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THE GLOBAL GOALS

INFLUENCE OF LIGHTING AND TEMPERATURE ON COGNITIVE PERFORMANCE: A CONTRIBUTION TO SUSTAINABLE DEVELOPMENT GOALS

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ABSTRACT

Objective: The objective of this study is to investigate the impact of varying lighting levels and room temperatures on cognitive task performance, to optimize mental efficiency and productivity in the workplace.

Theoretical Framework: This research is underpinned by principles of environmental ergonomics and cognitive psychology, emphasizing how workplace environmental factors like lighting and temperature critically influence cognitive performance and productivity.

Method: The methodology adopted for this research comprises a 3x2 factorial experimental design involving 20 university students. Cognitive performance was assessed using the Kraepelin Test, measuring speed, accuracy, and stability under six distinct environmental combinations of lighting and temperature. Data analysis utilized Two-Way ANOVA.

Results and Discussion: The results revealed that the condition of 350 lux lighting and 24°C temperature produced the highest cognitive performance across all indicators. Both lighting and temperature had significant effects, with their interaction notably influencing accuracy but not speed or stability. These findings highlight the importance of moderate lighting and cool temperatures for mental efficiency.

Research Implications: The practical implications of this research are discussed, providing insights into optimizing physical workspace environments. Results can influence practices in ergonomic work design and support regulatory recommendations for lighting and temperature standards in professional and educational settings, thereby contributing to the Sustainable Development Goals (SDGs), particularly Goal 3: Good Health and Well-being, by fostering healthier and more productive work environments.

Originality/Value: This study contributes original value to the literature through its integrative approach combining environmental ergonomics and cognitive testing. The relevance of this research is evidenced by its direct applicability in enhancing workplace efficiency and informing future studies on broader environmental factors affecting cognitive function.

Keywords: cognitive performance, design experiment, significance, Sustainable Development Goals (SDG).

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1 INTRODUCTION

In the era of globalization and Industry 4.0, modern organizations recognize that superior performance is not solely determined by human resource quality, but also by the design of an optimal physical work environment. A supportive environment plays a vital role in maintaining focus, reducing fatigue, and enhancing cognitive efficiency. Robbins and Judge (2019) emphasize that good physical working conditions are key determinants of both individual and organizational success. Among various environmental factors, illumination and ambient temperature stand out as critical elements that can either enhance or hinder cognitive performance.

Numerous studies have confirmed the significant impact of lighting and temperature on productivity. The International Labour Organization (2019) reported that inadequate lighting could reduce productivity, while the Occupational Safety and Health Administration (2021) found that uncomfortable temperatures can impair cognitive reaction time by approximately 18%. These findings highlight the importance of regulating lighting and temperature as integral components of ergonomic workplace design.

Optimal lighting supports both visual clarity and attention. Research by Wu (2022) and shows that lighting that is too dim or too bright can reduce concentration and accuracy. According to the Indonesian Ministry of Manpower Regulation No. 5/2018, the recommended lighting level for administrative spaces is 300 lux to 500 lux. This study applies lighting variations of 250 lux, 350 lux, and 450 lux to evaluate their impact on cognitive performance.

Temperature also plays a key role in maintaining physiological and mental balance. Knez (2000) highlights those temperatures outside the comfort range can cause stress and fatigue. Further research also comprehensively demonstrates how various thermal conditions, including humidity and ventilation, can significantly impact overall cognitive performance (Li *et al.*, 2023). The Indonesian National Standard (SNI 6390:2011) defines 23°C to 26°C as ideal for indoor work. Based on this, the study compares cognitive performance at 24°C and 28°C.

Previous studies, such as those by Yang and Moon (2019) and Wu *et al*. (2022), explored the separate effects of lighting and temperature using computer-based tasks. Hanui Yu and Takeshi Akita (2023), using EEG methods, found that lighting affects brain activity. However, few studies in Indonesia have used maximum performance tests like the Kraepelin Test to assess the combined effects of lighting and temperature in a controlled experimental setting.

The Kraepelin Test, developed by Emile Kraepelin, is a classical psychological tool that evaluates time-pressured task performance based on three core metrics: work speed, accuracy, and stability (Spearman, 1927). Its structure requires individuals to perform continuous mental arithmetic under strict time constraints—making it relevant to modern occupational demands.

This study aims to 1) Examine the effect of lighting intensity (250 lux, 350 lux, and 450 lux) on cognitive performance as measured by speed, accuracy, and stability using the Kraepelin Test. 2) Assess the influence of room temperature (24°C and 28°C) on these cognitive performance indicators. 3) Analyze the interaction effect between lighting and temperature on work performance outcomes.

The research took place in a climate-controlled lab at the Faculty of Engineering, Universitas Sebelas Maret, with controlled noise and air quality to maintain data validity. Participants were selected based on health criteria using DASS-21 and BMI screening. Each completed six sessions with randomized lighting and temperature conditions.

