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Effects of Physical Work Environment Factors on Task Duration and Error in Manual Banking Transactions

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ABSTRACT

The manual cash handling tasks require consistent attention and precision and can be affected by the physical working conditions. The aim of this study is to examine the effects of lighting, temperature, and aroma on the task completion time and the counting errors in simulated banking teller activities. In a laboratory experiment, six participants (three males and three females) aged between 20 and 24 years were selected based on their similar money-counting skills. We used a completely randomized factorial design with 2 × 2 × 2 factors with two lighting levels (150 and 350 lux), two temperatures (24 and 26 °C) and two aromas (lemongrass and rosemary). Performance measures were time to complete the task and number of counting errors. Statistical tests including analysis of variance (ANOVA) followed by Tukey's post hoc test where applicable were used to analyze the data. The results showed that lighting and aroma had a significant impact on the task performance, especially in female participants, and temperature had a significant impact on the task completion time in male participants. Within the experimental settings, the optimal condition was identified as the combination of 150 lux, 24°C, and the lemongrass aroma. These results suggest that physical workplace conditions may influence the speed and accuracy of simulated cash-handling tasks, with possible differences in response between male and female participants. This research provides preliminary experimental evidence to consider environmental factors in the ergonomic design of workplaces for manual banking activities.

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1. Introduction

Work productivity is a key indicator of industrial performance. It reflects how effectively and efficiently employees accomplish tasks (Freivalds & Niebel, 2012). This condition not only applies to the manufacturing industry but also to the service industry. Worker productivity is commonly assessed based on task completion time and the number of errors during task execution (Belany et al., 2024; Konstantzos et al., 2020; Ansori et al., 2025; Pimpong, 2023). Task completion time represents operational efficiency, whereas error frequency reflects work accuracy and consistency (Ansori et al., 2025). Workers are expected to work productively. Therefore, understanding the factors that influence both the time required and the error is essential for improving organizational performance.

Theoretically, worker productivity is influenced by the work environment, which constitutes an important component of an organization's ecosystem (Snell et al., 2023). The work environment consists of physical and non-physical dimensions (Chenarboo et al., 2022). Physical factors include lighting, temperature, and aroma, while non-physical factors encompass interpersonal communication, organizational climate, and social interactions (Wang et al., 2015; Nematchoua et al., 2019; Loske et al., 2021; Rezaie et al., 2021). An optimal work environment supports worker comfort, safety, and psychological well-being, thereby enhancing concentration and work effectiveness. Consequently, the physical work environment can be viewed as a strategic factor that supports workers' cognitive and operational performance (Astuti et al., 2024).

Previous studies have demonstrated that physical environmental factors significantly influence cognitive functions related to work performance. Lighting has been shown to affect task completion time and visual performance across various workplace settings (Belany et al., 2024; Konstantzos et al., 2020; Rahman, 2018). Temperature influences comfort, workplace stability, and productivity Kah et al. (2022), while aroma contributes to memory enhancement, mood improvement, and physiological relaxation (Jahan et al., 2024; Sriraksa et al., 2018). In particular, lemongrass aroma has been reported to improve cognitive performance through pharmacological, psychological, and physiological mechanisms (Howes et al., 2020; Moss & Oliver, 2012; Ok et al., 2021; Rezaie et al., 2021). Furthermore, these findings indicate that lighting, temperature, and aroma are important environmental stimuli that influence workers' speed and accuracy when performing cognitive tasks.

The relevance of these factors is especially evident in banking services, where tellers routinely perform tasks that require sustained attention, working memory, and high accuracy. Interviews with bank tellers revealed that their daily responsibilities include processing cash transactions, entering customer information into banking systems, and simultaneously interacting with customers. Such activities demand continuous cognitive effort and rapid decision-making. Previous research also suggests that suboptimal environmental conditions may reduce concentration, increase fatigue, and lower service quality (Zhenjing et al., 2022). Thus, banking services provide an appropriate context for investigating how physical environmental conditions affect employee performance. Empirical observations conducted at Bank Syariah Indonesia (BSI) KCP Trunojoyo Bangkalan further support this issue. Measurements taken during different operational periods revealed fluctuations in lighting intensity and room temperature that were associated with customer traffic and tellers' activities. Although these values remained within recommended standards, environmental conditions varied throughout the day. In addition, lemongrass aroma was routinely diffused in the workspace to improve comfort and maintain a pleasant atmosphere.

