The Impact of Indoor Lighting on Work Comfortability in Temporary Workspace at Home during Work from Home (WFH)

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Abstract. This study aims to determine the significance of the indoor lighting effect on work productivity. The outcome of this research is expected to become a reference in improving the indoor lighting quality for the temporary workspace at home. Space utilisation for work at home increases in line with the practice of Large-Scale Social Restrictions (PSBB) and Work from Home (WFH). It forces some of the space function changes in the worker’s house. Work activities need to be supported by Indoor Health and Comfort (IHC), one of which is the suitability of light intensity and light temperature to the room functions. By applying a mixed-method approach, the research began with quantitative research, correlating the result analysed by the Pearson method. The research continued by qualitative research, study case approach. The collected data is analysed by the Tau Kendall method. The result of this research indicates that there is a significant positive correlation but not significant as indicated by the Pearson r-value of 0.372 between the respondent’s thoughts about indoor lighting to their work duration.

Keywords: Indoor lighting; light intensity; light temperature; temporary working space; WFH

1. Introduction
Pandemic Covid 19 has happened since 2020 [1]. Indonesia's government conducted a regulation to face the pandemic, which is globally called physical distancing, in Indonesia adjusted to Pembatasan Sosial Berskala Besar (PSBB) and then adjusted to the term Pemberlakuan Pembatasan Kegiatan Masyarakat (PPKM). PSBB started on March 16, 2020, and was applied several times with different regulatory adjustments [1]. The PSBB policy reduces human mobility by 38.75% in Indonesia, but the economic factor increases mobility [2]. To maintain the economic cycle and work activities, a Work from Home (WFH) policy emerged, which forced the addition of the function in the home as the financial center of its users. More than half of companies in Indonesia implement WFH [2]. There is a higher pressure on workers in the WFH method, which affects productivity and job satisfaction [3]. The quality of the home-based office supports the flow of the country's economy at a macro level and protects the economic well-being of the employee. Increasing the comfort and intensity of activities in residential homes requires user awareness of indoor health comfort, one of which is lighting [4]. Health directly impacts work performance improvement, increasing the productivity of building users [5]–[7].
Changes in work location cause problems in optimising the lighting of temporary workspaces in residential areas in the face of changing work locations from permanent workspaces in offices to working in temporary workspaces in residential areas. Does this study answer whether there is a significant effect between optimising workspace lighting while achieving a light intensity of 300-350 lux and a light temperature of >3300K in a dwelling on the duration and comfort of workers? [8]–[10] The purpose of this study was to determine the significance of the p-value (> 0.5) of the effect of standardisation of temporary workspace lighting with a light intensity of 300-350 lux and a light temperature of > 3300K on work comfort that considers work duration. This research aims to determine the significance of the indoor lighting effect on work productivity and is expected to benefit building users, companies, science, society, and government as an additional insight into indoor lighting.

2. Literature Study

Lighting is an element that is considered in Indoor Health and Comfort (IHC) [7], [11]. A good IHC directly affects work performance, increasing the productivity of building users [5]–[7]. In a work environment, each employee needs to cooperate to support work productivity [12]. Many workers have experienced burnout phenomena during WFH [13]–[16]. Work activities are carried out for 40 hours a week [17]. In terms of work productivity, it is necessary to pay attention to several aspects, namely efficiency in work, innovation in working methods and products, and the quality of both work methods and products produced [12], [18]. Office typology changes according to the times and work methods [19]. The office (permanent workspace) already has provisions that need to be followed [9], [10].

Family is the minor social environment which workers made to solve an unhappy society in the community’s social life [19], [20]. The legal working age is 19 years old, and the maximum productive age is 64 years old [20], [21]. In a family, a different range of motion is owned by each family member [22]. There are six residential typologies [23]. The typology of houses discussed in this study is the typology of row houses and Koppel houses with less than 400m² by paying attention to the four-building orientation that affects the intensity of sunlight entering the room, the floor plan and area of the house are pretty uniform [4], [24]–[27].

