Luminance Ratio of Office Lighting on Perceived Visual Comfort: Insights from Office Interiors in Jakarta, Indonesia

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Abstract

One of the key factors influencing the quality of architectural and interior lighting is luminance (cd/m2), which represents the amount of light reflected or transmitted from a material. Office workers primarily focus their attention on computer screens or the work surfaces of their desks for various tasks, with the interior wall treatment serving as the common backdrop for their visual field. The ratio of luminance levels between the line of sight of the workers define the experienced lighting contrast. However, field studies evaluating different lighting qualities and the lighting contrast related to perceived visual comfort from the workers' points of views are scarce. This research evaluates how the differences in light contrast (low luminance ratio vs high luminance ratio) affects the visual performance and visual clarity of office workers.

The research employed an experiment as a research methodology involving tasks with office workers. The respondents included 40 workers from the creative divisions in two different offices with notable differences in lighting ambiance: one with a bright interior color scheme and general lighting, and the other with muted colors and more accentuated lighting. Luminance ratios between the computer screens, working areas, workstations, and backgrounds of each respondent, as well as the positions of their workstations within the office layouts, were measured. Moreover, subjective responses regarding perceived visual performance and clarity were evaluated.

The study shows that a high luminance ratio exceeding one-third in the worker's line of sight resulted in decreased visual performance and visual clarity. The adverse impact was observed in office environments with muted interior colors and a dominant use of accent lighting. The findings have proven beneficial for office stakeholders and serves as a valuable reference for lighting designers creating optimal working environments.

Keywords: Interior Lighting, Office, Luminance Ratio, Visual Performance, Visual Clarity. Interior Ambience.

Introduction

Building man-made physical realities are becoming integral to everyday life, constituting about ninety percent of total human existence (Dilani, 2005). Space, as a fundamental element in architecture, plays a crucial role in mediating the interactions between the built environment and individuals due to its function as a venue for human activities (Fuadiyah, Radja and Harisah, 2023). Interactions with the physical environments stimulate the five human senses: sight, hearing, touch, taste, and smell. Designers play a crucial role in manipulating stimuli from the physical environment to meet functional and aesthetic goals (Al-Olaimat et al. 2024). Prolonged exposure to physical environmental conditions significantly affects physical, physiological, and psychological aspects. Dilani (2005) shows that these conditions influence the development of a lifestyle, shaping habits and impacting health.

Human health, defined as a state of physical, psychological, and social well-being, is more than just the absence of disease. According to this perspective, psychological and social well-being is equally important to physical well-being and is linked to the lifestyle of individuals within man-made environments. In fact, Vischer (2005), point out that those with an urban lifestyle, such as workers in capital cities, often develop predictable habits due to a demanding work schedule, spending up to one-third of their lives in the workplaces. In cities with heavy traffic, workers may even adopt early starts and late departures to avoid traffic congestions, resulting in extended hours in the offices. During this prolonged time in the workspaces, external factors can provide stimuli that, if not aligned with individual needs and desires, may adversely affect physical and psychological well-being, potentially elevating stress levels (Broadbent, 1971).

Thus, in this context, this study evaluates how the differences in lighting ambience (low luminance ratio vs high luminance ratio) in actual office environments could affect subjective responses of visual performance and visual clarity. Its aim is to

Its objectives are:

- To provide novelty on clarification of lighting criterion that support visual performance and clarity among creative workers,
- To provide both objective measurement and subjective reports.
- To also also reveal the location of their workstation in office layout related to their responses.

Theoretical Framework

Ergonomists have identified environmental stressors, including temperature, noise, and lighting, as crucial factors to be considered (Broadbent, 1971). In this connection, Lamb and Kwok (2016) report the most significant decline in performance and individual stress was associated with inappropriate lighting, although the exact cause remains unspecified in their study. Kerkhof (1999), as cited in Van Bommel and Van den Beld (2004), reveals that groups of workers exposed solely to artificial light experience higher stress levels compared to those receiving a combination of artificial and natural light. In an open plan office layout, employees seated farther from openings may not receive sufficient daylight and rely on artificial lighting. Therefore, the implementation of artificial lighting plays a crucial role in open plan office settings. General lighting ensures an evenly illuminated room, while accentuated lighting creates highlights in specific areas. Combined with the choice of colors for interior treatments, these lighting strategies contribute to the overall ambiance of a space.

