Journal of Design and Built Environment
E-ISSN: 2232-1500 |Print ISSN: 1823-4208
https://ejournal.um.edu.my/index.php/jdbe
Volume 26, Issue 2, 2026

Evaluation of Visual Performance and Perception in Office Workspaces with Varying Lighting Designs in Indonesia

Nurul Jamala[1*], Rosady Mulyadi[2], Asniawaty Kusno[3] and Yusaumi Ramadhanti[4]

[1,2,3] Department of Architecture, Faculty of Engineering, Hasanuddin University, Jl. Poros Malino Km. 6, Gowa 92171, Indonesia.

[4] Department of Architecture, Faculty of Engineering, Makassar State University, Jl. A.P. Pettarani, Indonesia.

*Corresponding author: nuruljamala@unhas.ac.id

Article Info:

Submission date: 23rd November 2025
Acceptance date: 10th February 2026

Key words:

Visual performance, visual perception, office workspace, illuminance

Abstract

The design of artificial lighting systems in office workspaces in Indonesia generally refers to the 350-lx illuminance standard. However, these standards do not fully reflect the actual visual needs of users, particularly when it comes to visual performance and visual perception. This study aims to determine the optimal level of desktop lighting and the optimal lighting ratio between the desktop and the surrounding area in achieving the visual comfort of the office workspace. This study uses a quantitative method through visual performance and visual perception experiments. Visual performance data was analyzed through homogeneity test and ANOVA test, while visual perception data was analyzed using the Multidimensional Scaling (MDS) method. The results showed that the best visual performance was achieved at the desktop illumination level of 200 lx, while the highest visual perception was obtained at the desktop and surrounding illumination ratio of 1:2. MDS analysis confirms that the most visually comfortable lighting conditions are achieved at a desktop lighting level of 200 lx with a desktop–surrounding ratio of 1:2 (200 lx : 400 lx). These findings provide empirical evidence for the development of office workspace artificial lighting design guidelines that are more responsive to user needs, beyond conventional lighting standards.

1.0 INTRODUCTION

In designing an artificial lighting system in a workspace, the aspect of visual comfort is one of the main factors that determine the effectiveness and productivity of space users. Visual comfort is influenced by two important components, namely visual performance and visual perception. Visual performance refers to an individual's ability to complete visual tasks efficiently, accurately, and quickly. This visual performance is greatly influenced by the level of illuminance in the work area, the contrast of the object, and the distribution of light in the room (Boyce et al., 2000, 2006). Visual perception is concerned with how the user perceives the quality of lighting subjectively, i.e. the perception of the distribution of light between the main work area and the surrounding area. This perception plays an important role in determining the psychological comfort of users and can affect attitudes and work performance (Veitch & Newsham, 1996, 2000). Therefore, understanding these two aspects is crucial in designing a lighting system that not only meets technical standard but also corresponds to the perceptual needs of workspace users.

Some countries have set recommended illuminance value standards for various space functions, including office workspace. For example, international standards such as EN 12464-1 (Europe) and the IESNA Lighting Handbook (USA) recommend a lighting level of ≥500 lx for office workspace to optimally support visual activities (Boyce, 2014). In Indonesia, the design of office workspace lighting systems refers to Indonesian National Standard 03-6575-2001 and 03-6197-2020 which recommends an illuminance level of 350 lx. Some previous studies have shown that the level of illuminance in a workspace does not always have to follow the highest standard values, depending on the type of activity, the perception of visual comfort, as well as the adaptation of the space user to lighting conditions (Chen et al., 2022). Preliminary research conducted by a number of researchers shows that the activities of workspace users can still take place effectively even if the lighting level is below the recommended standard. These findings indicate the need for visual performance experiments to evaluate the suitability of applicable lighting standards and subsequently visual perception experiments to create visual comfort in office workspace. The results of the study are expected to provide a scientific basis to strengthen or revise the recommendations for office workspace lighting standards in Indonesia.

Therefore, further experiments are needed that test the visual performance and user perception of different levels of illuminance. The results of this experiment are expected to provide a scientific basis to revise or strengthen the recommendations of office workspace lighting standards in Indonesia. Visual comfort is determined not only by the fulfillment of lighting standards, but also by the ability of lighting design to efficiently optimize natural light, which is one of the main principles in the application of the green building concept (Safa et al., 2022; Haider et al., 2022).

Research on visual performance can be carried out through various methods, such as trials in lighting laboratories or direct observation in the office work environment. Several previous studies have evaluated visual performance through activities such as text editing, reading, and writing on paper in several different lighting settings in the field. (Yu & Akita, 2023; Lee et al., 2014). Several previous studies have also analyzed visual performance with respondents' activities using computers in various lighting settings on desktop workspace (Viitanen et al., 2013; Sheedy et a., 2005; Konstantzos et al., 2020; Shieh & Lin, 2000; Han et al., 2021). The duration of work activities also affects visual performance, where the perception of comfort during work is often influenced by the length of work time. Such expectations of comfort can have an impact on eye fatigue levels, especially when work is done for a long time (Vink et al., 2017; Shen et al., 2009). Several previous studies related to lighting systems in office workspace, have shown that it is necessary to analyze lighting settings, especially in office workspace (De Vries et al., 2018; Wei et al., 2014; Mills et al., 2007; Boyce et al., 2006).

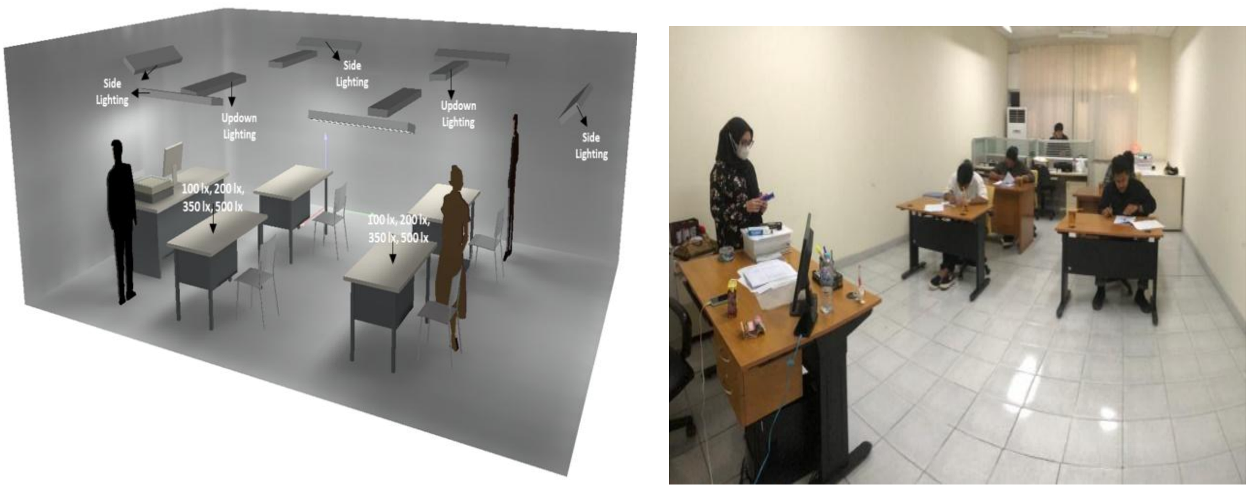
The lighting quality parameters in the lighting setting in the office workspace are very diverse and there are several types of luminaries, including: 1) square LED panel luminaries (Sq-LED); 2) round LED down light luminance (Ro-LED); and 3) luminaire concealed rectangular T5 fluorescent lamp (Re-T5) (Shieh & Lin, 2000). The types of luminaires also vary from the reflected colors and some previous researchers have analyzed the influence of light color on visual performance (Hwang et al., 2012; Chen et al., 2023; Shieh, 2000; Yu & Akita, 2019, 2023; Durmus, 2022). Previous research has shown that lighting factors that can describe feelings of brightness, spaciousness, privacy, comfort, and relaxation of very small spaces involving spatial displays, moods, and user conditions are correlated color temperature (CCT) and illuminance (Chen et al., 2023; Yu & Akita, 2023). The shape of the armature also has an impact on the reflection of light in the desktop, and also affects work activities or visual comfort (Veitch & Newsham, 2000; Chen et al., 2023).