This study offers both practical and academic value. It provides insights for improving productivity and well-being through ergonomic design and contributes empirically to environmental psychology and cognitive ergonomics. The findings support the development of adaptive and high-performance work environments.

2 THEORETICAL FRAMEWORK

Cognitive performance, which includes the ability to process information, maintain focus, and complete tasks accurately, is influenced by

environmental factors such as lighting and temperature. According to Cognitive Load Theory (Sweller, 2010), poor environmental conditions can increase mental workload, reducing task efficiency. Attention Resource Theory (Kahneman, 1973) highlights that attention is a limited resource that can be diminished by discomfort. Additionally, Executive Control Theory (Miyake & Friedman, 2012) emphasizes that a stable environment helps individuals maintain consistency during cognitive tasks.

Lighting is critical for visual comfort and focus. Studies by Knez and Enmarker (1998) and Chinazzo *et al*. (2019) show that both insufficient and excessive lighting can reduce accuracy and increase fatigue. In Indonesia, the recommended lighting range for offices is 300–500 lux (Permenaker No. 5/2018). Research by Wu (2022) suggests that 350 lux provides optimal conditions for cognitive tasks.

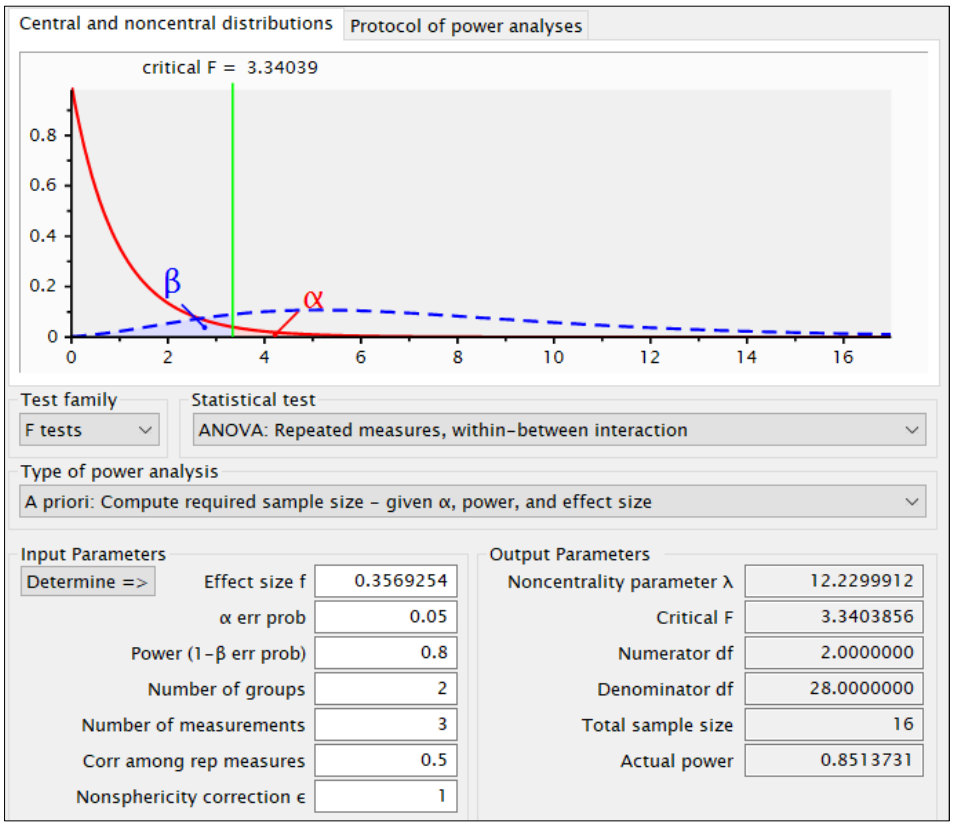
Temperature also affects mental stamina and concentration. Studies by Knez (2000) found that temperatures above 26°C increase fatigue, while a range of 23°C–26°C is ideal (SNI 6390:2011). OSHA (2021) also reports that thermal discomfort can impair reaction time by up to 18%. While many studies analyze lighting and temperature separately, interaction effects are less explored. Research by Yang and Moon (2019) and Sepehri *et al*. (2019) suggests potential combined effects, but objective testing remains limited. To address this, this study uses the Kraepelin Test, which objectively measures speed, accuracy, and stability under time pressure, providing a more realistic evaluation of cognitive performance (Sugimoto *et al*., 2009).

3 METHODOLOGY

This quantitative experimental study examined the effects of lighting and temperature on cognitive performance using the Kraepelin Test. A total of 20 participants were selected through convenience sampling (Firmasnyah & Dede, 2022), in line with Roscoe's (1975) guideline for simple experiments. Power analysis using G*Power confirmed the adequacy of the sample size for ANOVA repeated measures.

