 2.17$, $SD = 1.64$). In scores on illuminance level ($M = 3.21$, $SD = 0.84$), there was statistically significant difference between veiling reflection ($M = 2.33$, $SD = 1.76$), colour perception ($M = 2.17$, $SD = 1.19$), and when the OLED lighting condition was compared to other lighting conditions ($M = 5.00$, $SD = 1.35$). In scores on brightness ratio ($M = 3.08$, $SD = 1.40$), there was statistically significant difference between veiling reflection ($M = 2.22$, $SD = 1.78$), colour perception ($M = 2.17$, $SD = 1.19$), flicker effect ($M = 2.22$, $SD = 1.64$), and the comparison of the other lighting conditions ($M = 5.00$, $SD = 1.35$). In scores on colour perception ($M = 2.17$, $SD = 1.19$), there was statistically significant difference between when the OLED lighting condition was compared to other lighting conditions ($M = 5.00$, *SD* = 1.35) and overall satisfaction (*M* = 2.17, *SD* = 1.19). In addition, there was statistically significant difference in scores for flicker effect (*M* = 2.17, *SD* = 1.64) when the OLED lighting condition was compared to other lighting conditions (*M* = 5.00, *SD* = 1.35) and overall satisfaction (*M* = 2.17, *SD* = 1.19). Table 3 displays the paired samples t-test results and statistically significant pairs of visual comfort criteria.

Table 3- Results of Paired Samples t-test

Pair	Criteria		Paired Differences: Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Lower	Upper	t	df	Sig. (2-tailed)
1	overall comfort	illuminance	1,54	1,99	0,58	0,27	2,81	2,68	11,00	0,02
3		veiling reflections	2,42	2,91	0,84	0,57	4,26	2,88	11,00	0,01
4		colour perception	2,58	2,19	0,63	1,19	3,98	4,08	11,00	0,00
5		flicker effect	2,58	2,43	0,70	1,04	4,13	3,68	11,00	0,00
9	illuminance	veiling reflections	0,88	1,35	0,39	0,02	1,73	2,24	11,00	0,05
10		colour perception	1,04	1,10	0,32	0,34	1,74	3,29	11,00	0,01
12		comparision with other lighting conditions	-1,79	1,88	0,54	-2,98	-0,60	-3,31	11,00	0,01
14	brightness ratio	veiling reflections	0,75	0,94	0,27	0,15	1,35	2,76	11,00	0,02
15		colour perception	0,92	1,14	0,33	0,19	1,64	2,77	11,00	0,02
16		flicker effect	0,92	1,43	0,41	0,01	1,82	2,22	11,00	0,05
17		comparision with other lighting conditions	-2,25	1,47	0,42	-3,18	-1,32	-5,30	11,00	0,00
20	colour perception	comparision with other lighting conditions	-1,92	2,60	0,75	-3,57	-0,26	-2,55	11,00	0,03
21		overall satisfaction	-2,25	2,49	0,72	-3,83	-0,67	-3,13	11,00	0,01
22	flicker effect	comparision with other lighting conditions	-2,83	2,48	0,72	-4,41	-1,26	-3,96	11,00	0,00
23		overall satisfaction	-2,25	2,73	0,79	-3,99	-0,51	-2,85	11,00	0,02

According to the results, the visual comfort of OLED lighting differed significantly at illuminance level and colour perception. Additionally, the overall comfort was provided in the indoor office environment while the illuminance level, no veiling reflections, good colour perception, and no flicker effect were offered. This finding suggests that these visual comfort criteria were significant for the overall comfort of OLED lighting. The findings also indicate that the illuminance level of OLED lighting was significant to avoid veiling reflections, to provide good colour perception under this lighting condition and when compared to other lighting conditions in the indoor office environment. Similarly, the brightness ratio of OLED lighting in the indoor office environment was significant to prevent veiling reflections and flicker effects in the environment and achieve good colour perception. The findings also show that the brightness ratio was an important parameter when comparing OLED lighting conditions to other lighting conditions. According to the study's findings, providing a good colour perception and preventing flicker effects were essential criteria when comparing OLED lighting conditions to other lighting conditions and achieving overall satisfaction with OLED lighting in the indoor office environment. Although there has not been a lot of research done on interior design related to OLED lighting, studies in both lighting and other areas of research can be mentioned. For instance, Avcı (2017) conducts a study to investigate the effects of LED and OLED lighting conditions on task performance. The results for OLED lighting indicated that the illuminance level of 500 lx was slightly more comfortable than the other illuminance levels in terms of visual distraction, visual clarity, visual fatigue, burning eye and focusing problem. On the contrary, the illuminance level of OLED at 200 lx was found to be slightly more comfortable than others in terms of glare affecting task performance. However, this study suggests that the visual comfort criteria were all met by OLED lighting in terms of overall comfort, illuminance level, brightness ratio, colour perception, flicker effect, and overall satisfaction Besides visual aspects of OLED lighting, in terms of none-visual aspects, Jo et al. (2021) investigate the effects of OLED and LED at a different color temperature (3,000 K) on melatonin profile, sleep, and vigilance. The study found that exposure to light in the evening can suppress melatonin secretion late at night and disturb deep sleep, and these effects are slightly worse with LED lighting than with OLED lighting.