In addition to considering visual performance and perception for users' productivity, lighting design should not only involve artificial lighting but also natural lighting that avoids glare, excessive brightness, and heat, thereby creating visual comfort for space users (Jamala et al., 2021). Natural light distribution in office workspaces influences visual performance, as excessive luminance and glare reduce comfort and task efficiency, requiring façade design to control daylight and illuminance levels (Jamala et al., 2023, 2024).

2.0 METHODOLOGY

This experiment on visual performance and perception was conducted at the Lighting Laboratory of the Department of Architecture, Faculty of Engineering, Hasanuddin University, Indonesia. The experiment took place in a mock-up office workspace equipped with a workbench layout as shown in Figure 1. The artificial lighting system consisted of 10 LED luminaires, with four directed downward to illuminate the desktop and six directed toward the surrounding walls (Fig. 1). The illuminance level was adjusted using a dimmer to ensure uniform lighting across all positions on the workbench. In the visual performance experiment, desktop illuminance was set at four levels: 100 lx, 200 lx, 350 lx, and 500 lx. A total of 54 respondents were instructed to identify word or sentence errors in a provided manuscript. Each respondent was given 3 minutes to complete a manuscript correction task consisting of 300 sentences. After each correction session, a 2-minute time lag is provided before the change of lighting conditions to allow the visual adaptation of the respondent's eyes to the next lighting conditions.

The number of errors detected by each respondent was analyzed to determine the most optimal illuminance level for task performance. The findings indicate that the fastest, most accurate, and most consistent task performance occurred at one of these illuminance levels.



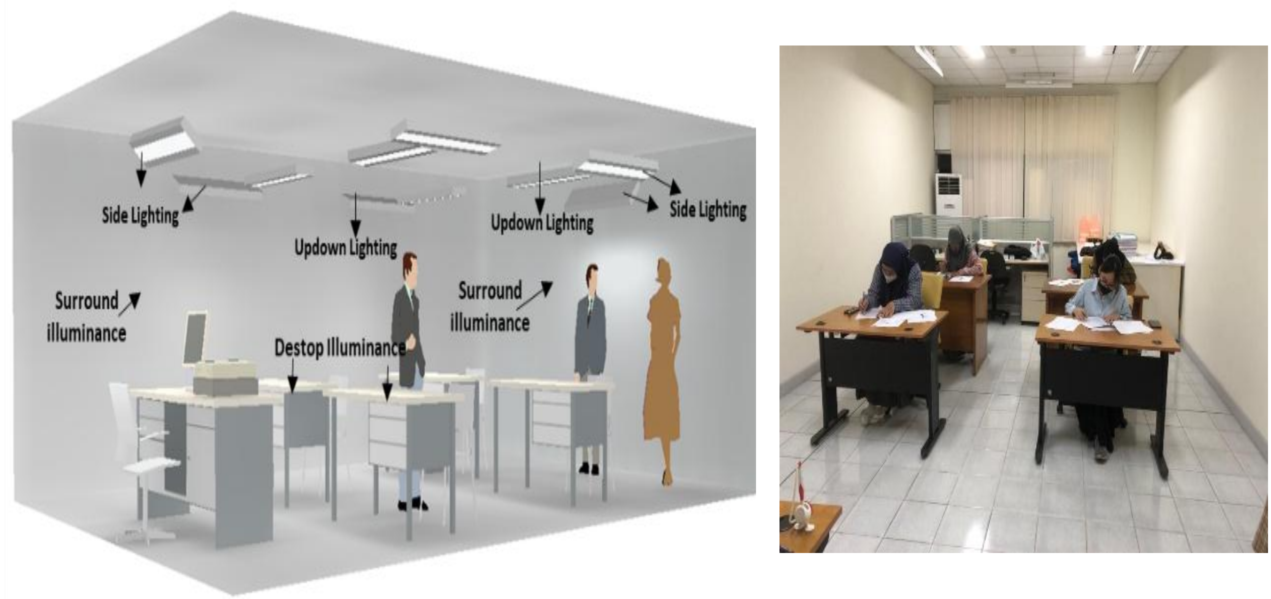
(a) (b)

Figure 1. Visual performance experiment: (a) Designed illuminance level at the desktop and (b) Respondents' correcting the manuscript

Figure 1(a) shows that all desktop positions have uniform task illuminance levels across the work surface for each test condition. Illuminance level varied across four levels; 100 lx, 200 lx, 350 lx and 500 lx, which were adjusted using dimmer on the side and down light to achieve the preset values. Figure(b) shows the respondents' activities while performing a manuscript correction task at each illuminance level. Testing was conducted in stages at each for the four-illuminance level to evaluate the effect of varying task illuminance on the respondents’ visual performance.

Furthermore, the lighting settings in the visual perception experiment were designed by arranging different illuminance ratios between the desktop and the surrounding workspace (the area around the space/wall). Five illuminance ratio models were tested: (a) Model 1 — 1:2 (100 lx : 200 lx); (b) Model 2 — 1:3.5 (100 lx : 350 lx); (c) Model 3 — 1:2 (200 lx : 400 lx); (d) Model 4 — 1:1 (200 lx : 200 lx); and (e) Model 5 — 1:1 (500 lx : 500 lx).

Under these five lighting conditions, respondents completed a questionnaire assessing visual comfort in the office workspace to determine the most suitable illuminance ratio. The questionnaire used a semantic differential scale, and prior to data analysis, validity and reliability tests were performed. The validated data were then analyzed using the Multi-Dimensional Scaling (MDS) method.