Figure 1

Sample Size Determination Results

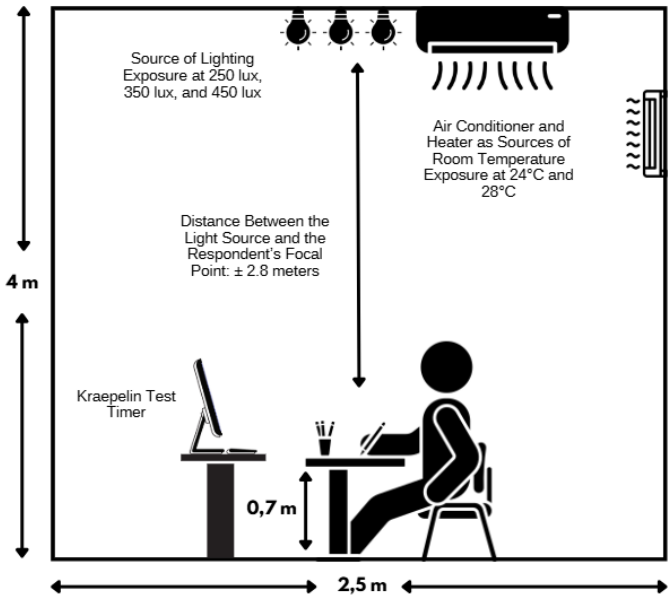


Source: G*Power Software

Power analysis showed that a minimum of 16 participants was required (actual power = 0.851), making the final sample of 20 respondents sufficient. Participants were selected based on the following criteria: physically and mentally healthy (normal DASS scores) (Lovibond & Lovibond, 1995), BMI between 18.5–24.9, and aged 21–25 years from the Industrial Engineering program at Sebelas Maret University, reflecting high motivation levels (Hartshorne *et al.*, 2015). The experiment was conducted from March 5 to 17, 2025, in the Climate-Controlled Room of the Ergonomics Laboratory, Faculty of Engineering, Universitas Sebelas Maret.

Figure 2

Layout of the Climate-Controlled Room



Source: Developed for the research

Research variables are defined as attributes, values, or characteristics of an object that exhibit certain variations between one another, determined by the researcher for study and analysis (Sekaran & Bougie, 2019).

This study involves two independent variables:

- Lighting Level, divided into three levels: 250 lux, 350 lux, and 450 lux.
- Temperature, divided into two levels: 24°C and 28°C.

The dependent variable is the result of the independent variables, which is work performance during a time-pressure task, measured using the Kraepelin Test. The parameters measured in the Kraepelin Test include:

- Work Speed (speed factor),
- Work Accuracy (accuracy factor),
- Work Stability (rhythm factor).

The experimental design is shown in Table 1

Table 1

3x2 Factorial Research Design

Temperature	Lighting Level								
	250 lux (B1)			350 lux (B2)			450 lux (B3)		
	spd	*acc*	*rhy*	*spd*	*acc*	*rhy*	*spd*	*acc*	*rhy*
24˚C (A1)	A1B1			A1B2			A1B3		
28˚C (A2)	A2B1			A2B2			A2B3		

Source: Developed for the research

A research hypothesis is a provisional assumption that needs to b empirically tested. In quantitative research, hypotheses consist of a null hypothesis (H_0), which states there is no relationship or difference, and an alternative hypothesis (H_1), which suggests the presence of a relationship or difference (Creswell & Creswell, 2018). The hypotheses in this study are as follows:

1. Hypothesis for the lighting difference test in performing the Kraepelin Test on work speed, work accuracy, and work stability:

- H_0a: There is no significant difference between lighting levels and work speed, work accuracy, and work stability.
- H_1a: There is a significant difference between lighting levels and work speed, work accuracy, and work stability.

2. Hypothesis for the temperature difference test in performing the Kraepelin Test on work speed, work accuracy, and work stability:

- H_0b: There is no significant difference between room temperature and work speed, work accuracy, and work stability.
- H_1b: There is a significant difference between room temperature and work speed, work accuracy, and work stability.

3. Hypothesis for the interaction of lighting and temperature in performing the Kraepelin Test on work speed, work accuracy, and work stability:

- H_0c: Lighting levels of 250 lux, 350 lux, and 450 lux, along with room temperatures of 24˚C and 28˚C, do not affect cognitive performance.
- H_1c: Lighting levels of 250 lux, 350 lux, and 450 lux, along with room temperatures of 24˚C and 28˚C, affect cognitive performance.

This study begins with a literature review to design the experimental framework regarding the effects of lighting and temperature on cognitive performance. The selection of the Kraepelin Test as the measurement tool is

based on its ability to assess work speed, accuracy, and stability. The research focuses on improving work productivity through environmental optimization, with variables limited to three lighting levels (250 lux, 350 lux, 450 lux) and two temperature levels (24°C and 28°C).