CONCLUSION

This study aimed to investigate the influence of OLED lighting conditions on visual comfort, including general comfort parameters, in an indoor office environment. An experiment was carried out in a full-scale indoor office environment using OLED lighting to illuminate the environment. In contrast to earlier lighting studies, this study does not include any assessment tools. Instead, it focused solely on visual comfort by examining individuals' everyday routines in the indoor office environment while they were exposed to OLED lighting. This study might be limited in terms of participants, yet this study is a preliminary study that provides the basis for doctoral research.

Aside from its effect on visual performance, lighting can also have a considerable influence on atmosphere and the visual impression of the workplace. When properly planned, the entire working environment can have a stimulating effect on the people who work in it (Van Bommel & Van den Beld, 2004). Boyce (2004) states that lighting conditions fundamentally influence the health, wealth, and safety of human life. He further explains the three types of routes that influence human performance due to lighting conditions in an environment. These routes influence humans through the visual system, circadian system, and perceptual system. The route through the visual system explains how illumination and task parameters interact to influence visual performance and how visual performance affects visual, cognitive, and motor performance. The route through the perceptual system originates from visual discomfort, delivering the message in the general perception of the environment through mood and motivation on human performance. The route through the circadian system explains how illuminance, light spectrum, and timing and length of light exposure affect human performance in general and increase alertness via the circadian system (Boyce, 2004).

Light provides visual information for communicating with our environment and influences our physiological systems. Lighting has a significantly greater range of impacts than we previously anticipated. Recent studies have consistently revealed that light entering the human eyes has substantial non-visual biological effects on the human body in addition to a visual influence (van Bommel, 2006; Cajochen, 2007). These non-visual biological impacts are closely tied to the circadian system, a body balance associated with behavioural, mental, and physical changes during 24 hours (Circadian Rhythms, 2017). The circadian system is influenced by lighting parameters such as intensity, spatial distribution, spectral composition, as well as the time of day and duration of the stimulus.

Consequently, further research is needed to investigate the effects of exposed OLED lighting conditions on the human circadian system as well as visual comfort and well-being in an indoor office environment, considering both visual and non-visual aspects.

Acknowledgements

The research presented in this article is part of the Ph.D. study of the first author. This research is also part of General Scientific Project supported by Çankaya University with the project number MF.20.007. The authors would like to express their gratitude to Çankaya University and the Building Science and Environmental Control Laboratory of the Faculty of Architecture for providing the equipment and hosting the study. The authors would also like to thank the members of Faculty of Architecture at Çankaya University who volunteered to participate in this study.

Conflict of Interest Statement

There is no conflict of interest for conducting the research and/or for the preparation of the article.

Financial Statement

The equipment infrastructure of the project has been supported as "BAP Project" by Çankaya University.

Ethical Statement

We the authors confirm that the article 'Visual comfort assessment of OLED lighting in an indoor office environment' was written with full consideration to ethical norms and all consents were received from the participants. In addition, we declare that the research started with the approval of the Human Research Ethics Committee of Çankaya University with the decision dated 12.08.2020 and numbered 80281877-050.99.

All procedures followed in accordance with the ethical standards.

Copyright Statement for Intellectual and Artistic Works

In the article, copyright regulations have been complied with for intellectual and artistic works (figures, photographs, graphics, etc.).