(a) (b)

Figure 2. Visual perception experiment: (a) Desktop and surrounding illuminance design and (b) Respondents’ activity vs. desktop/ surround illuminance ratio

Figure 2(a) illustrates the illuminance ratio settings of desktop and surround illuminance, while Figure 2(b) presents the repondents’ visual perception activities according to the workspace lingting settings. The respondents answered 15 questions based on five design settings of illuminance ratios in a workspace mock-up. The questionnaire responses were then categorized into four groups: spatial effect of space, space lighting, space comfort, and desktop illuminance. This analysis aimed to determine the respondents’ perception of the illuminance ratio settings that were most comfortable for performing activities in the workspace.

To ensure a clear link between the objectives, methods, and results of the research, the research is organized in several main stages. These stages include determining lighting conditions, conducting visual performance and visual perception experiments, and MDS analysis. The complete flow of the research is shown in the research chart in Figure 3.

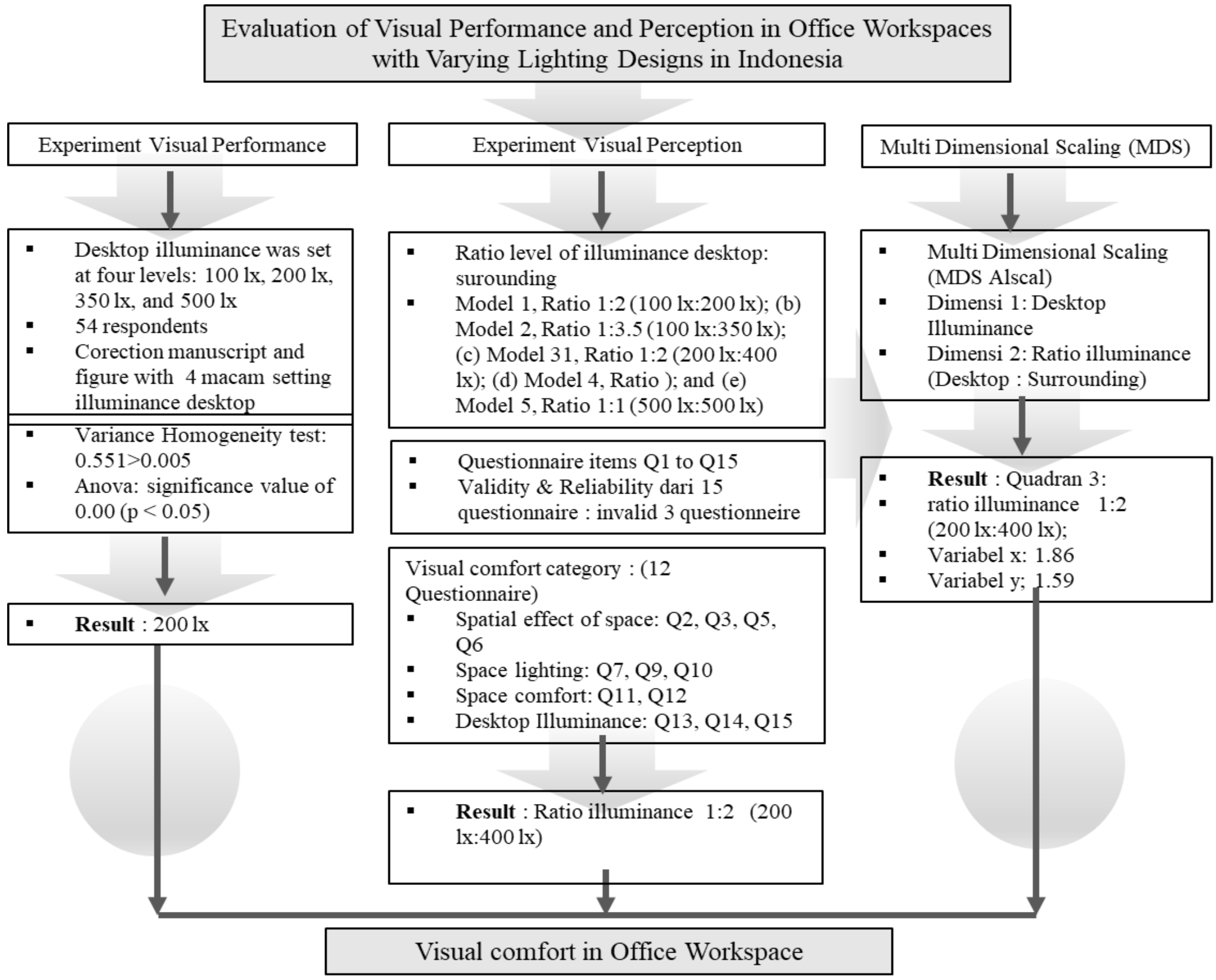


Figure 3. Research Chart

3.0 RESULTS AND DISCUSSIONS

3.1 Analysis of The Results of the Visual Performance Experiment

The visual performance experiment involved 54 respondents. Each respondent was instructed to read the manuscript, identify any incorrect words, and review the accompanying images. The activity was conducted for two minutes under each lighting condition. Four task illuminance levels on the work surface (desktop) were tested: 100 lx, 200 lx, 350 lx, and 500 lx. The manuscript was printed on white paper with a reflectance of 78%, while the text had a reflectance of 23% (concrete grey).

The desktop surface wa light brown (wood texture) with a reflectance of 52%. The typeface use in this study wa time new roman at 12 pt. The contrast value between the text and the background was calculated using the standard luminance contrast formula. For example, at an illuminance level of 100 lx, the contrast value is calculated as follows: $C = (24.84–7.32)/24.84 = 0.71$.

Before analyzing the diagram of the results of the script and image correction experiment, the Homogeneity of Variances test was carried out. Table 1 show that based on the results of statistical analysis, the variance homogeneity test showed a significance value of 0.151 ($p > 0.05$). These results indicate that the variance of data between groups is homogeneous, so the basic assumptions for conducting the ANOVA test have been met. Furthermore, the results of the ANOVA test on data involving 54 respondents showed a significance value of 0.00 ($p < 0.05$) (Table 2). These findings indicate a statistically significant difference between the illuminance values of 100 lx, 200 lx, 350 lx and 500 lx.

Table 1. Test of Homogeneity of Variances

Levene Statistic	df1	df2	Sig.
1.787	3	212	0.151

Table 2. Anova

	Sum of square	df	Mean Square	F	Sig
Between Groups	896.937	3	298.979	109.208	0.000
Within Groups	580.392	212	2.738		
Total	1477.329	215			

The diagram presents a comparative distribution of measured values under four different illuminance levels: 100 lx, 200 lx, 350 lx, and 500 lx (Figure 4). At 100 lx, the values appear relatively low and widely dispersed, indicating weaker and less uniform illuminance. In the 200 lx condition, the bars become noticeably higher and more consistent, suggesting improved lighting performance and greater stability. The desktop illuminance value of 350 lx shows moderately high values but with more variation compared to 200 lx. Meanwhile, at 500 lx, the distribution appears slightly lower and more irregular than the 350 lx condition, indicating a possible decline in uniformity at higher illuminance levels.