According to Steffy (2008), interior lighting impacts subjective evaluations, including perceived visual performance and visual clarity. Perceived visual performance refers to the user's perception of how quickly and accurately visual information is processed. It functions as a remote sensing system, allowing people to recognize their surroundings based on the amount of light that reaches the retina of the eye. While visual clarity is defined as the user's perception of how well the appearance of the atmosphere of a room, including objects and interior details, facilitates the recognition of other people (Steffy, 2008), Both visual preference and visual clarity contribute to determining the visual comfort associated with architectural lighting

Luminance (cd/m2) is the amount of light reflected or transmitted from a material. According to Steffy (2008), lighting captured by users is the luminance of various objects around them. Among the four photometric measures; luminous flux, intensity, illuminance, and luminance, luminance is the one most strongly associated with the way the human eye perceives light (Rockcastle and Andersen, 2014). It is the sole measure capable of conveying visual discomfort. Thus, the measurement of the quality of interior lighting is determined more by the luminance value.

Review of Literature

Numerous prior studies have explored the effects of luminance on occupants' perceptions, preferences, and working performance. Rockcastle and Andersen (2014), examine luminance level variations evaluated in rendering images of daylit architecture, illustrating hourly and seasonal fluctuations in contrast composition. They show that higher wall luminance significantly enhanced room appraisal, subsequently influencing the subjective alertness of observers (de Vries et al., 2018) and facilitating concentration on tasks (Van Ooyen, Van De Weijgert and Begemann, 1987). Moreover, the distribution of luminance across an occupant's field-of-view was found to influence user preferences (Tiller, DK and Veitch, 1995). Importantly, the amount of daylight intensity entering a room at a specific height may not always have a positive effect and could lead to glare. Factors such as color contrast and brightness play a crucial role in determining the degree of eye fatigue.

Unfortunately, however, none of the abovementioned studies has evaluated the luminance ratio or lighting contrast from the points of views of the workers. Moreover, its evaluation on actual office setting is scarce.

Research Methods

This research employs case study as a research method. Two architectural and interior consulting offices (Office A and B) specializing in creative works in Jakarta, Indonesia were chosen as the case studies. Both offices are well-established in Jakarta and have a creative division consisting of designers, architects, and drafters. This division was selected due to its extended working hours, frequent time constraints, and exposure to high-stress levels associated with tight deadlines. The respondents include creative division workers aged 25-40 years, known for their productivity and good visual health (IESNA, 2000). All the respondents with visual impairments wear corrected lenses and are not color-blind. Each office has 20 staff members occupying individual workstations in an open-plan office setting. The choice of an open-plan office setting is deliberate, given its tendency to present more complex issues, such as variable natural light distribution and privacy concerns among workers. Both offices are situated in different high-rise buildings, each exceeding the 10th floor, to capture potential glare effects. Measurements in Office A and B are taken on separate days under similar weather conditions.

Office A uses fluorescent-warm white lighting with general distribution and bright-colored interior treatment, while the Office B employs halogen-yellow light with dominant accent lighting distribution. Interior treatment of Office B featured muted colors with a focus on accent lighting (Fig. 1). The office area is categorized into daylight and less-daylight zones based on the observations of sunlight presence in a lights-off condition at 10 AM.

Each office has twenty respondents, identified, and coded based on their workstation positions (Fig. 2). Respondents A01-A10 and B01-B10 occupy the workstations in the daylight and less-daylight areas, respectively. Half of the respondents are measured at 10 AM (A01-A05 and B01-B05), while the others are measured at 3 PM (A06-A10 and B06-B10) to observe the effects of varying daylight intensity.

a b

Fig. 1: Open plan office Image in (a) Office A and (b) Office B
Source: Author, 2023

a)

b)

Fig. 2: Workstation layout and respondent seating position of (a) Office A and (b) Office B
Blue colored workstation indicates the workstation area with less daylight exposure.
Source: Author, 2023