Comparing the lighting between the rooms in the house and the workspace, they have different light intensities and colour temperatures. The space in a home beside the workspace has a higher light intensity and lower light temperature [8]–[10]. In Figure 1, starting with the big issue of architecture and sustainability, there is an increasing need for home offices due to the change in work location during PSBB and WFH that cause much of the burnout phenomenon [13]–[16], [19], [29]. IHC supports the health of the building and its occupants in increasing work comfort, where there are
regulations that standardise space lighting, temperature, and light intensity. With this adjustment, it is necessary to examine the significant effect of lighting on workers’ comfort in the temporary workspace in the house. Some developed research pays attention to lighting as one of the criteria in a healthy home [4]. There are many examples of home office applications in English villages, where the worker adjusts the workspace to the other activities in the house [30]. In lighting, there are various analyses in improving lighting and airflow [26], [27], [31]–[34]. Considering that previous research, the novelty in this study is the significance score (p-value>0.5) of the effect of lighting by optimising the lighting of temporary workspaces in workers’ dwellings, refers to SNI 6197: 2011 and PERMENKES NO. 70: 2016, so there is a description of the actual condition and explanation of how to increase the lighting intensity of temporary workspaces in the house.

3. Method
This research uses mixed methods. It began with a study literature followed by quantitative methods (surveys), the result is being analysed by qualitative methods, single instrumental case studies [35]–[38]. This research explores the analysis of quantitative data (light intensity, light temperature) and qualitative data (subjective opinions of respondents as ordinal data) as insights in explaining the results of the relationship and the significance of lighting effect on the work comfortability in temporary workspaces in the house. East Jakarta has the most significant number of households and is growing according to the BPS survey in 2010, 2018, and 2019 [39]. The research took place in the largest district in East Jakarta, especially in a sub district with the most population growth rate in 2019 [48]. Questionnaires were distributed randomly to 518 households in a national housing estate with an area of 307,908, 67 m². The housing consists of houses with a low building covered ratio. That national housing estate also has medium-high building covered ratio housing zone types, namely R.4 and R.5, that describe typical housing in the sub-district fit the typology of row houses and Koppel houses that are being analysed in this research [23], [40].

The researcher decided the construct validity of the questionnaire on 52 respondents by comparing r product moment, followed by examining the correlation with the Pearson correlation and its significance in the two-tailed test and the Independent Sample T-Test. For testing the influence of the independent variable on the dependent variable. The variables in this study consisted of Independent variables, which were light intensity and light temperature [8]–[10], [35], [41]. The dependent variable applied in this research is the work duration and work comfort [12], [18]. The control variables are the opening orientation, the opening dimension, the room dimensions and the working position [7]. Of the 52 respondents who answered the questionnaire, scores were obtained from respondents’ opinions about indoor lighting on the comfort of working at home and respondents’ views about working comfort while working at home. From the 52 respondents, the researcher screened respondents for the observation and experiment stages using a systematic sampling method, paying attention to the building orientation and the workspace location, into 8 respondents. In Observation stage researcher record actual indoor lighting (lux) in the workspace. While at the experiment stage, the indoor lighting at the working space is adjusted in the working hour. Respondents need to fill daily and weekly questionnaires with a score range 1-6 at observation and experiment stage. The research continued with a case study approach where the researcher collected data on respondents’ opinions through a questionnaire. And the data from the simulation analysis. However, the number of respondents were statistically below the central limit of 30 respondents. Thus the research then was analysed non-parametrically with a study case approach. The explanation is done by describing the resulting numbers both with JASP and excel software. The significance of the effect of light on working comfort was analysed using the Tau Kendall method.

Each observation and experiment was held for a week. Respondents were analysed during working hours (08.00-17.00). The respondent fills out a daily questionnaire about the respondent’s experience during the study every day and a weekly questionnaire about comfort on the last day of the observation and experiment stages. In the survey, researchers analysed the 52 respondents’
questionnaire results using JASP software. The questionnaire data was compiled and then tested for reliability with the parallel method and then calculated Cronbach’s Alpha value.