Work performance is measured using the Kraepelin Test, with parameters:

- Work Speed is calculated by averaging the number of correct sums:

$$Mean = \frac{\sum fxi}{30} \quad (1)$$

- Work Accuracy is measured based on the number of errors and skips.
- Work Stability is assessed using the average deviation:

$$Avedev = \frac{1}{n}\sum_{1=1}^{n} |X_i - \bar{X}| \quad (2)$$

The data processing phase begins with assumption testing to ensure the feasibility of parametric analysis. Normality is tested using the Shapiro-Wilk Test to determine whether the data are normally distributed, with a significance level (Sig.) > 0.05 indicating normal distribution (Field, 2013). Subsequently, variance homogeneity is tested using Levene's Test to ensure the variance across treatment groups is homogeneous.

If the normality and homogeneity assumptions are met, the data are analyzed using Two-Way ANOVA to examine the main effects of lighting, temperature, and their interaction on work performance. The analysis model follows the equation:

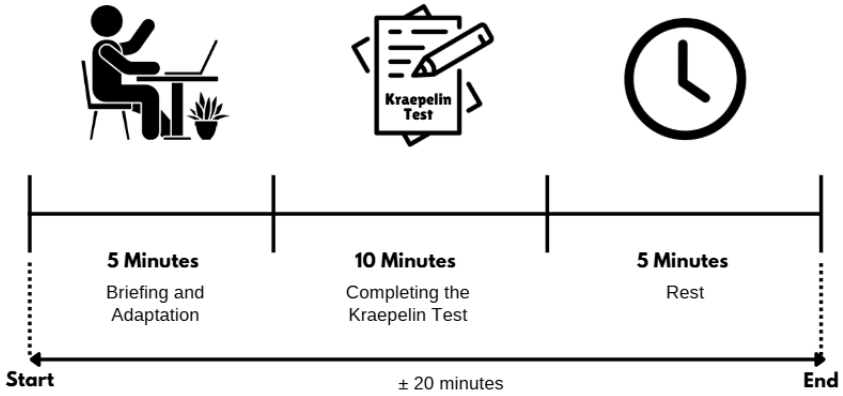
$$Y_{ijk} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + \varepsilon_{ijk} \quad (3)$$

If significant differences are found ($p < 0.05$), post hoc analysis is conducted using the Tukey LSD method to identify significantly different treatment pairs. If the data do not follow a normal distribution, a non-parametric Friedman test is used to examine differences between treatment conditions.

The research schematic, which outlines the steps of the experiment, is shown in the figure below.

Figure 3

Experimental Phases Schematic



Source: Developed for the research

The experiment was conducted over six days. Each participant completed one session per day under a different combination of lighting (250 lux, 350 lux, or 450 lux) and temperature (24°C or 28°C), totaling six unique treatment conditions. Before each session, participants received a brief explanation of the procedure. They then performed the Kraepelin Test for approximately 10 minutes in a climate-controlled room. A 5-minute break was given after each session, and the results were recorded and analyzed by the researcher.

Table 2

Definition of Notations

Notation	Definition
x_i	The i-th data point
X_i	The individual value of the i-th data point
$\bar{X}$	The mean of all data points
n	The total number of data points
Y_{ijk}	Performance score of individual k
μ	The overall mean
α_i	The effect of the i-th lighting level
β_j	The effect of the j-th temperature level
$(\alpha\beta)_{ij}$	The interaction effect between lighting and temperature
ε_{ijk}	The residual error term for the i-th, j-th treatment combination

Source: Developed for the research

4 RESULTS AND DISCUSSIONS

This study encompasses data collection, data processing, and analysis related to the results of an experiment design examining the effects of lighting levels and room temperature on cognitive performance, specifically in terms of work speed, accuracy, and stability.

4.1 DATA COLLECTION

Exclusion Criteria include individuals with a Body Mass Index (BMI) outside the normal range and those showing signs of depression, anxiety, or stress. After establishing the inclusion and exclusion criteria, 20 respondents were selected, with their characteristics summarized in Table 3.

Table 3

Respondent Characteristics

Respondent	Age	Gender	BMI	DASS-21
1	22	Male	20,1	Normal
2	21	Male	24,4	Normal
3	21	Female	18,9	Normal
4	22	Female	22,7	Normal
5	21	Female	20,8	Normal
6	22	Male	24,0	Normal
7	22	Female	18,7	Normal
8	21	Male	21,0	Normal
9	22	Male	24,7	Normal
10	22	Male	24,9	Normal
11	22	Female	20,3	Normal
12	21	Male	24,5	Normal
13	23	Female	20,5	Normal
14	22	Female	21,6	Normal
15	21	Female	24,3	Normal
16	21	Female	21,6	Normal
17	22	Female	21,6	Normal
18	22	Male	24,9	Normal
19	23	Male	24,3	Normal
20	22	Male	22,2	Normal

Source: Data Processed

Based on Table 3, the study subjects consisted of 20 respondents, with a balanced gender distribution (10 males and 10 females). The majority of the respondents were 22 years old (45%), followed by 21 years old (30%) and 23 years old (25%). All respondents had a normal Body Mass Index (BMI) and did not show indications of depression, anxiety, or stress based on the DASS-21 scores.