Objective Measurement

This study places emphasis on the contrast or luminance ratio between the most frequent points of view during work: the computer screen, working area, workstation, and background or interior wall (Fig. 3). To measure the luminance of light reflected by these points, a Luminance meter (MACAM) was employed to calculate the ratio of light. Luminance measurements were taken three times for each point, and the values were averaged to obtain an objective measurement. The luminance measurements are conducted twice, at 10:00 and 15:00, for both the daylight and less daylight areas. These specific times are chosen due to the high intensity of daylight entering the room from different directions. The ratio between points is crucial to determine the proportion of brightness levels, specifically: Luminance of Computer Screen-to-Working Area (LC:LWA), Computer Screen-to-Workstation (LC:LWS), and Computer Screen-to-Background (LC:LB).

Fig. 3: Points of Luminance Measurement
Source: Author, 2023

Subjective Measurement

Along with objective measurements of lighting, collect subjective responses on Visual Performance and Visual Clarity are also obtained addressing related statement to their condition (Steffy, 2008). Participants responded to a questionnaire prepared in a seven-point Likert scale with the higher score defining the more comfortable conditions. Respondents filled out a questionnaire at the same time the measurement of luminance. Data of subjective responses were evaluated by descriptive analysis and qualitatively compared to the lighting luminance data to evaluate effects of luminance on user's visual and psychological comforts.

Results and Discussion

Luminance Level

Luminance measurements were taken on the computer screen (LC), working area (LWA), workstation (LWS), and background (LB) at both 10:00 and 15:00 for the respondents in both the daylight and less-daylight areas. The luminance level data for both the Office A and B is presented in Table 1. Notably, the luminance levels of the working area in Office B were significantly lower than those in Office A across all the groups. High standard deviations indicate wide data variation within the groups, possibly influenced by seating positions in the office.

In Office A, luminance levels were lower at 15:00 compared to those at 10:00, attributed to reduced daylight intensity in the evening. This change aligns with the understanding that the brightness, direction, and color spectrum of daylight evolve with fluctuations in the time of day (Leslie, 2003). Interestingly, Office B exhibited the opposite pattern, with luminance levels at measurement points being higher at 15:00 compared to those at 10:00. This suggests that Office B, with its dominant use of accent lighting and muted interior color, tends to create a low-lit office room. Consequently, as daylight intensity decreased, the office room became darker, resulting in recorded luminance levels on the computer screen being higher than its surroundings.

Table 1: Average of Luminance Level of each Measurement Points
Source: Author

		Average of Luminance (cd/m2)			
		LC	LWA	LWS	LB
Office A	A_Daylight Area_10:00	94,9 ± 34,8	80,3 ± 53,6	48,3 ± 36,7	77,4 ± 67,7
	A_Daylight Area_15:00	30,3 ± 17,9	53,0 ± 35,4	32,8 ± 20,1	38,8 ± 21,1
	A_Less Daylight Area_10:00	64,3 ± 44,3	89,2 ± 8,9	30,3 ± 11,7	59,2 ± 51,2
	A_Less Daylight Area_15:00	29,2 ± 16,4	35,6 ± 21,6	25,2 ± 17,8	27,1 ± 11,0
Office B	B_Daylight Area_10:00	36,8 ± 15,4	5,0 ± 3,1	28,9 ± 33,3	110,6 ± 86,2
	B_Daylight Area_15:00	49,8 ± 26,0	18,6 ± 16,3	49,2 ± 37,6	57,7 ± 38,4
	B_Less Daylight Area_10:00	17,8 ± 12,5	5,9 ± 4,2	35,7 ± 20,9	35,7 ± 20,9
	B_Less Daylight Area_15:00	93,9 ± 15,4	52,3 ± 26,5	28,3 ± 20,2	26,8 ± 20,0

Values are presented in mean ± standar deviation

Luminance Ratio

Luminance ratio is crucial for determining the proportion of brightness levels at predominant viewpoints during work (Boubekri, 1995; Geerdinck, Van Gheluwe and Vissenberg, 2014). In this study, the evaluated viewpoints were the Luminance of Computer Screen-to-Working Area (LC:LWA), Computer Screen-to-Workstation (LC:LWS), and Computer Screen-to-Background (LC:LB) for each participant. Figure 4 illustrates the average luminance ratio between LC:LWA, LC:LWS, and LC:LB for each respondent category in he Offices A and B. The data shows that the luminance ratio in the Office B, which employed non-uniform lighting, was notably higher than in the Office A at all the measurement points.