4. Result and Discussion

4.1. Result

From the 52 research respondents, various descriptions of workers at research location were obtained, according to Figure 2, 15 of the 52 respondents were aged 29-38 years. Most of the respondent’s building orientation is towards the east. 76.9% of respondents do not have a particular workspace to work at home. Therefore, the most used room by the respondent (26.9%) is the bedroom. More than 50% of the respondents rated the light in the room as having less effect on the work comfort.

![Figure 2](image-url)

**Figure 2.** Survey result to 52 respondents: a. Gender; b. Building orientation; c. Availability of working space in the respondent's house; d. Space in the house that was used for work; e. Respondent’s age

From the 52 respondents, the researcher screened respondents for the observation and experiment stages using a systematic sampling method, paying attention to the building orientation and the workspace location (Table 1). The researcher selected four female respondents and four male respondents with the same working method and various building orientation and various rooms that they use for work from home. The age range of respondents from 33-65 years with the lowest comfort score of 3.16 and the highest 5.25 with a score range 1-6.

| Table 1. screened respondent’s brief data |
|------------------------------------------|
| 1st Respondent (Female, 50yrs) | 2nd Respondent (Male, 65yrs) | 3rd Respondent (Female, 42yrs) | 4th Respondent (Female, 34yrs) | 5th Respondent (Male, 50yrs) | 6th Respondent (Male, 54yrs) | 7th Respondent (Male, 64yrs) | 8th Respondent (Female, 33yrs) |
| Southern building orientation. | Southern building orientation. | East building orientation. | North building orientation. | East building orientation. | West building orientation. | North building orientation. | North building orientation. |
| Work in family room 1st floor | Work in workspace 1st floor | Work in bedroom 1st floor | Work in family room 1st floor | Work in living room 1st floor | Work in family room 1st floor | Work in living room 1st floor |
| Work comfort score | 4.5 | 5.25 | 4.5 | 3.83 | 4.92 | 5.58 | 3.16 | 4.33 |

Workspace model was created for the observation and experiment stage, and the light intensity was simulated on the observation date compared to the actual condition (Figure 3 and Table 2), which shows the simulation at 08.00, 12.00 and 17.00 on weekdays. Figure 4. shows that the average respondents’ score for indoor lighting comfort increased by 3.83%. The building orientation of Participant 1 is facing west. It has a high wall boundary, and the dimensions of the backyard are smaller than the front yard. Respondent 4 positions were opposite to the source of indoor lighting. Moreover, Participant 7 used artificial lighting when working at a distance from the work area. At the experiment stage, the score from 3 of 8 respondents was lower than the observation stage (Table 2 and Table 3).
Figure 3. Actual Light intensity in observation stage

Table 2. Light intensity simulation in observation stage

|       | 08.00 | 12.00 | 17.00 | 08.00 | 12.00 | 17.00 |
|-------|-------|-------|-------|-------|-------|-------|
| 1st respondent |       |       |       |       |       |       |
| 2nd respondent |       |       |       |       |       |       |
| 3rd respondent |       |       |       |       |       |       |
| 4th respondent |       |       |       |       |       |       |
| 5th respondent |       |       |       |       |       |       |
| 6th respondent |       |       |       |       |       |       |
| 7th respondent |       |       |       |       |       |       |
| 8th respondent |       |       |       |       |       |       |