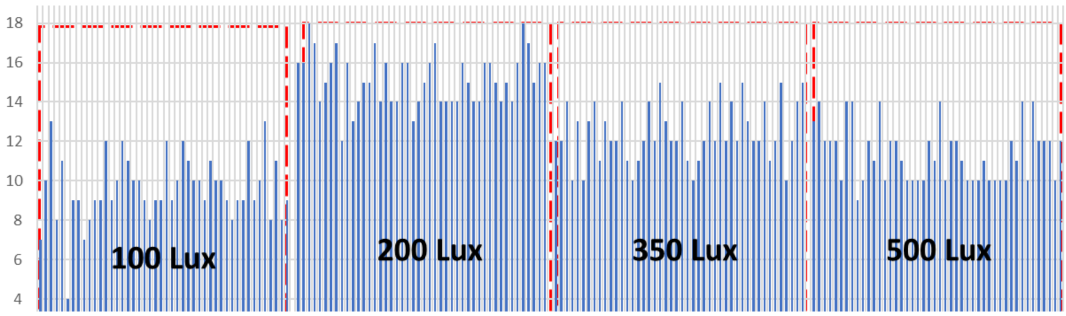


Figure 4. Script Correction Data Graph in Visual Performance Experiment

The results of the visual performance experiment showed that the highest average score occurred at the task illuminance level of 200 lx, reaching 15.07 points or the equivalent of 693 script corrections. In contrast, the lowest average score was recorded at 100 lx, with 9.52 points or 438 corrections (Figure 4).

The analysis indicates that respondents were able to perform correction tasks most effectively at an illuminance level of 200 lx. However, the illuminance level recommended by the Indonesian National Standard (SNI) for office workspaces is 350 lx.

3.2 Analysis of the Results of the Visual Perception Experiment

The analysis of the visual performance experiment results was conducted after completing the validity and reliability testing stages. The validity test aimed to assess the extent to which the questionnaire items accurately reflected the variables under investigation. In this study, the validity test was performed using the SPSS program on 15 questionnaire items across five different lighting conditions, each defined based on the illuminance ratio. The number of respondents in this study was 54 people ($N = 54$). With a significance level (α) of 0.05 and a degree of freedom ($df = N – 2 = 52$), a table t value of 1.662 was obtained.

The results of the validity test on the Q1 indicator in setting 1 show that the calculated t value is smaller than the t table, which is $1.473 < 1.662$. Therefore, H_0 is rejected and the Q1 indicator at setting 1 is declared invalid because it lacks a significant correlation. On the other hand, the results of the validity test on the Q2 indicator in setting 1 showed that the calculated t value was greater than the t table, which was $4.873 > 1.662$. Thus, H_0 cannot be rejected, which means that there is a significant positive correlation, so the Q2 indicator is declared valid. The full results of the validity test can be seen in Table 2, which contains a list of valid and invalid indicators at settings 1-5.

Table 3. Validity and Reliability Test Result

Quesioner	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15
Pearson Correlation	0.230	0.803	0.849	0.0295	0.887	0.804	0.645	0.268	0.402	0.772	0.394	0.851	0.462	0.629	0.574
Interpretasi Validitas	Invalid	Very Valid	Very Valid	Invalid	Very Valid	Very Valid	Quite Valid	Invalid	Less Valid	Valid	Less Valid	Very Valid	Quite Valid	Quite Valid	Quite Valid
Cronbach's Alpha if Item Deleted	-	0.81	0.79	-	0.83	0.81	0.83	-	0.85	0.82	0.85	0.83	0.84	0.83	0.83

Table 3 presents the results of the validity test for questionnaire items Q1 to Q15. From the results of the validity test on five different lighting conditions, it was found that the Q1 and Q8 items were invalid under all conditions. Item Q4 shows validity only on Setting 4 (200:200), and is invalid on the other four settings. Meanwhile, items Q2–Q3, Q5–Q7, and Q9–Q15 proved to be valid in almost all conditions, showing the consistency of respondents' perception of these aspects of the general limit of validity, namely: (a) Very Valid: > 0.70; (b) Sufficiently Valid: 0.40–0.70; and (c) Invalid: < 0.40. Next, a reliability test was carried out to measure the internal consistency of the research instrument. The reliability test uses the SPSS program and the high reliability is reflected in the coefficient value that is close to 1. Cronbach's Alpha coefficient is declared good if Cronbach's Alpha is 0.8-1.0 and in general, reliability is considered adequate if it has a value of ≥ 0.700

The results of the SPSS data test produced Cronbach's Alpha value of > 0.70 so that 12 questionnaires were declared valid and overall the statistical reability value was also stated to be satisfactory, which was 0.898 so that the entire questionnaire with a total of 54 respondents could be analyzed the data.

Furthermore, the visual perception analysis of office work was carried out only on valid questionnaires, namely as many as 12 questionnaires. The average value of the visual perception questionnaire is as shown in table 4 below.

Table 4. Average value of visual perception questionnaire data

Ratio desktop: surround illuminance	Q2 (low-high)	Q3 (Crowd -wide)	Q5 (Vertical-horizontal)	Q6 (Private-Public)	Q7 Unclear -clear)	Q9 (Blur-clear)	Q10 (Dim-Bright)	Q11 (Concern-relaxed)	Q12 (Discomfort -Comfort)	Q13 (Desktop Glare - Not glare)	Q14 (Desktop dim - bright)	Q15 (Desktop discomfort -comfort)	Average value	Visual perception
Setting 5 (500:500) lx	3.85	4.37	3.33	4.33	4.37	4.33	4.70	2.04	3.37	2.59	3.44	3.17	3.66	Inconvenient
Setting 4 (200:200) lx	2.91	2.93	3.07	3.26	3.19	3.19	3.04	3.19	3.07	4.57	4.31	4.31	3.42	Very Uncomfortable
Setting 3 (200:400) lx	4.09	4.33	3.93	4.48	4.59	4.26	4.63	4.00	4.37	4.56	4.26	4.33	**4.32**	**Very Convenient**
Setting 2 (100:350) lx	2.22	2.07	3.37	2.37	4.26	4.70	3.41	3.19	3.41	3.22	3.26	3.30	3.23	Very Uncomfortable
Setting 1 (100:200) lx	3.19	2.07	3.04	3.37	3.26	3.70	3.41	3.19	3.41	3.22	3.26	3.30	3.20	Very Uncomfortable

The average score of questionnaire answers was categorized qualitatively based on the highest (4.32) and lowest (3.20) score ranges with five levels of visual comfort perception as follows: (a) Very uncomfortable: 3.20–3.48; (b)Uncomfortable: 3.49–3.76; (c) Neutral: 3.77–4.04; (d) Comfortable: 4.05–4.10 and (e) Very comfortable: 4.11–4.32.