Author Contribution Statement

A. Fikir / Idea, Concept	B. Çalışma Tasarısı, Yöntemi / Study Design, Methodology	C. Literatür Taraması / Literature Review
D. Danışmanlık / Supervision	E. Malzeme, Kaynak Sağlama / Material, Resource Supply	F. Veri Toplama, İşleme / Data Collection, Processing
G. Analiz, Yorum / Analyses, Interpretation	H. Metin Yazma / Writing Text	I. Eleştirel İnceleme / Critical Review

AUTHOR 1: A / B / C / E / F / G / H / I
AUTHOR 2: A / B / C / D / E / F / G / H / I

REFERENCES

Al horr, Y., Arif, M., Katafygiotou, M., Mazroei, A., Kaushik, A., & Elsarrag, E. (2016). Impact of indoor environmental quality on occupant well-being and comfort: A review of the literature. *International Journal of Sustainable Built Environment*, 5(1), 1-11. doi: 10.1016/j.ijsbe.2016.03.006

Allan, A. C., Garcia-Hansen, V., Isoardi, G., & Smith, S. S. (2019). Subjective assessments of lighting quality: A measurement review. *Leukos*. Doi: 10.1080/15502724.2018.1531017

ASHRAE, A. (2004). Standard 55-2004, thermal environmental conditions for human occupancy, Atlanta: American Society of Heating, Refrigerating, and Air-Conditioning Engineers. *Inc., USA*.

Avcı, A. N. (2017). *Effects of Illuminance Levels of Solid-State Lighting Sources on Visual Comfort.* (Unpublished Master Thesis). Çankaya University, Ankara, Turkey.

Avcı, A. N., & Memikoğlu, İ. (2017). Effects of LED lighting on visual comfort with respect to the reading task. *International Journal of Electrical and Computer Engineering*, *11*(8), 974-978.

Avcı, A.N. & Memikoğlu, İ. (2021). Evaluating effectiveness of LED and OLED lights on user visual comfort and reading performance. *A|Z ITU Journal of the Faculty of Architecture 18(*2), 397-411. doi: 10.5505/itujfa.2021.22438

Boyce, P., Hunter, C., & Howlett, O. (2003). The benefits of daylight through windows. Troy, New York: Rensselaer Polytechnic Institute.

Boyce, P. R. (2004). Lighting research for interiors: the beginning of the end or the end of the beginning. *Lighting Research & Technology*, *36*(4), 283-293. doi: 10.1191/1147715350411118oa

Boyce PR. 2014. Human factors in lighting. 2nd ed. Boca Raton (FL): CRC Press.

Cajochen, C. (2007). Alerting effects of light. *Sleep Medicine Reviews, 11*(6), 453–464. doi: 10.1016/j.smrv.2007.07.009

Canazei, M., Pohl, W., Bliem, H. R., & Weiss, E. M. (2017). Acute effects of different light spectra on simulated night-shift work without circadian alignment. *Chronobiology International*, *34*(3), 303-317. doi: 10.1080/07420528.2016.1222414

CIE, C. (1995). 117: Discomfort Glare in Interior Lighting. International Commission on Illumination: Vienna, Austria.

Circadian Rhytms. (2017). Retrieved from https://www.nigms.nih.gov/education/pages/factsheet_circadianrhythms.aspx.

Eklund, N. H., & Boyce, P. R. (1996). The development of a reliable, valid, and simple office lighting survey. *Journal of the Illuminating Engineering Society*, 25(2), 25-40. doi: 10.1080/00994480.1996.10748145

European Standards, (2019). Light and lighting - Lighting of workplaces - Part 1: Indoor workplaces. Retrieved from https://www.valosto.com/tiedostot/prEN%2012464-1.pdf.

Ferlazzo, F., Piccardi, L., Burattini, C., Barbalace, M., Giannini, A.M. & Bisegna, F. (2014). Effects of new light sources on task switching and mental rotation performance. *Journal of Environmental Psychology*, 39, 92-100. doi: 10.1016/j.jenvp.2014.03.005

Gazete, R. (2017). Binaların Gürültüye Karşı Korunması Hakkında Yönetmelik.

Hawes, B. K., Brunyé, T. T., Mahoney, C. R., Sullivan, J. M., & Aall, C. D. (2012). Effects of four workplace lighting technologies on perception, cognition and affective state. *International Journal of Industrial Ergonomics*, *42*(1), 122-128. doi: 10.1016/j.ergon.2011.09.004

Iacomussi, P., Radis, M., Rossi, G., Rossi, L. (2015) Visual comfort with LED lighting. *6th International Building Physics Conference,* 78, 729-734.

Jo, H., Park, H. R., Choi, S. J., Lee, S. Y., Kim, S. J., & Joo, E. Y. (2021). Effects of Organic Light-Emitting Diodes on Circadian Rhythm and Sleep. Psychiatry investigation, 18(5), 471.