Table 3. Light intensity simulation at experiment stage

|       | 08.00 | 12.00 | 17.00 | 08.00 | 12.00 | 17.00 |
|-------|-------|-------|-------|-------|-------|-------|
| 1st respondent |       |       |       |       |       |       |
| 2nd respondent |       |       |       |       |       |       |
| 3rd respondent |       |       |       |       |       |       |
| 4th respondent |       |       |       |       |       |       |
| 5th respondent |       |       |       |       |       |       |
| 6th respondent |       |       |       |       |       |       |
| 7th respondent |       |       |       |       |       |       |
| 8th respondent |       |       |       |       |       |       |
Figure 4.b. shows the difference in the average value increased by 11.11%. Most respondents experienced an increase in the duration of work. The intensity of the respondent’s distraction is shown in Figure 4.c. there is a decrease in the mean value of 10.08%. According to the interview results, respondents think that the adjusted light intensity helps them in their work. However, apart from lighting, there are relationships with other family members who have a significant influence on causing them to leave the workplace. The work comfort increased by 8.44%, while there is a reduction in respondents’ opinions of the costs incurred about the lighting (2.47%). The result illustrates the respondent’s view that the expenses incurred for the light electricity used are lower than the benefits obtained from the increase in lighting. Furthermore, there is an increase in the mean score of the respondent’s comfort in working at home, increasing by 8.44%.

![Figure 4](image)

**Figure 4.** Comparison between observation and experiment stage: a. Respondent’s rate about indoor lighting; b. Respondent’s rate the work duration; c. Respondent rate the distraction intensity.

### 4.2. Discussion

The researcher applies a Reliability test to measure the strength of the tools [42]. From Table 4, although some of the questions in the questionnaire can be ignored, all questions in the questionnaire still used in this study. Considering that the whole questionnaire has a score above the reliability limit. In the questionnaire, respondents were asked about their opinion of indoor lighting, the comfort of working in actual conditions, and an assessment of working comfort. According to the hypothesis test about the normal distribution of data from the initial questionnaire, there is a correlation between respondents’ opinions of light and work comfort (Table 5). A Pearson test was carried out to check the significance correlation, which in Table 6 shows a positive correlation between the two things but not significant as indicated by the Pearson r-value of 0.372.

| Frequentist Scale Reliability Statistics | Frequentist Individual Item Reliability Statistics |
|------------------------------------------|-----------------------------------------------|
| **Frequentist Scale Reliability Statistics** | **Frequentist Individual Item Reliability Statistics** |
| Estimate | McDonald’s $\omega$ | Cronbach’s $\alpha$ | Average interitem correlation | Item | McDonald’s $\omega$ | Cronbach’s $\alpha$ | Item-rest correlation |
| Point estimate | 0.838 | 0.870 | 0.231 | Item | Item | Item | Item |
| 95% CI lower bound | 0.774 | 0.810 | 0.162 | V3.1 | 0.845 | 0.873 | 0.229 |
| 95% CI upper bound | 0.901 | 0.914 | 0.302 | V3.2 | 0.829 | 0.860 | 0.590 |
| Item | McDonald’s $\omega$ | Cronbach’s $\alpha$ | Item-rest correlation | Item | McDonald’s $\omega$ | Cronbach’s $\alpha$ | Item-rest correlation |
| V3.3 | 0.828 | 0.861 | 0.541 | V3.3 | 0.823 | 0.859 | 0.570 |
| V3.4 | 0.821 | 0.858 | 0.629 | V3.4 | 0.831 | 0.867 | 0.373 |

Table 4. Single-Test Reliability Analysis
To determine the intensity of light needed in the experimental stage, the researcher compares the light intensity in actual conditions and simulations that show the model error, then compared with the simulations for the experimental period. In Figure 5.a. at 08.00, it is necessary to increase 200-250 lux visible from a distance between the minimum and maximum limits of the workspace guidelines [8]–[10]. In Figure 5.b. The need for an increase in light intensity is more minor (100-150 lux), which is also the highest light intensity in the room. Figure 5.c. indicated a need for an increase of 150-200 lux. The light temperature used was 6500 K. The lamp is placed on a work plane as high as 40 cm with the light intensity set at 08.00, 12.00, and 17.00. Considering the variations in the orientation of the respondent’s residential building as shown in Figure 5.d. and Table 1 shows that for respondents with the north building orientation, the mean score about indoor lighting increased by 28.3%, distraction intensity decreased by 28.28% and working comfort increased by 12.58% while the most significant increase in work duration was in respondent with east building orientation (23.48%). Pay attention to Figure 5.d. The workspace location has a high effect on indoor lighting (5.96%) and work comfort (11.06%). Meanwhile, the workspace in the middle of the house has the most significant changes in the work duration (12.9%) and the reduction in distraction intensity (15.20%). In Figure 5.d., comparison between genders significantly affects the increase in the opinion of female respondents to indoor lighting (9.25%), work duration increases 16.5% and distraction decreases by 19.69%, while work comfort is very influential for male respondents who responded to lighting adjustments (15.84%).