Table 4 presents the average score of each questionnaire item that has been grouped into the qualitative category. For example, the average value of 3.20 is in the "very uncomfortable" category (>3.20–3.48), so the respondents' perception of lighting conditions at setting 1 with a desktop illuminance to surround ratio of 100 lx: 200 lx can be said to be very uncomfortable. For more information, the distribution of the average scores of the 12 questionnaires for the five lighting settings can be seen in Figure 5 below.

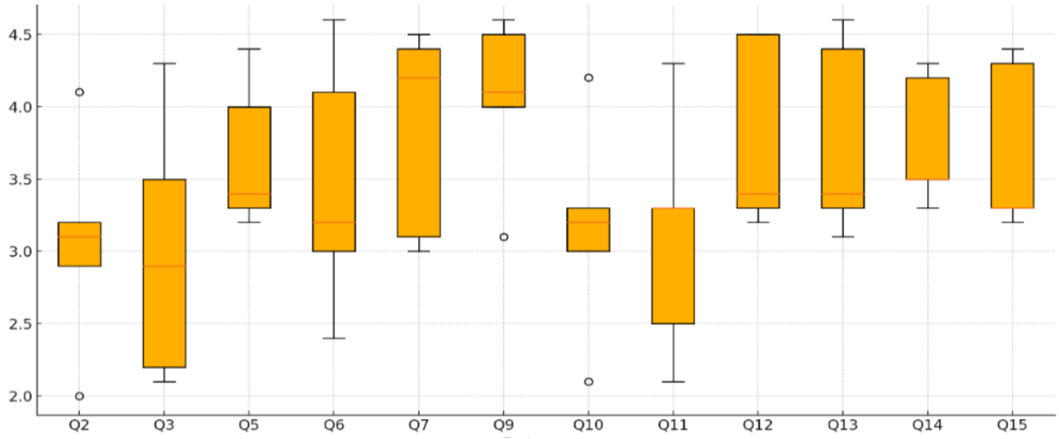


Figure 5. Graphics of distribution respondent questionnaire.

Table 5. Visual perception questionnaire data based on perception category

No.	Category questionnaire	Questionnaire	Visual comfort perception	Average maximum	Discomfort perception	Average minimum	Visual perception results
1	Spatial effect of space	Q2, Q3, Q5, Q6	Setting 3 (200: 400) lx	4,21	Setting 2 (100: 350) lx	2,51	Ratio 1: 2 gives a very comfortable spatial impression
2	Space lighting	Q7, Q9, Q10	Setting 3 (200: 400) lx	4,49	Setting 1 (100: 200) lx	3,46	High surround lighting enhances comfort
3	Space comfort	Q11, Q12	Setting 3 (200: 400) lx	4,19	Setting 5 (500: 500) lx	2,70	The most comfortable combination of 200 lx and 500 lx surround tasks
4	Desktop illuminance	Q13, Q14, Q15	Setting 3 & 4 (200: 400 & 200:200) lx	4,40 & 4,38	Setting 1 & 5 (100:200 & 100:500) lx	< 4,00	Task illuminance 200 lx most optimal

Table 5 present the visual perception questionnaire data grouped according to perception categories. The spatial impression analysis of the workspace was conducted by integrating four related perceptual questionnaires: high–low (Q2), crowded–wide (Q3), vertical–horizontal (Q5), and closed–open (Q6). The average results indicated that the lowest score, 2.92 (setting 1, ratio 1:2), was categorized as very uncomfortable, while the highest score, 4.21 (setting 3, ratio 1:2), was categorized as very comfortable. Overall, the lighting configuration with a desktop illuminance ratio of 200 lx: 400 lx provided the most favorable spatial perception.

The perception of room lighting was analyzed base on three questionnaire items: Q7, Q9, and Q10. The most comfortable condition was setting 3 (200 lx: 400 lx, 1:2 ratio), with an average score of 4.49, whereas the least comfortable was setting 4 (200 lx: 200 lx, 1:1 ratio), with an average score of 3.14. These findings suggest that higher surround illuminance enhances overall lighting comfort within the space.

Space comfort was assessed through the perception of relaxation (Q11) and general comfort (Q12). The highest score was observed in setting 3 (200 lx:400 lx), with an average of 4.19, while the lowest was recorded in setting 5 (500 lx: 500 lx), with an average of 2.70. These findings are consistent with the visual performance results, indicating that a desktop illuminance of 200 lx provides optimal comfort when paired with an appropriate level of surround illuminance. The perception of desktop lighting was measured using Q13, Q14, and Q15. The highest perception scores were obtained in setting 3 (200 lx: 400 lx) and setting 4 (200 lx: 200 lx), respectively. This indicates that a task illuminance level of 200 lx offers the greatest visual comfort compared to 100 lx or 500 lx, regardless of the surrounding illuminance ratio.

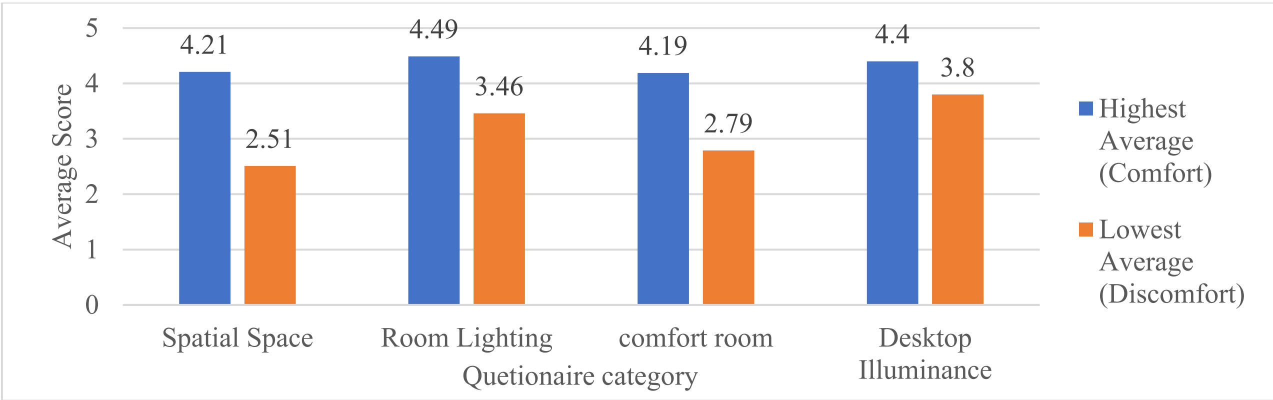


Figure 6. Comparison of visual perception questionnaire results (questionnaire category)

Figure 6 shows a comparison graph of respondents' average visual perception scores across four main aspects: spatial impression, spatial lighting, spatial comfort, and perception of desktop lighting (desktop illuminance). Each aspect was evaluated by comparing the most comfortable setting (highest average score) with the least comfortable setting (lowest average score).