The results of the work speed scores from the Kraepelin Test at three lighting levels (250 lux, 350 lux, 450 lux) and two temperature levels (24˚C and 28˚C) are presented in Table 4.

Table 4

Work Speed Scores from Kraepelin Test

No.	Speed Score					
	24˚C			28˚C		
	250 lux	350 lux	450 lux	250 lux	350 lux	450 lux
1	14.967	17.633	16.367	13.233	16.467	15.067
2	15.267	18.133	16.767	14.567	17.167	15.833
3	11.867	15.100	12.867	10.933	14.400	12.567
4	15.400	19.067	17.067	11.467	17.033	15.500
5	17.167	19.267	18.400	14.533	17.467	15.167
6	12.533	17.733	15.067	11.867	15.967	14.367
7	12.467	15.700	14.167	14.267	15.000	13.667
8	14.400	18.033	16.833	12.133	17.233	14.633
9	13.267	17.133	16.233	11.800	16.867	14.367
10	15.533	16.233	16.667	11.767	17.433	13.767
11	16.167	18.767	17.533	13.433	17.300	16.433
12	13.300	18.633	16.267	14.067	17.033	15.633
13	14.267	19.533	16.133	13.100	17.800	15.200
14	15.667	19.333	15.633	11.367	15.967	15.133
15	14.500	19.933	15.333	13.333	18.533	14.867
16	14.033	19.700	16.967	12.133	18.367	15.333
17	14.667	19.067	15.367	12.633	18.167	14.733
18	16.967	18.233	17.133	14.067	17.133	15.333
19	15.867	17.767	16.667	13.567	16.633	15.467
20	14.733	17.700	16.567	12.533	16.833	16.267
$\bar{X}$	**14.652**	**18.135**	**16.202**	**12.840**	**16.940**	**14.967**

Source: Data Processed

The results of the work accuracy scores from the Kraepelin Test at three lighting levels (250 lux, 350 lux, 450 lux) and two temperature levels (24˚C and 28˚C) are presented in Table 5.

Table 5

Results of the work accuracy scores

No.	Accuracy Score					
	24˚C			28˚C		
	250 lux	350 lux	450 lux	250 lux	350 lux	450 lux
1	6	2	5	6	3	6
2	9	1	3	10	4	6
3	4	5	2	9	5	9
4	5	3	4	8	5	7
5	7	4	5	8	5	5
6	5	5	2	13	3	7
7	7	4	2	8	4	8
8	8	0	4	8	6	7
9	7	5	7	7	4	7
10	10	4	8	13	3	11
11	9	2	3	14	5	4
12	7	7	2	7	7	7
13	5	4	5	10	5	9
14	9	1	3	9	5	8
15	6	0	2	12	4	7
16	11	6	4	11	6	8
17	5	0	3	10	2	5
18	7	3	5	9	3	6
19	9	5	4	15	5	12
20	7	4	6	11	4	8
$\bar{X}$	**7.15**	**3.25**	**3.95**	**9.9**	**4.4**	**7.35**

Source: Data Processed

The results of the work stability scores from the Kraepelin Test at three lighting levels (250 lux, 350 lux, 450 lux) and two temperature levels (24˚C and 28˚C) are presented in Table 6.

Table 6

Work Stability Scores from Kraepelin Test

No.	Stability Score					
	24˚C			28˚C		
	250 lux	350 lux	450 lux	250 lux	350 lux	450 lux
1	2.571	1.840	2.318	3.449	2.067	2.400
2	1.982	1.333	1.367	1.558	1.711	1.822
3	2.116	1.987	1.578	1.738	2.240	1.947
4	1.840	0.747	1.227	1.764	2.164	1.367
5	1.444	1.027	1.587	1.364	1.800	1.400
6	1.764	1.520	1.671	2.516	1.898	1.858
7	1.564	1.560	1.600	2.018	1.800	1.622
8	2.080	1.309	1.400	2.027	1.464	1.967
9	1.867	1.111	1.229	2.480	2.036	2.209
10	1.889	1.449	1.756	2.684	1.424	1.900
11	1.456	0.696	0.898	2.358	1.587	1.938
12	2.027	1.380	1.884	2.209	1.569	1.942
13	1.484	0.653	1.924	2.793	1.387	1.636
14	1.844	0.844	1.742	2.507	1.573	2.018
15	1.833	0.693	2.156	2.267	1.258	2.076
16	2.040	0.440	2.178	2.133	1.276	2.311
17	2.889	0.684	1.876	2.367	1.556	1.698
18	2.251	1.049	1.342	3.053	1.751	2.067
19	2.044	1.249	1.400	2.758	1.876	1.933
20	2.000	1.300	1.587	2.831	1.578	1.769
$\bar{X}$	1.949	1.144	1.636	2.344	1.701	1.894

Source: Data Processed by SPSS Statistical Data

Based on the results shown in Table 6, it was found that variations in temperature and lighting levels affect the stability of performance during the Kraepelin Test. At a temperature of 24˚C, the lighting level of 350 lux resulted in a higher stability score compared to 250 lux and 450 lux, indicating that this condition better supports work stability. Since a higher work stability score indicates more consistent performance, the combination of 350 lux lighting and 24˚C temperature is the most optimal condition for maintaining work stability during the test.