These observations indicate that manual bank tellers work in dynamic environmental conditions that may affect both task completion speed and accuracy, highlighting the need for a more comprehensive investigation of physical workplace factors. Despite extensive research on the work environment, several important gaps remain. Most studies have examined lighting, temperature, and aroma separately as predictors of performance (Bueno et al., 2021; Broday & De Paula Xavier, 2020; Ok et al., 2021; Rezaie et al., 2021; Warburton et al., 2023). Moreover, Belany et al. (2024) used lighting and temperature to predict task duration, but their study considered only task duration. As a result, the combined effects of these factors remain inadequately understood. Furthermore, a related study by Doohan et al. (2023) on Systematic Review and Meta-Analysis (PRISMA) showed that task duration in most studies was partially influenced by temperature. Similarly, Li et al. (2023) stated that cognitive performance is indicated by reaction time and concentration. Previous studies have predominantly focused on a single performance. Although Ansori et al. (2025) considered task duration and number of errors concurrently, the study did not investigate the integrated influence of aroma within a unified analytical framework that compared genders. Therefore, existing literature has not yet provided a holistic understanding of how multiple physical environmental factors jointly affect worker performance. Table 1 presents the state-of-the-art (SOTA) of this research and illustrates the research contributions, including the limitations of each study.

Spektrum Industri
Vol. 24, No. 2, 2026, pp. 268–288

Table 1. State of The Art

No	Author	Year	Method	Independent Variable			Dependent Variable		Research Limitation
				Lighting	Temperature	Aroma	Task Duration	Number of Errors	
1	Broday & De Paula Xavier	2020	Probit regression model	-	V	-	-	-	Response for Actual Percentage of Dissatisfied women
2	Konstantzos et al.	2020	Analysis of variance (ANOVA), Linear mixed models	V	-	-	V	-	Single factor, single response
3	Bueno et al.	2021	A Systematic Literature Review	V	-	-	-	-	Productivity response, mostly subjective methods
4	Ok et al.	2021	T-test	-	-	V	-	-	Cognitive factors focus on memory
5	Rezaie et al.	2021	T-test	-	-	V	-	-	Single factor, female, memory response
6	Doohan et al.	2023	Systematic Review and Meta-Analysis (PRISMA)	-	V	-	V	-	Systematic review. Most task durations are influenced by temperature
7	Li et al.	2023	Review of the study	-	V	-	V	-	Cognitive performance based on reaction time and concentration
8	Warburton et al.	2023	Covariance analysis	-	-	V	-	-	Single factor, concentration-related response
9	Belany et al.	2024	Literature review	V	V	-	V	-	Single response
10	Ansori et al.	2025	ANOVA, Fisher LSD	V	V	-	V	V	No aroma, one gender
11	Proposed study	2026	ANOVA Multi response, Tukey	V	V	V	V	V	

2. Method

This research is an experimental study. The experiment was conducted in the Ergonomics and Work System Design Laboratory of the Industrial Engineering Study Program, Trunodjoyo University, Madura. Sekaran & Bougie (2016) stated that an experiment is a type of quantitative research in which numerical data are collected or analyzed in a structured, systematic, and planned manner.

Research tools used to support experimental research include: a lux meter to measure lighting, a digital hygrometer to measure room temperature, an air conditioner (AC) to regulate room temperature, a lamp for room lighting, and a KBAYBO ultrasonic air humidifier-type diffuser with lemongrass & rosemary aroma. A stopwatch to measure the time required to complete the task and a visual analogue scale questionnaire. A 2016 emission banknote to measure the duration of task completion and the number of errors. IBM SPSS Statistics 25 software to test data normality and analyze subjective data on the visual analogue scale (VAS). Minitab 19 software to assist in data processing.

2.1. Determination of Participants

Studies by Marrs & Sigler (2012);Stupurienė et al. (2022);Teplá & Distler (2025) report differences in concentration levels, motivation, and attitudes toward task completion between men and women. The proposed study was conducted with six participants (three male and three female). Consideration of limited sample assignment, as in the studies by Ansori et al. (2025);Digiesi et al. (2020);Guo et al. (2021);Riesthuis et al. (2023);Sapp et al. (2023), suggests that the number of participants in the laboratory experiment may be limited. Statistical power should be managed through the experimental design, as analytical decisions can significantly impact power, as demonstrated by Ahmed (2024);Cash et al. (2022);Serdar et al. (2021).