The results of the analysis showed that setting 3 with a combination of 200 lx lighting in the desktop and 500 lx in the surrounding area (ratio 1:2) consistently provided the highest perception value in all aspects, especially in space lighting and space comfort. In contrast, setting 2 and 5, which involve extreme lighting of either too low (100 lx) and too high (400 lx), produces the most uncomfortable perception.

The analysis shows that setting 3, featuring a combination of 200 lx desktop illuminance and 400 lx surround illuminance (ratio 1:2), consistently produced the highest perception value across all aspects, particularly in spatial lighting and spatial comfort. In contrast, settings 2 and 5, which represent extreme lighting conditions, either too low (100 lx) or too high (400 lx), yielded the lowest comfort perceptions.

Overall, the graph reinforces the conclusion that optimal workspace lighting depends not only on the intensity of desktop illuminance but also on the balanced ratio between task and surround illuminance. A well-proportioned lighting ratio significantly enhances visual comfort, perceived lighting quality, and overall spatial impression.

3.3 Evaluation Multidimensional Scaling (Alscal) as Follows

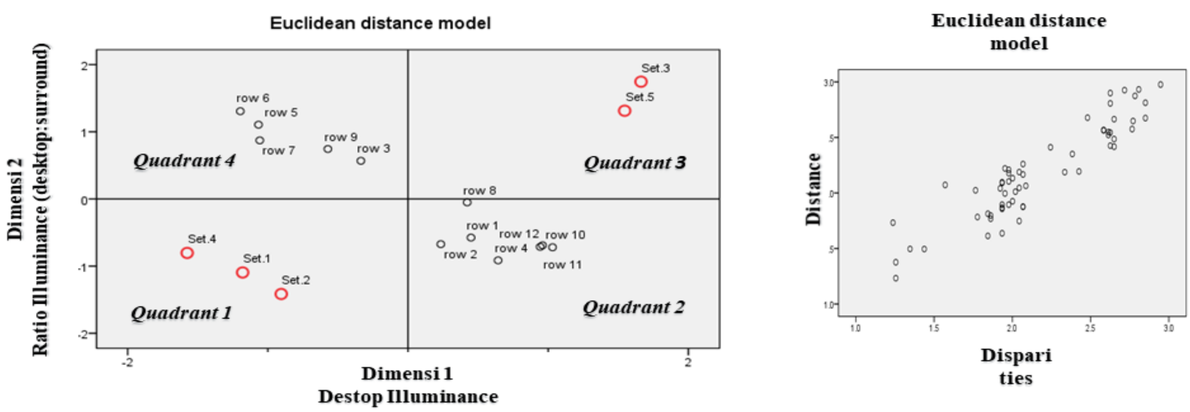


Figure 7. (a) Multi Dimensional Scaling (MDS Alscal) derived stimulus configuration and (b) Scatterplot of linear fit.

Visual perception analysis was conducted using MDS method with a two-dimensional Euclidean model. Dimension 1 represents task illuminance, while Dimension 2 reflects the illuminance ratio between desktop lighting and the surrounding area (Figure 7a). The linear-fit scatterplot shows several points that lie close to or converge with one another, indicating similarities in respondents' perceptions when evaluating the lighting settings of the workspace (Figure 7b).

The MDS analysis shows a clear spatial clustering of lighting conditions across the perceptual dimensions. Quadrant 3 represents the most favorable condition, as it is positioned closest to the attributes associated with higher visual comfort, better task performance, and balanced luminance distribution. This indicates that respondents consistently perceived this lighting configuration as both comfortable and supportive of visual tasks. Quadrant 3 can be interpreted as optimal because it reflects a balanced relationship between desktop illuminance and surrounding brightness ratio while maintaining adequate task visibility. The proximity of this quadrant to positive perceptual attributes suggests that this configuration provides the most stable and acceptable visual environment among the tested conditions.

Table 6. SPSS Data Dimensions X and Y (MDS Alscal)

Room lighting settings	Ratio illuminance (Desktop: Surround)				
	Setting 1 (100:200) lx	Setting 2 (100:350) lx	Setting 3 (200:400) lx	Setting 4 (200:200) lx	Setting 5 (500:500) lx
Dekstop illuminance (Dimension 1)	-1.23	-0.94	1.86	-1.65	1.67
Ratio illuminance (Dimension 2)	-0.95	-1.35	1.59	-0.56	1.12

Table 6 shows SPSS data for dimensions X and Y, namely setting 3 is a high positive illuminance ratio compared to other settings, namely Dimension 1 of 1.86 and dimension 2 of 1.59. The mapping results (Figure 11) show that Setting 3 (200 lx: 400 lx) is in quadrant 3 and is perceived as the most convenient setting. Setting 5 (500 lx: 500 lx) is also in the same quadrant, but with slightly lower comfort perception. In contrast, Settings 1, 2, and 4 are in quadrant 1, which indicates uncomfortable visual perception due to lighting imbalances.

The distribution of 12 questionnaires showed mixed perceptions. Questionnaires row 3, 5, 6, 7, and 9 were in quadrant 4, indicating a low perception of the illuminance ratio. Meanwhile, rows 1, 2, 4, 8, 10, 11, and 12 are in quadrant 2, with a more positive perception of the illuminance task. Some questionnaires in the same quadrant showed differences in perception, such as row 11 being more comfortable than others in quadrant 2. The results of the evaluation concluded that the most comfortable lighting setting was in setting 3, namely the illuminance ratio of 1:2 or 200 lx : 400 lx. Overall, these results confirm that visual comfort is influenced by a combination of task and surround illuminance, rather than by a single variable.

The MDS criteria are as follows: >20%: poor; (2) 10 - 20%: Fair; (3) 5 - 10%: Good; (4) 2.5 - 5%: Excellent; and (5) 0.0% Perfect. Based on the results of the MDS analysis, it can be seen that the stress level in the MDS analysis is 11.4% or Fair and RSQ (distance diversity in MDS) 98.85% or similarity is very good.

The design of lighting systems in office workspaces, as outlined in the Indonesian National Standard (SNI 03-6575-2001), recommends an artificial lighting level of 350 lx for office environments. Several previous studies have shown that even when desktop illuminance falls below this recommended value, users can still perform their tasks adequately. Building on these findings, the present study further examines visual comfort in office workspaces to strengthen the conclusions of earlier research. Visual comfort is achieved when users are able to perform their activities effectively, and beyond task performance alone, the overall sense of comfort within the space plays a crucial role in enhancing user productivity.