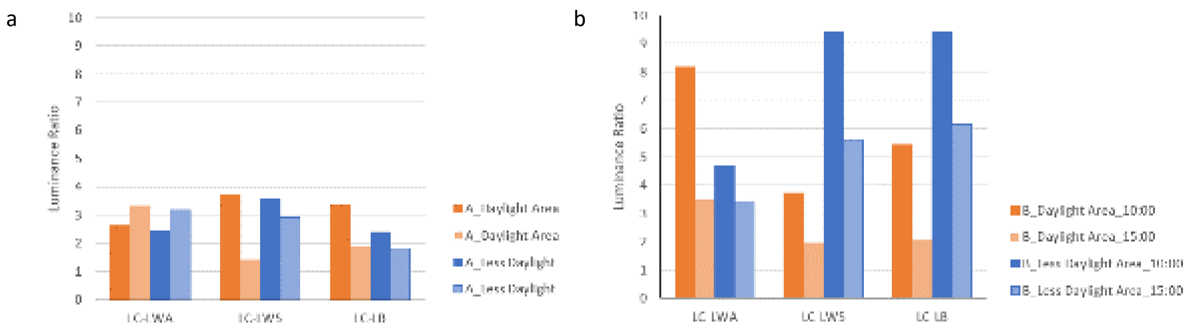

Fig. 4: Average of Luminance Ratio in a) Office A and b) Office B
Luminance ratio between Computer Screen-to-Working Area (LC:LWA), Computer Screen-to-Workstation (LC:LWS), and Computer Screen-to-Background (LC:LB) for each respondent category in Office A and B.
Source: Author, 2024

The highest contrast in Office A was observed between Computer Screen-to-Workstation (LC-LWS) for the participants seated in the Daylight Area and Less Daylight Area at 10:00. Considering the layout, the contrast between the computer screen and workstation (including the partition or background behind the computer screen) was influenced by the moderate intensity of daylight reflected by neighboring buildings. This reflection on the computer screen increased the luminance value. However, in general, Office A exhibited relatively equal luminance ratios at all measured points, with a luminance ratio of about 1:3, indicating low lighting contrast. Contrary, lighting in Office B resulted in higher luminance ratios compared to Office A, ranging from 1:3 up to 1:9. Specifically, the highest contrast in Office B was found between Computer Screen-to-Workstation (LC-LWS) and Computer Screen-to-Background (LC-LB) for participants seated in the Less Daylight Area at 10:00. Respondents in Office B who were seated in the less daylight area depended on halogen lighting placed above their seating positions. The dark surroundings color and lower intensity of daylight caused a high contrast between the measured points.

The data indicates that the Office B, characterized by a dominant use of accentuated lighting distribution and muted interior color, created a high luminance ratio, especially in the less daylight area. This higher luminance ratio between points of view can lead to discomfort glare when the eyes adapt to the notable difference in luminance levels between each point of view (Boubekri, 1995). According to the IESNA, to mitigate the impact of transient adaptation, luminance ratios between a task and its immediate surroundings should not exceed one to three (1:3) (Kaufman, John E and Haynes, 1981). Additionally, Van Ooyen et al. (1987) has suggested a preferred luminance ratio between the computer screen and the background/wall luminance of 4:3 to reduce the contrast. The observed luminance ratios in the Office A met the lighting standard in avoiding discomfort glare. However, in the Office B, the luminance ratios were considered high, indicating a lighting contrast. This phenomenon aligns with a recent study showing that a non-uniform lighting distribution leads to higher luminance ratios or lighting contrast (Geerdinck, Van Gheluwe and Vissenberg, 2014).