However, the effect size results indicate that the effect of aroma on task duration among male participants is large (Cohen's f = 0.718; η^2 = 0.340). In contrast, the effect of aroma on the number of errors in men is relatively small to moderate (f = 0.241; η^2 = 0.055). In female respondents, the effect of aroma on task duration (f = 0.322; η^2 = 0.094) and the number of errors (f = 0.298; η^2 = 0.082) is in the moderate category. As Lakens (2013) stated, experimental psychology research inherently requires examining intra-individual effects, which makes effect sizes that incorporate correlations between measurements the best summary of results.

Meanwhile, studies by Ansori et al. (2025);Reyes-Cruz et al. (2020) involved 5 participants to represent the basic competencies to be addressed. This consideration aligns with Reyes-Cruz et al. (2020), who state that the prerequisite for participants in laboratory-scale research is identical (uniform) abilities/competencies. This study involved six laboratory assistants from the Ergonomi dan Perancangan Sistem Kerja (EPSK) laboratory. It was to ensure the accuracy of the research methodology, obtain relevant participant characteristics, and reduce time and resources. This aligns with the research by Memon et al. (2025), which indicates that the purposive method is particularly effective when researchers need a well-defined group of participants who share characteristics central to the study. This is done to ensure the reliability and validity of measurements (Ahmed, 2024). In addition, the criteria for participants and pre-experimental training of operators before conducting experiments include operator selection and experimental procedures. This consideration aligns with Ansori et al. (2025);Triyanti et al. (2024), which involve students.

In this study, participants were 20–24 years old. They should have consistent (identical) performance in counting money; therefore, participants did not have any visual impairments, as described in the studies by Jafri et al. (2022);Kacorri et al. (2017) regarding the ability to distinguish objects based on shape, color, and size. Meanwhile, participants did not have a history of sensitivity to extreme temperatures, characterized by sensitive skin, such as itching, burning, or pain due to exposure to various stimuli. Also, they did not have any impairments in their sense of smell. Studies by Mullol et al. (2012);Schäfer et al. (2021) stated that a person is considered to have no olfactory impairment if they can recognize and identify distinct odors. Participants did not have any visual impairments, as described by Ffytche et al. (2011), such as difficulty seeing colored numbers and difficulty revisiting objects after not seeing them. Informed consent has been obtained from the participants. Additionally, the response evaluated in this study was a behavioral change in response to the conditioned stimulus. Therefore, the parameter evaluated was the presence of behavioral change or a response to the treatment. Therefore, even though the participants were not actors in the system being studied, evaluations could still be conducted (Ahmed, 2024; Ansori et al., 2025; Ansori et al., 2026; Triyanti et al., 2024).

2.2. Research Variables

Experimental research involves two types of variables: independent and dependent. The independent variables are lighting, temperature, and aroma, while the dependent variables are task duration and number of errors. The research was conducted in a climate room using a 2-factor design. Studies used lighting levels of 150 and 350 lux, which had the most significant impact on task completion time (Veitch, 2001; Wang et al., 2015). According to Bjarne Olesen & Ash Rae (2000); Broday & De Paula Xavier (2020);Cena & de Dear (1999);Nematchoua et al. (2019), the recommended temperature range for a comfortable workplace is 24°C to 26°C. Sriraksa et al. (2018) stated that the aroma of lemongrass can affect the nervous system, which plays a role in memory processes, including cognitive function and working memory. In addition, studies Howes et al., 2020; Moss et al. (2018);Ok et al. (2021); Rezaie et al. (2021) have shown that rosemary aroma improves aspects of cognition, including working and short-term memory, in men and women. The treatment in the study involved adding aroma to the room using a diffuser (Warburton et al., 2023). Diffusers allow the aroma to be spread evenly throughout the room. They can also distribute it over a more extended period, allowing the long-term effects of exposure on memory function to be observed. Table 2 details the independent and dependent variables.

Spektrum Industri
Vol. 24, No. 2, 2026, pp. 268–288

Table 2. Research Variable

Variable	Factor	Definition	Level
Independent Variable	Light	Climate room lighting during simulation (Veitch, 2001; Wang et al., 2015)	150 lux 350 lux
	Temperature	Climate room temperature during simulation (Broday & De Paula Xavier, 2020; Cena & de Dear, 1999; Nematchoua et al., 2019)	24°C 26°C
	Aroma	Aroma of a climate room using a diffuser when doing simulation (Howes et al., 2020; Moss & Oliver, 2012; Ok et al., 2021; Rezaie et al., 2021)	Lemongrass Rosemary
Dependent Variable	Task Duration	The time required for an operator to complete a task	
	Number of Errors	The number of errors that operators made while completing tasks	

2.3. Design of experiment

The experimental design in this study used a Completely Randomized Design (CRD) with a 2x2x2 factorial, yielding eight treatments. This experimental design was used to test the influence of physical work environment factors, namely lighting, temperature, and aroma, on task completion duration and the number of errors. Table 3 shows the experimental design of the study.