Visual comfort is determined by the illuminance levels at the desk and in the surrounding area. Although many previous studies have examined visual performance and visual perception, these investigations were often carried out separately. Even though some researchers have combined both aspects in a single study, their experimental procedures differ from the approach used in this research (Durmus, 2022). In this research, these two variables were combined and analyzed the level of comfort in the workspace by knowing the ratio illuminance of desktop: surround illuminance.

Visual performance research conducted a text correction experiment, reading on 4 changes in the illuminance value on the desktop to find out how many illuminances are very comfortable at work, previous research has also been done but with different experimental models (Janabi et al., 2011). This visual perception study concluded that the perception of space users will be comfortable if the immune value in the surroundings is higher than in the illumnance task (Sheedy et al., 2005; Pracki et al., 2020). Some previous research on visual perception has also been carried out, namely analyzing the spatial brightness perception ratio, but not comparing desktop and background illuminance (Duff et al., 2017), so it can be said that the results of this study are a new finding.

Some previous studies have relied solely on direct observations in existing office buildings, which prevented them from controlling or adjusting the artificial lighting conditions in the workspace (Richter et al., 2019). This research was conducted in the Building Science and Technology Laboratory (Lighting Laboratory), where the space can be configured as a mock-up of office workspace using dimmers. This aspect also represents a research novelty; although similar experimental models have been used previously, the configuration of the lighting settings on the desktop and surrounding areas in this study differs from earlier designs.

Many previous researchers have applied the SPSS MDS program using similarity assessments, but not within the context of artificial lighting. What is notable in this study is the ability to analyze the desktop illuminance levels and their relationship with the ratio between desktop and surrounding illuminance. Based on this experiment, the most comfortable illuminance ratio for users performing activities in office workspaces particularly in Indonesia can be identified.

The results of this study can serve as a reference for planning lighting systems in office workspace, as the identified illuminance levels were shown to support work productivity, even though they fall below the current recommendations of the Indonesian National Standard. Reducing the use of energy as a source of artificial lighting in office workspaces is a reference in designing energy-efficient buildings. Several previous studies have conducted similar studies, but with the difference that they affirm the importance of differentiating lighting predictors based on monitor type, lighting source, and classroom setting (Kong & Jakubiec, 2021), while other studies have shown that spatial lighting does not provide a significant difference in subjective health and performance aspects, although it does increase satisfaction with dynamic lighting (De Kort & Smolders, 2010). This research can serve as a foundation for further research on natural and artificial lighting in Indonesian office workspaces, and may also inform future revisions to lighting standard recommendations in Indonesia.

4.0 CONCLUSIONS

The novelty of this research lies in the formulation of the illumination ratio between the desktop area and the surrounding area (surround) in the workspace through a comprehensive experimental approach. The study not only evaluated visual performance quantitatively but also integrated it with visual perception experiments. Furthermore, the results of visual perception were strengthened through the analysis of questionnaire data using MDS method.

This study shows an approach to assessing visual comfort in office workspaces in Indonesia through two main methods, namely visual performance experiments and visual perception. Assessments are carried out on space users' activities such as reading, writing, and correcting images, taking into account the illuminance in the desktop (*task illuminance*) and the lighting ratio between the desktop and its surroundings (*surround illuminance*). The results of the visual performance experiment showed that the most optimal lighting level for work activities was at 200 lx. Meanwhile, the visual perception experiment, which was categorized into four questionnaire groups, namely: (1) Spatial impression of space; (2) Perception of the space lighting system; (3) Perception of comfort of space; and (4) Perception of comfort on desktop illuminance and analysis results show that the best lighting ratio is 200 lx: 400 lx. This setting was consistently perceived to be the most comfortable by respondents compared to other illuminance ratio comparisons.

Furthermore, the results of MDS analysis also corroborate the previous findings. Setting 3 (200 lx : 400 lx) is located in the quadrant that shows the highest perception, both in the dimensions of the comfort of the lighting of the room (Dimension 1) and the ratio of illuminance (Dimension 2). Although Setting 5 (500 lx: 500 lx) is in the same quadrant, the perception of comfort is lower. This indicates consistency between the results of visual performance, visual perception, and MDS experiments.

Thus, the results of this research can be used as the basis for designing artificial lighting systems in office workspaces, especially in the context of climate and work habits in Indonesia. The use of 200 lx task illuminance with a surround ratio of 400 lx (Ratio illuminance 1:2) is recommended as a design guide to support visual comfort and performance of space users.

ACKNOWLEDGEMENT

This research was conducted as part of the Collaboration Fundamental Research program, funded by the Institute for Research and Community Service, Hasanuddin University, in Fiscal Year 2024 (Grant Number 02993/UN4.22/PT.01.03/2024). The authors sincerely thank the reviewers for for their valuable comments and suggestions, which improved this paper.

5.0 REFERENCES

Boyce, P. R., Veitch, J. A., Newsham, G. R., Jones, C. C., Heerwagen, J., Myer, M., & Hunter, C. M. (2006). Lighting quality and office work: Two field simulation experiments. Lighting Research and Technology, 38(3), 191–223. https://doi.org/10.1191/1365782806LRT161OA

Boyce, Peter Robert. (2014). Human factors in lighting, third edition. Human Factors in Lighting, Third Edition, 1–666. https://doi.org/10.1201/B16707

Boyce, P. R., Eklund, N. H. & Simpson, S. N. (2000) 'Individual lighting control: Task performance, mood, and illuminance', Journal of the Illuminating Engineering Society, 29(1), pp. 131–142. doi: 10.1080/00994480.2000.10748488

Chen, R., Tsai, M. C. & Tsay, Y. S. (2022) 'Effect of Color Temperature and Illuminance on Psychology, Physiology, and Productivity: An Experimental Study', Energies. MDPI, 15(12). doi: 10.3390/en15124477

Chen, T., Wang, L., Li, Y., Chen, P., & Yu, J. (2023). Modeling perceptions of very small space in physical dimension: Effect of the form of line light-emitting units with preference. Building and Environment, 228. https://doi.org/10.1016/J.BUILDENV.2022.109803

De Kort, Y. A. W. & Smolders, K. C. H. J. (2010) 'Effects of dynamic lighting on office workers: First results of a field study with monthly alternating settings', Lighting Research and Technology. SAGE Publications Ltd, 42(3), pp. 345–360. doi: 10.1177/1477153510378150

De Vries, A., Souman, J. L., de Ruyter, B., Heynderickx, I., & de Kort, Y. A. W. (2018). Lighting up the office: The effect of wall luminance on room appraisal, office workers' performance, and subjective alertness. Building and Environment, 142, 534–543. https://doi.org/10.1016/j.buildenv.2018.06.046

Duff, J., Kelly, K. & Cuttle, C. (2017) 'Spatial brightness, horizontal illuminance and mean room surface exitance in a lighting booth', Lighting Research and Technology. SAGE Publications Ltd, 49(1), pp. 5–15. doi: 10.1177/1477153515597733.