4.2 DATA PROCESSING

4.2.1 Normality test

Normality testing was conducted using the Shapiro-Wilk method, suitable for small samples (Shadish *et al.*, 2002), to assess whether work speed, accuracy, and stability scores were normally distributed. Analysis with SPSS

27.0 showed that all significance values were above 0.05, indicating that the data met the assumption of normality (Gravetter & Wallnau, 2017).

Table 7

Test of Normality (Speed)

Tests of Normality (Speed)				
Treatment		Shapiro-Wilk		
		Statistic	df	Sig.
24°C	250 lux	0.974	20	0.841
	350 lux	0.932	20	0.171
	450 lux	0.927	20	0.138
28°C	250 lux	0.949	20	0.350
	350 lux	0.937	20	0.209
	450 lux	0.946	20	0.316

Source: Data Processed by SPSS Statistical Data

Table 8

Test of Normality (Accuracy)

Tests of Normality (Accuracy)				
Treatment		Shapiro-Wilk		
		Statistic	df	Sig.
24°C	250 lux	0.947	20	0.322
	350 lux	0.936	20	0.201
	450 lux	0.907	20	0.055
28°C	250 lux	0.953	20	0.415
	350 lux	0.945	20	0.292
	450 lux	0.940	20	0.237

Source: Data Processed by SPSS Statistical Data

Table 9

Test of Normality (Stability)

Tests of Normality (Stability)				
Treatment		Shapiro-Wilk		
		Statistic	df	Sig.
24°C	250 lux	0.916	20	0.083
	350 lux	0.963	20	0.606
	450 lux	0.980	20	0.937
28°C	250 lux	0.990	20	0.999
	350 lux	0.965	20	0.641
	450 lux	0.970	20	0.765

Source: Data Processed by SPSS Statistical Data

Based on the results of the normality tests shown in Tables 7, 8, and 9, all data for the parameters of speed, accuracy, and stability are normally distributed. In Table 7, all lighting and temperature conditions show significance values greater than 0.05, indicating that the speed data are

normally distributed. The same applies to Table 8 for accuracy and Table 9 for stability, where the significance values are also greater than 0.05. Therefore, the assumption of normality is satisfied for all three parameters, allowing for further analysis using Two-Way ANOVA.

4.2.2 Homogeneity test

Homogeneity testing was conducted using SPSS version 27 to assess whether the data had equal variance across groups. According to Field (2013), a significance value above 0.05 indicates homogeneous variance. The results showed that work speed, accuracy, and stability all met this requirement, allowing the use of parametric statistical analysis.

Table 10

Homogeneity Test for Work Speed

Tests of Homogeneity of Variance (Speed)					
		Levene Statistic	df1	df2	Sig.
Speed	Based on Mean	1.088	5	114	0.371

Source: Data Processed by SPSS Statistical Data

Table 11

Homogeneity Test for Work Accuracy

Tests of Homogeneity of Variance (Accuracy)					
		Levene Statistic	df1	df2	Sig.
Accuracy	Based on Mean	1.842	5	114	0.110

Source: Data Processed by SPSS Statistical Data

Table 12

Homogeneity Test for Work Stability

Tests of Homogeneity of Variance (Stability)					
		Levene Statistic	df1	df2	Sig.
Stability	Based on Mean	2.294	5	114	0.050

Source: Data Processed by SPSS Statistical Data

Based on the results of the homogeneity of variance tests shown in Tables 10, 11, and 12, all parameters (speed, accuracy, and stability) exhibit homogeneous variance. For the work speed parameter, Table 10 shows a significance value of 0.841 (Sig. > 0.05), indicating variance homogeneity. For

the accuracy parameter, Table 11 shows a significance value of 0.110 (Sig. > 0.05), and for the stability parameter, Table 12 shows a significance value of 0.050 (Sig. > 0.05), which is at the threshold of 0.05 but still satisfies the assumption of homogeneity. Therefore, all data can be further analyzed using Two-Way ANOVA.

4.2.3 Two-Way ANOVA test

Two-Way ANOVA, as explained by Field (2013), is used to assess the individual and interaction effects of two independent variables on a dependent variable. A significance value below 0.05 indicates that the null hypothesis (H_0) is rejected. In this study, SPSS was used to analyze work speed, accuracy, and stability, with results summarized in Tables 13 to 15.