Visual Performance and Visual Clarity

The average luminance level in the visual field is closely related to the perception and visual comfort criteria (Bodmann, 1967). The research further explorees how the obtained luminance ratio in the workstations of workers in both offices may correlate with their perceived visual performance and clarity. The average data of subjective responses for each variable in the Offices A and B is presented in Figure 5. It is evident that the perceived visual clarity of the respondents in all the categories in the Office A is higher than in the Office B. In the Office A, workers experienced a decrease in visual clarity as the measured time progressed, with slightly reduced visual clarity at 15:00 compared to 10:00. This result is predictable, as light intensity is a primary factor influencing visual clarity in lighting (Bennett, 1984). The decrease in daylight at 15:00 likely reduced the total lighting intensity, impacting the clear appearance of the room's atmosphere, including objects and interior details.

The visual performance data for the Office B had average scores relatively similar to those in Office A. Interestingly, workers in the Office B perceived more satisfaction in visual performance at 15:00 compared to 10:00. Additionally, they reported better visual clarity at 15:00, with notably lower satisfaction scores than those in Office A. This suggests that evening daylight was preferable in a relatively dark interior with dominant accent lighting, as observed in Office B. Dawn daylight has lower intensity and warmer color than in the morning or noon (Knoop *et al.*, 2020), resulting in no significant difference in luminance between the room color and reflected lighting from surfaces. It is pertinent to a recent systematic review that identified diverse factors affecting 'Visual Comfort' within the luminous environment, including environmental factors such as the quality of light, color, and temperature of light (Dhayal and Jha, 2023). Therefore, the specification of office artificial lighting is crucial in determining workers' visual comfort. It is certain that an office with a low luminance ratio resulted in higher satisfaction in perceived visual performance and visual clarity, owing to the lack of glare.

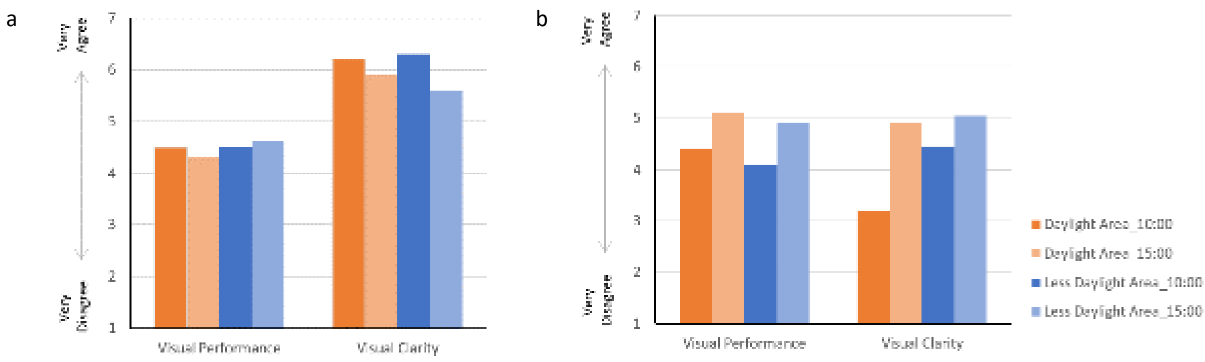

Fig. 5: Average of Perceived Visual Performance and Clarity of a) Office A and b) Office B
Source: Author, 2024

Figure 6 presents the direct relationship between luminance ratios obtained for Luminance of Computer Screen-to-Working Area (LC:LWA), Computer Screen-to-Workstation (LC:LWS), and Computer Screen-to-Background (LC:LB) with Perceived Visual Performance and Visual Clarity of combined respondents in Office A and B. Figure 7 shows that most of the data were clustered in the upper-left part of the graph, while other data spread more into the lower-right parts. This suggests that subjects who predominantly reported good visual performance and visual clarity experienced luminance ratios below 1:3 in all measured viewing points. Moreover, higher luminance ratios led to more adverse results in visual performance compared to visual clarity. The correlation was evident in the luminance ratios between the computer screen and working area (LC-LWA) and the computer screen and background (LC-LB), known as the frequent gazing points while working (de Vries et al., 2018).

Data outliers were found in the relation graph between visual performance and clarity with the luminance ratio of the computer screen and workstation (Error! Reference source not found.b). This might be due to the position of specific respondents affected by reflected daylight from neighboring buildings. These data show that some respondents experiencing high luminance contrast still perceived good visual performance and clarity. Interestingly, these responses were reported by those seated in the daylight area, close to the window. Studies on discomfort glare resulting from high luminance from daylight or electric lighting suggest a higher tolerance when mild discomfort glare is associated with daylight (Knoop *et al.*, 2020). This explains why respondents seated in close proximity to windows perceive high luminance contrasts as less disturbing.