Durmus, D. (2022) 'Correlated color temperature: Use and limitations', Lighting Research and Technology. SAGE Publications Ltd, 54(4), pp. 363–375. doi: 10.1177/14771535211034330.

Han, L., Zhang, H., Xiang, Z., Shang, J., Anjani, S., Song, Y., & Vink, P. (2021). Desktop lighting for comfortable use of a computer screen. Work, 68(s1), S209–S221. https://doi.org/10.3233/WOR-208018

Hwang, T., Lee, D. G. & Kim, J. T. (2012) ‘Optimal illuminance of seven major lighting colours in LED: Focus on occupant comfort and communication in an indoor environment’, Indoor and Built Environment, 21(1), pp. 122–128. doi: 10.1177/1420326X11420013.

Indonesian National Standard (SNI 03-6575-2001), Procedures for designing artificial lighting systems, https://www.scribd.com/document/654836671/dokumen-tips-sni-03-6575-2001

Indonesian National Standard (SNI 03-6197-2020), Energy Coservation in lighting systems, Badan Stadarirasi Nasional BSN 2020, https://iai-jatim.com/wp-content/uploads/2023/11/SNI-6197_2020-Konservasi-Energi-Pada-Sistem-Pencahayaan.pdf

Jamala, N., Rahim, R., Ishak, T., & Mohamad Shukri, S. (2021). The Analysis of the Illuminance Level in the Workspace, Using Natural and Artificial Lighting in Graha Pena Building in Makassar, Indonesia. In Journal of Design and Built Environment (Vol. 21).

Jamala, N., Hamzah, B., Mulyadi, R., & Cahyani, I. (2023). The Architectural Design of Building Façade Models Related to Optimizing Daylight Distribution. Journal of Daylighting, 10(1), 60–71. https://doi.org/10.15627/jd.2023.5

Jamala, N., Rahim, R. & Kusno, A. (2024) The Façade Model Effect on the Distribution on Daylight in Buildings. AIP Conf. Proc. 2838, 030005 (2024), https://doi.org/10.1063/5.0186073

Janabi-Sharifi, F. & Vakanski, A. (2011) ‘Analysis of visual acuity and motion resolvability as measures for optimal visual perception of the workspace’, Applied Ergonomics. Elsevier, 42(3), pp. 473–486. doi: 10.1016/J.APERGO.2010.09.008.

Kong, Z. & Jakubiec, J. A. (2021) ‘Evaluations of long-term lighting qualities for computer labs in Singapore’, Building and Environment. Elsevier Ltd, 194. doi: 10.1016/J.BUILDENV.2021.107689.

Konstantzos, I. et al. (2020) ‘The effect of lighting environment on task performance in buildings – A review’, Energy and Buildings. Elsevier Ltd, 226. doi: 10.1016/J.ENBUILD.2020.110394.

Lee, J. H., Moon, J. W. & Kim, S. (2014) ‘Analysis of Occupants’ Visual Perception to Refine Indoor Lighting Environment for Office Tasks’, Energies. Multidisciplinary Digital Publishing Institute (MDPI), 7(7), pp. 4116–4139. doi: 10.3390/en7074116.

Mills, P. R., Tomkins, S. C. & Schlangen, L. J. M. (2007) ‘The effect of high correlated colour temperature office lighting on employee wellbeing and work performance’, Journal of Circadian Rhythms, 5. doi: 10.1186/1740-3391-5-2.

Pracki, P., Dziedzicki, M. & Komorzycka, P. (2020) ‘Ceiling and wall illumination, utilance, and power in interior lighting’, Energies. MDPI AG, 13(18). doi: 10.3390/EN13184744.

Richter, H. O., Sundin, S. & Long, J. (2019) ‘Visually deficient working conditions and reduced work performance in office workers: Is it mediated by visual discomfort?’, International Journal of Industrial Ergonomics. Elsevier B.V., 72, pp. 128–136. doi: 10.1016/j.ergon.2019.05.007.

Safa Achour Younsi et al., (2022) ‘A Proposal to Mitigate Energy Consumption through the Sustainable Design Process in tunis’, Journal of Contemporary Urban Affairs, vol 22, page 193-205.

Sheedy, J. E., Smith, R. and Hayes, J. (2005) ‘Visual effects of the luminance surrounding a computer display’, Ergonomics, 48(9), pp. 1114–1128. doi: 10.1080/00140130500208414.

Shen, I. H., Shieh, K. K., Chao, C. Y., & Lee, D. S. (2009). Lighting, font style, and polarity on visual performance and visual fatigue with electronic paper displays. Displays, 30(2), 53–58. https://doi.org/10.1016/j.displa.2008.12.001

Shieh K & C. Lin (2000) ‘Effects of screen type, ambient illuminance, and color combination on VDT visual performance and subjective preference’, vol. 26, pp. 527–536.

Veitch, J. A. & Newsham, G. R. (2000) 'Preferred luminous conditions in open-plan offices: Research and practice recommendations', Lighting Research & Technology, 32(4), pp. 199–212. doi: 10.1177/096032710003200404.

Veitch, J. A. and Newsham, G. R. (1996) 'Determinants of Lighting Quality II: Research and Recommendations'. National Research Council of Canada, https://nrc-publications.canada.ca/eng/view/object/?id=437024b7-c483-4b53-9909-aa0f16e81379.

Viitanen, J., Lehtovaara, J., Tetri, E., & Halonen, L. (2013) 'User preferences in office lighting: A case study comparing LED and t5 lighting', LEUKOS - Journal of Illuminating Engineering Society of North America, 9(4), pp. 261–290. doi: 10.1582/LEUKOS.2013.09.04.003.

Vink, P., Anjani, S., Smulders, M., & Hiemstra-van Mastrigt, S (2017) 'Comfort and discomfort effects over time: the sweetness of discomfort and the pleasure towards of the end', 1st International Comfort Congress, (December), pp. 8–12.

Wei, M., Houser, K. W., Orland, B., Lang, D. H., Ram, N., Sliwinski, M. J., & Bose, M. (2014) 'Field study of office worker responses to fluorescent lighting of different CCT and lumen output', Journal of Environmental Psychology. Academic Press, 39, pp. 62–76. doi: 10.1016/j.jenvp.2014.04.009.

Yu, H. & Akita, T. (2019) 'The effect of illuminance and correlated colour temperature on perceived comfort according to reading behaviour in a capsule hotel', Building and Environment. Elsevier Ltd, 148, pp. 384–393. doi: 10.1016/j.buildenv.2018.11.027.

Yu, H. & Akita, T. (2023) 'Effects of illuminance and color temperature of a general lighting system on psychophysiology while performing paper and computer tasks', Building and Environment. Elsevier Ltd, 228. doi: 10.1016/j.buildenv.2022.109796.