| V3.5 | 0.835 | 0.865 | 0.440 | V4.5 | 0.860 | 0.857 | 0.672 |
| V3.6 | 0.815 | 0.854 | 0.750 | V4.6 | 0.860 | 0.856 | 0.708 |
| V3.7 | 0.837 | 0.859 | 0.599 | V4.7 | 0.822 | 0.861 | 0.597 |
| V3.8 | 0.840 | 0.864 | 0.470 | V4.8 | 0.839 | 0.873 | 0.099 |
| V3.9 | 0.843 | 0.872 | 0.226 | V4.9 | 0.826 | 0.863 | 0.478 |
| V3.10 | 0.836 | 0.869 | 0.281 | V4.10 | 0.839 | 0.868 | 0.343 |
| V3.11 | 0.827 | 0.861 | 0.582 | V4.11 | 0.841 | 0.875 | 0.030 |

| V3.12 | 0.835 | 0.865 | 0.404 |

*Note: Reverse item scale V3.1, V3.9, V4.1, V4.10.*

| Table 5. Descriptive Statistic |
|--------------------------------|
| Respondent rate indoor lighting | Comfortability |
| Shapiro-Wilk P-value | 0.976 | 0.983 |
| Result | Normal/Parametric | Normal/Parametric |

| Table 6. Pearson Correlation |
|-------------------------------|
| Variable | Pearson’s r | p-value |
| comfortability | 0.372 | 0.007 |

| Table 7. Shapiro-Wilk Test for Bivariate Normality |
|-----------------------------------------------|
| Respondent rate indoor lighting Comfortability | Shapiro-Wilk | p |
| 0.965 | 0.135 |

Figure 5. The Chart of light intensity comparison between actual condition and software simulation: a. 08.00; b. 12.00; c. 17.00; d. Bar chart of Daily Questioner score
Figure 6 shows the mean score of all respondents for the observation stage and the experimental stage. There was an increase in the respondent’s experience of light. The mean score is still between 4-5 (bright-brighter). According to the respondent’s opinion, they did not experience glare, even though the light intensity is brighter than what is needed. Changes in the increasing work duration from the observation to experimental stages coincided with an increment in light intensity, following the respondents’ positive responses in the interview after the experimental stage took place with the increasing duration of work in contrast to changes in the decrease of distraction intensity. The result is related to respondents who think that it is easier to focus on doing their job. With these changes, there is also an increment in work comfort.

Figure 6 shows the changes in values that occurred throughout the research. The most significant change (33.20%) is the working duration. The changes in circumstances (the adjustment of light intensity and light temperature) have the most effect on increasing the working duration experiment stage. However, the correlation is less significant because the p-value is between 0-0.5; however, if the effect of light with the duration of work has a statistically significant positive impact.

![Figure 6](image)

**Figure 6.** a. Average Score comparison between observation stage and experiment stage; b. Score changes from observation stage to experiment stage in each topic

The result is also an increase in work comfort. The mean score is still between 4-5 (bright-brighter). According to the respondent’s opinion, they did not experience glare, even though the light intensity is brighter than what is needed. Changes in the increasing work duration from the observation to experimental stages coincided with an increment in light intensity, following the respondents’ positive responses in the interview after the experimental stage took place with the increasing duration of work in contrast to changes in the decrease of distraction intensity. The result is related to respondents who think that it is easier to focus on doing their job. With these changes, there is also an increment in work comfort.