Table 13

Two-Way ANOVA for Work Speed

Tests of Between-Subjects Effects					
Dependent Variable		**Speed**			
Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Corrected Model	349.833[a]	5	69.967	49.526	0.000
Intercept	29289.688	1	29289.688	20732.840	0.000
Suhu	60.070	1	60.070	42.521	0.000
Pencahayaan	287.354	2	143.677	101.702	0.000
Suhu * Pencahayaan	2.409	2	1.205	0.853	0.429
Error	161.050	114	1.413		
Total	29800.571	120			
Corrected Total	510.883	119			

a. R Squared = 0.685 (Adjusted R Squared = 0.671)

Source: Data Processed by SPSS Statistical Data

Table 14

Two-Way ANOVA for Work Accuracy

Tests of Between-Subjects Effects					
Dependent Variable			**Accuracy**		
Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Corrected Model	653.600[a]	5	130.720	35.113	0.000
Intercept	4320.000	1	4320.000	1160.415	0.000
Suhu	177.633	1	177.633	47.715	0.000
Pencahayaan	449.150	2	224.575	60.324	0.000
Suhu * Pencahayaan	26.817	2	13.408	3.602	0.030
Error	424.400	114	3.723		
Total	5398.000	120			
Corrected Total	1078.000	119			

a. R Squared = 0.606 (Adjusted R Squared = 0.589)

Source: Data Processed by SPSS Statistical Data

Table 15

Two-Way ANOVA for Work Stability

Tests of Between-Subjects Effects					
Dependent Variable			**Stability**		
Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Corrected Model	15.829[a]	5	3.166	22.370	0.000
Intercept	379.301	1	379.301	2680.154	0.000
Suhu	4.878	1	4.878	34.465	0.000
Pencahayaan	10.503	2	5.251	37.107	0.000
Suhu * Pencahayaan	.449	2	0.224	1.585	0.209
Error	16.134	114	0.142		
Total	411.263	120			
Corrected Total	31.963	119			

a. R Squared = 0.495 (Adjusted R Squared = 0.473)

Source: Data Processed by SPSS Statistical Data

Two-Way ANOVA results showed that both lighting and temperature significantly affected work speed, accuracy, and stability (p = 0.000). For speed and stability, there was no significant interaction between the two variables, indicating they influenced performance independently. However, a significant interaction was found for accuracy (p = 0.030), suggesting that the combination of lighting and temperature can jointly impact task precision.

4.2.4 Post hoc test

According to Keppel & Wickens (2004), post hoc tests are applied after ANOVA analysis to identify which groups show significant differences when the

ANOVA results indicate such differences, typically with a significance value (Sig.) < 0.05. This test helps control the potential for Type I errors resulting from multiple comparisons and provides deeper insight into the patterns of differences between groups.

Tabel 16

Post Hoc Test for Work Speed Parameter

Multiple Comparisons						
Dependent Variable: Speed_Score						
Tukey HSD						
(I) Lighting	(J) Lighting	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
250 lux	350 lux	-3.7899*	0.26577	.000	-4.4210	-3.1587
	450 lux	-1.8367*	0.26577	.000	-2.4678	-1.2055
350 lux	250 lux	3.7899*	0.26577	.000	3.1587	4.4210
	450 lux	1.9532*	0.26577	.000	1.3221	2.5844
450 lux	250 lux	1.8367*	0.26577	.000	1.2055	2.4678
	350 lux	-1.9532*	0.26577	.000	-2.5844	-1.3221

Source: Data Processed by SPSS Statistical Data

Tabel 17

Post Hoc Test for Work Accuracy Parameter

Multiple Comparisons						
Dependent Variable: Accuracy_Score						
Tukey HSD						
(I) Lighting	(J) Lighting	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
250 lux	350 lux	4.70*	0.431	0.000	3.68	5.72
	450 lux	2.88*	0.431	0.000	1.85	3.90
350 lux	250 lux	-4.70*	0.431	0.000	-5.72	-3.68
	450 lux	-1.82*	0.431	0.000	-2.85	-.080
450 lux	250 lux	-2.88*	0.431	0.000	-3.90	-1.85
	350 lux	1.82*	0.431	0.000	0.80	2.85

Source: Data Processed by SPSS Statistical Data

Tabel 18

Post Hoc Test for Work Stability Parameter

Multiple Comparisons						
Dependent Variable: Stability_Score						
Tukey HSD						
(I) Lighting	(J) Lighting	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
250 lux	350 lux	0.7243*	.08412	0.000	0.5246	0.9241
	450 lux	0.3815*	.08412	0.000	0.1817	0.5812
350 lux	250 lux	-0.7243*	.08412	0.000	-0.9241	-0.5246
	450 lux	-0.3428*	.08412	0.000	-0.5426	-0.1431
450 lux	250 lux	-0.3815*	.08412	0.000	-0.5812	-0.1817
	350 lux	0.3428*	.08412	0.000	0.1431	0.5426

Source: Data Processed by SPSS Statistical Data

Tukey HSD post hoc tests showed that lighting significantly influenced all three parameters: speed, accuracy, and stability ($p < 0.05$). The 350 lux condition consistently yielded the best results, while both 250 lux and 450 lux led to lower performance. Temperature also had a significant effect ($p = 0.000$), with 24°C resulting in better cognitive performance than 28°C across all variables. These findings confirm that moderate lighting and cooler temperatures are optimal for maintaining speed, accuracy, and consistency in cognitive tasks.