Kazemi, R., Choobineh, A., Taheri, S., & Rastipishe, P. (2018). Comparing task performance, visual comfort and alertness under different lighting sources: An experimental study. *EXCLI journal*, *17*, 1018. doi: 10.17179/excli2018-1676

Lee, J. H., Moon, J. W., & Kim, S. (2014). Analysis of occupants' visual perception to refine indoor lighting environment for office tasks. Energies, 7(7), 4116-4139. doi: 10.3390/en7074116

Montoya, F. G., Peña-García, A., Juaidi, A., & Manzano-Agugliaro, F. (2017). Indoor lighting techniques: An overview of evolution and new trends for energy saving. *Energy and Buildings*, 140, 50-60. doi: 10.1016/j.enbuild.2017.01.028

Nardelli, A., Deuschle, E., de Azevedo, L. D., Pessoa, J. L. N., & Ghisi, E. (2017). Assessment of Light Emitting Diodes technology for general lighting: A critical review. *Renewable and Sustainable Energy Reviews*, *75*, 368-379. doi: 10.1016/j.rser.2016.11.002

Okamoto, Y., & Nakagawa, S. (2015). Effects of daytime light exposure on cognitive brain activity as measured by the ERP P300. *Physiology & Behavior*, *138*, 313-318. doi: 10.1016/j.physbeh.2014.10.013

Sahin, L., Wood B.M., Plitnick B. & Figueiro, M.G. (2014). Day-time light exposure: Effects on biomarkers, measures of alertness, and performance. *Behavioural Brain Research*, 274, 176-85. doi: 10.1016/j.bbr.2014.08.017

Summers, A. J. (1989). Lighting and the office environment: A review. *Australian Journal of Physiotherapy*, *35*(1), 15-24.

Van Bommel, W. J. (2006). Non-visual biological effect of lighting and the practical meaning for lighting for work. Applied Ergonomics, 37(4), 461-466.

Van Bommel, W. J. M., & Van den Beld, G. J. (2004). Lighting for work: a review of visual and biological effects. *Lighting Research & Technology*, *36*(4), 255-266. doi: 10.1191/1365782804li122oa

Van Den Wymelenberg, K.G. (2012). Evaluating Human Visual Preference and Performance in an Office Environment Using Luminance-based Metrics. PhD Dissertation, University of Washington, USA.

Veitch, J. A., & Newsham, G. R. (1996). Determinants of Lighting Quality II: Research and Recommendations. doi:10.1006/jevp.1999.0169

Why OLED, 2020. Retrieved from https://www.oledworks.com/inspiration/#why-oled.

BIOGRAPHIES OF THE AUTHORS

Ayşe Nihan AVCI (Res. Asst.)

Ayşe Nihan Avcı received BA and MFA degrees from the Department of Interior Architecture at Çankaya University. She has been a Ph.D. student in the Institute of Fine Arts at Çankaya University, Ankara, Turkey, and a research assistant since 2015 in the Interior Architecture Department, Faculty of Architecture, Çankaya University, Ankara, Turkey. She is a member of Chambers of Interior Architects of Turkey, and Turkish National Committee on Illumination. She teaches design studio and drawing courses in the Department of Interior Architecture at Çankaya University. Her research interests are human centric lighting, artificial lighting technologies, and color and light.

Saadet AKBAY (Asst. Prof. Dr.)

Saadet Akbay received BA and MFA degrees from the Department of Interior Architecture and Environmental Design at Bilkent University, and a PhD degree from Industrial Design at Middle East Technical University (METU), Ankara, Turkey and postdoctoral degree from Architecture (Colour Laboratory- LABCOR: EXPER-CHROMA) at the University of Lisbon, Portugal. She is currently an assistant professor in the Interior Architecture Department, Faculty of Architecture, Çankaya University, Ankara, Turkey, and served as the Department Chair between 2019 and 2020. Her teaching includes colour theory, colour design, colour and lighting, and basic design studio. She is a member of International Colour Association (AIC) Study Group on Environmental Design, AIC Study Group on Arts and Design, Colour and Light Research Group of CIAUD, and Chambers of Interior Architects of Turkey, where she served as the Treasurer on the Board of Directors between 2006 and 2008. She is an NCS Advisor, who participates in projects as a colour designer. Her research interests include colour perception, colour education, colour and light, design education, and the constructivist approach.