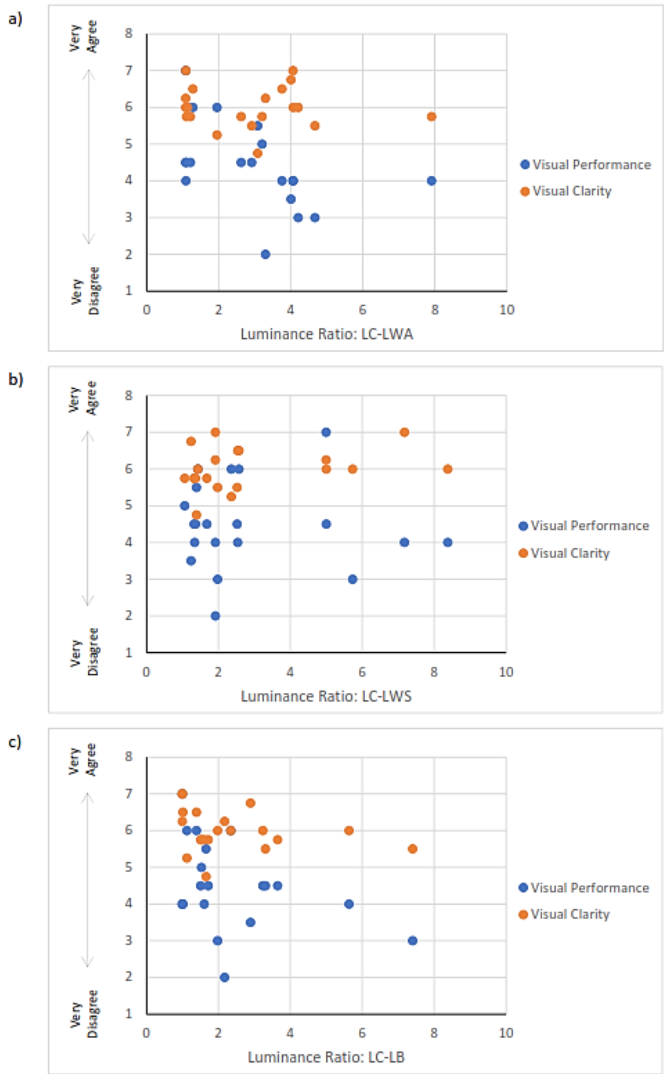

Fig. 6: Relation of Luminance Ratio with Perceived Visual Performance and Clarity.
Scatter plot shows the relation of reported Visual Performance and Visual Clarity between;
(a) Computer Screen-to-Working Area (LC:LWA), (b) Computer Screen-to-Workstation (LC:LWS),
and (c) Computer Screen-to-Background (LC:LB) for combined workers of Office A and B.
Source: Author, 2024

Conclusion

This research explored the effects of luminance ratio on the subjective evaluation of visual performance and clarity. The results reveal significant differences in luminance ratios and perceived visual comfort between the two offices, with implications for subjective responses to visual performance and clarity. The office with general lighting distribution and bright-colored interior treatment exhibits a generally low luminance ratio, averaging at 1:3, resulting in minimal experienced glare. In contrast, the office with halogen-yellow light, dominant accent lighting distribution, and a muted interior color created high luminance levels and a higher level of glare.

This study ascertains the close relationship between luminance ratio and respondents' subjective evaluations, where a higher luminance ratio led to increased dissatisfaction with visual performance and clarity. The time of day and seating position towards the window emerged as crucial factors influencing luminance ratio and subjective evaluations, owing to the variations in the intensity and direction of daylight. While this study did not perform inferential statistics due to the limited sample size in each group, future research is recommended to include statistical analysis for clearer results. Additionally, measuring other lighting indexes such as illuminance and color rendering index could be incorporated for a more comprehensive analysis. The findings of this study have practical implications for office stakeholders and can serve as a valuable reference for lighting designers in creating optimal working environments.