4.3 ANALYSIS

4.3.1 Analysis of the effect of lighting levels and room temperature on work speed

Work speed is an important indicator of cognitive performance, especially in tasks requiring sustained attention. In this study, it was measured using the Kraepelin Test under various lighting and temperature conditions. The highest speed was observed at 24°C with 350 lux lighting, while the lowest occurred at 28°C with 250 lux. This suggests that cooler temperatures combined with moderate lighting enhance response time and focus.

Two-Way ANOVA results showed that both lighting and temperature significantly affect work speed ($p < 0.05$). Higher temperatures were associated with slower responses, supporting findings from previous studies (Cen *et al.*, 2025; Ranjbar, 2019).

These findings are consistent with government recommendations (Permenkes No. 405/2002; Permenaker No. 5/2018), which advise temperatures between 23°C–26°C and lighting levels between 300–500 lux for office settings. Based on Cognitive Load Theory (Sweller, 2010), such environmental conditions help reduce mental strain and support efficient task execution. Therefore, the combination of 24°C and 350 lux is considered most effective for optimizing work speed.

4.3.2 Analysis of the effect of lighting levels and room temperature on work accuracy

Work accuracy reflects an individual's precision in performing tasks that require concentration. In this study, accuracy was measured by the number of errors on the Kraepelin Test. The best accuracy was achieved under 350 lux lighting at 24°C, while the worst occurred at 250 lux and 28°C. This suggests that moderate lighting and cooler temperatures reduce errors.

Two-Way ANOVA confirmed that both lighting and temperature significantly affect accuracy ($p = 0.000$), with a significant interaction effect ($p = 0.030$). This indicates that their combination plays a role in shaping accuracy outcomes. These findings align with previous studies by Sun *et al*. (2024), which showed that poor lighting and high temperatures impair attention and increase cognitive errors.

Although 450 lux is brighter, it did not outperform 350 lux in minimizing errors. In contrast, 250 lux lighting led to more mistakes, reinforcing the importance of balanced illumination. According to Attention Resource Theory (Kahneman, 1973), inadequate environmental conditions reduce attentional resources and increase error rates.

The results support national standards (Permenkes No. 405/2002; Permenaker No. 5/2018), which recommend lighting levels of 300–500 lux and temperatures between 23°C–26°C. Thus, maintaining these conditions is essential for improving accuracy in cognitively demanding tasks.

4.3.3 Analysis of the effect of lighting levels and room temperature on work stability

Work stability reflects a person's ability to maintain consistent performance during tasks. In this study, lower scores indicated better consistency. The best stability was observed at 24°C with 350 lux lighting, while the poorest occurred at 28°C with 250 lux. This suggests that moderate lighting and cooler temperatures support performance consistency.

Two-Way ANOVA results showed significant effects of both temperature and lighting on stability (p = 0.000), while their interaction was not significant (p = 0.209), indicating independent influences. Post hoc analysis confirmed that 350 lux at 24°C provided the most stable outcomes.

These findings are supported by Hygge (2016), who noted that proper lighting reduces fluctuations in task performance. From the perspective of Executive Control Theory (Miyake & Friedman, 2012), consistent cognitive performance requires stable environmental support to sustain attention and mental energy over time.

The results align with national regulations (Permenkes No. 405/2002; Permenaker No. 5/2018), which recommend lighting levels of 300–500 lux and room temperatures between 23°C and 26°C. Thus, adopting these conditions can enhance not only comfort but also work consistency.

This study directly supports SDG 3: Good Health and Well-being. By identifying optimal environmental conditions, specifically lighting at 350 lux and temperature at 24°C that significantly improve cognitive function (speed, accuracy, and stability) and reduce errors. The findings contribute to fostering healthier and more supportive work and educational environments. Such environments are crucial for enhancing overall well-being, promoting mental efficiency, and reducing factors that contribute to stress and fatigue among individuals.

5 CONCLUSION

Based on the results of the study, it can be concluded that lighting levels have a significant effect on work speed (p = 0.000), work accuracy (p = 0.000), and work stability (p = 0.000). The lighting condition of 350 lux produced the best performance across all three parameters compared to 250 lux and 450 lux. In addition, room temperature also had a significant effect on work speed (p = 0.000), work accuracy (p = 0.000), and work stability (p = 0.000), with 24°C resulting in better performance than 28°C.

The interaction between lighting and temperature was found to have a significant effect on work accuracy (p = 0.009), but not on work speed (p =

0.296) or work stability (p = 0.209). The optimal condition for cognitive performance in the Kraepelin Test was the combination of 350 lux lighting and 24°C room temperature, which enhanced work speed, accuracy, and stability.

Thus, optimizing the work environment with bright lighting and cool temperature settings can significantly support improvements in cognitive performance and overall work effectiveness.

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