![Figure 6](image)

**Figure 6.** a. Average Score comparison between observation stage and experiment stage; b. Score changes from observation stage to experiment stage in each topic

**Table 8.** Tau Kendall correlation

| Variable                  | indoor lighting observation | indoor lighting experiment | work duration observation | work duration experiment | distraction observation | distraction experiment | comfortability observation | p-value |
|---------------------------|----------------------------|----------------------------|---------------------------|--------------------------|-------------------------|-------------------------|---------------------------|---------|
| indoor lighting observation| Kendall's Tau B            |                            |                           |                          |                         |                         |                           | —       |
| indoor lighting experiment| p-value                   | -0.189                     |                            |                          |                         |                         |                           | —       |
| work duration observation | Kendall's Tau B            | 0.109                      | 0.371                     |                          |                         |                         |                           | —       |
| work duration experiment  | p-value                   | 0.708                      | 0.209                     |                          |                         |                         |                           | —       |
| distraction observation   | Kendall's Tau B            | -0.074                     | 0.189                     | 0.327                    |                         |                         |                           | —       |
| distraction experiment    | p-value                   | 0.802                      | 0.527                     | 0.262                    | -0.255                  | -0.444                  |                           | 0.006   |
| comfortability observation| Kendall's Tau B            | -0.111                     | -0.038                    | -0.546                   | -0.815 **               | 0.667 *                 |                           | 0.063   |
| comfortability experiment | p-value                   | 0.706                      | 0.899                     | 0.061                    | 0.006                   | 0.024                   |                           | 0.398   |
|                           |                           | 0.209                      | 0.376                     | -0.327                   | -0.667 *                | 0.222                   |                           | 0.519   |
|                           |                           | 0.264                      | -0.615 *                 | -0.445                   | -0.264                  | -0.189                  |                           | 0.113   |
|                           |                           |                           |                           |                           |                         |                         |                           | 0.340   |

* p < .05, ** p < .01, *** p < .001

5. Conclusion and Suggestion

5.1. Conclusion

It concluded that there is an influence between the respondent’s experience of lighting in the room on the work duration (p-value > 0.5) but less significant with work comfort even though it is positively correlated with the hypothesis (p-value < 0.5).

The initial lighting conditions of the observation stage in seven of the eight residences showed a light intensity below 300 lux and a light temperature below 3300 K. There was an increasing score for indoor lighting and the work duration from observation to experimental. Meanwhile, there is a
decrease in work distraction. That result is in line with the respondents’ positive opinion on light adjustment. From interviews and graphs on ongoing research, it can be concluded that a room with a height of the 2nd floor (3.5 m above the ground floor) with a position close to the opening of the building has better light intensity according to the lighting needs of the workspace, while in the north building orientation with a height of the 1st-floor room has a more stable natural light intensity approaching 300-350 lux.

Work Comfort influenced by room light adjustment increases higher on male workers while working duration increases higher on female respondents. The high level of distraction from working at home activities at home shows the relationship between employees and other family members with a low level of privacy, especially in the workspace outside the bedroom, because the position of the space is rarely partition and close to the residential circulation area and activities of other family members. Adjustment of light intensity and light temperature can be applied to the new normal, which can significantly increase the duration of work.

5.2. Suggestion
This study provides some suggestions for people working from home to take indoor lighting into consideration. Take advantage of natural lighting by positioning the workspace near building openings. Employers can expect the employee to increase the work duration by ensuring the adequacy of the lighting intensity and temperature of the light in the employee’s workspace. Further research is needed for comprehensive input to science studying aspects of IHC other than light.

The study also provides a scientific basis for the government to develop policies on the quality of lighting in residential buildings and other IHC elements and provide benefits to building owners who apply for green housing to increase public interest in making a healthy building environment at least in terms of lighting and overall are all aspects of IHC.

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Acknowledgement
The authors would like to thank Mr Toga H. Panjaitan for all the insight that increased the researcher's knowledge and many critics and suggestions that help the researcher revise the mistake made and develop better research.