References

Al-Olaimat, Duha J., Isra, Shdafat, M. Sukinah H. &Al-Khazaleh (2024) Norman Foster & Modern Architecture: Does Foster's High-Tech Architecture Respect the Building Context? Archi-Texts e-journal, 1(2), 65-76

Bennett, hyam N. G. (1984) Visual Clarity: Some Determinants. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, 28, 820–821. Available at: https://doi.org/10.1177/154193128402800919.

Bodmann, H. W. (1967) Quality of Interior Lighting Based on Luminance. *Lighting Research and Technology*, 32, 22–40. Available at: https://doi.org/10.1177/147715356703200104.

Van Bommel, W. J. M. & Van den Beld, G. (2004) Lighting for work: a review of visual and biological effects. *Lighting research & technology*, 36(4), 255–266. Available at: https://doi.org/10.1191/1365782804li122oa

Boubekri, M. (1995) Appraisal of the Lighting Conditions in an Office Building: Results of a Survey. *Indoor and Built Environment*, 4(3–4), 162–169. Available at: https://doi.org/10.1177/1420326X9500400306.

Broadbent, D. E. (1971) Decision and stress. London: *Academic Press*.

Dhayal, P. & Jha, B. (2023) Indoor Visual Comfort: A Review of Factors and Assessments. *International Society for the Study of Vernacular Settlements*, 10(11), 40–61. Available at: https://doi.org/10.61275/isvsej-2023-10-11-03.

Dilani, A. (2005) A new paradigm of design and health in hospital planning. *World hospitals and health services: the official journal of the International Hospital Federation*, 41(4), 17–21.

Fuadiyah, N., Radja, A. M. & Harisah, A. (2023) Public Space as a Stress-Relieving Healing Environment : Insights from the Center Point of Indonesia. *International Society for the Study of Vernacular Settlements*,10(12), 235–246. Available at: https://doi.org/10.61275/ISVSej-2023-10-12-16

Geerdinck, L. M., Van Gheluwe, J. R. & Vissenberg, M. C. J. M. (2014) Discomfort glare perception of non-uniform light sources in an office setting. *Journal of Environmental Psychology*, 39, 5–13. Available at: https://doi.org/10.1016/j.jenvp.2014.04.002.

Kaufman, John E & Haynes, H. (1981) *IES Lighting Handbook; reference volume and application volume*.

Knoop, M. *et al.* (2020) Daylight: What makes the difference? *Lighting Research and Technology*, 52(3), 423–442. Available at: https://doi.org/10.1177/1477153519869758.

Lamb, S. & Kwok, K. C. S. (2016) A longitudinal investigation of work environment stressors on the performance and wellbeing of office workers. *Applied Ergonomics*, 52, 104–111. Available at: https://doi.org/10.1016/j.apergo.2015.07.010.

Leslie, R. P. (2003) Capturing the daylight dividend in buildings: Why and how?', *Building and Environment*, 38(2), 381–385. Available at: https://doi.org/10.1016/S0360-1323(02)00118-X.

Van Ooyen, M. H. F., Van De Weijgert, J. A. C. & Begemann, S. H. A. (1987) Preferred Luminances in Offices. *Journal of the Illuminating Engineering Society*, 16(2), 152–156. Available at: https://doi.org/10.1080/00994480.1987.10748695.

Rockcastle, S. & Andersen, M. (2014) Measuring the dynamics of contrast & daylight variability in architecture: A proof-of-concept methodology. *Building and*

Environment, 81, 320–333. Available at: https://doi.org/10.1016/j.buildenv.2014.06.012.

Steffy, G. (2008) *Architectural Lighting Design*. Third Edit. John Wiley & Sons. Available at: https://books.google.co.id/books?id=W87rdTo9fZ0C.

Tiller, DK & Veitch, J. (1995) Perceived room brightness: Pilot study on the effect of luminance distribution. *International Journal of Lighting Research and Technology*, 27(2), 93–101. Available at: https://doi.org/10.1177/14771535950270020.

Vischer, J. (2005) *Space Meets Status*. 1st edn. London: Routledge. Available at: https://doi.org/10.4324/9780203087770.

de Vries, A. *et al.* (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. Available at: https://doi.org/10.1016/j.buildenv.2018.06.046.