Table 3. Design of experiment

Light (lux)	Temperature (°C)	Aroma	
		Lemongrass	Rosemary
150	24	A	B
	26	C	D
350	24	E	F
	26	G	H

The number of repetitions in the experimental design is determined using the formula $t(n-1) \geq 15$, where $8(n-1) \geq 15$, so that $n \geq 2.875 \approx 3$. Therefore, the experiment was conducted with eight treatments and three replicates, yielding a total of 24 samples per response variable.

2.4. Data Collection

Data collection was conducted by simulating lighting, temperature, and aroma to assess their effects on task duration and the number of errors. The simulated activities included completing identification tasks (selecting and sorting) and counting banknotes. The testing steps included randomization, pre-experiment, and experiment. Randomization was performed to ensure that each treatment had an equal chance of inclusion in the experiment, resulting in more accurate and structured results. The distribution and sequence of the experiments were randomly assigned using Microsoft Excel based on the treatments. Prior to the experiment. Participants were briefed on the procedures to be followed during the experiment. The climate control room was adjusted to the predetermined parameters. The Kaybob ultrasonic air humidifier diffuser was conditioned to an aroma concentration of 1%: 5–6 drops of essential oil in 30 ml of water. The Kbaybo ultrasonic air humidifier diffuser was placed at a distance of 50–100 cm to affect physiological and psychological conditions, including improving participants' concentration (Warburton et al., 2023).

Meanwhile, in the studies of Moss et al. (2018);Moss & Oliver (2012), aromatherapy was activated for 5 minutes before the experiment. Meanwhile, to confirm that participants meet the prerequisites, participants should undergo a visual acuity test using the Hess Chart and Checker Board methods. The Hess Chart is a test that uses objects represented as numbers, grouped by difficulty level. Meanwhile, the Checker Board is a test that uses objects arranged in a black-and-white checkered pattern, with a viewing distance of approximately 6 meters (Rufli et al., 2008).

Then, participants underwent a color blindness test using the Ishihara method, using colored circles, some of which contain specific numbers or patterns (Utama et al., 2016). Last, participants were asked to count a stack of money (100 bills) under normal conditions without the distractions of lighting, temperature, or odor. The time required to complete the count was recorded. According to Zhenjing et al. (2022), completing manual counts within 15 to 30 seconds is considered proficient for tellers. If the pre-experimental results show that participants manually count money for more than 30 seconds, they are categorized as not proficient.

After conducting a pre-experiment briefing and adjusting the climate room conditions to the predetermined parameters, participants then conducted the experimental test, firstly by adjusting the climate room conditions to the experimental conditions according to the predetermined factor levels. The lighting factor was measured with an illuminance meter, and the temperature factor with a digital hygro-thermometer placed near the participants to ensure accurate results. Then, prepare the task of identifying (selecting, sorting), and counting banknotes. Participants were given a stack of banknotes totaling a specific amount, consisting of denominations of Rp 1.000, Rp 2.000, Rp 5.000, Rp 10.000, Rp 20.000, Rp 50.000, and Rp 100.000, with the total randomly selected within a specific range. Fig. 1 shows a randomly assigned banknote.



Fig. 1. Emission banknote size of 2022 (https://www.bi.go.id/id/rupiah/gambar-uang)

Participants were asked to manually sort, select, and count banknotes according to the specified denominations. Task instructions were provided to participants using a monitor. Variations in the format of this task significantly affected working memory performance. This activity used various colored banknote denominations, thereby involving not only the counting process but also participants' visual engagement. Several previous studies have shown that color plays a significant role in influencing cognition. Red can improve focus on details, while blue enhances creativity. Meanwhile, the green speeds up reaction time in the early stages of working memory impairment. Examples of task instructions were providing five Rp 20.000 bills, five Rp 10.000 bills, five Rp 5.000 bills, and five Rp 2.000 bills as the first scenario. Providing Rp 455.000 in denominations of 100.000, Rp 20.000, Rp 10.000, Rp 5.000, and Rp 2.000 as the second scenario. After completing the task, participants were asked to complete a questionnaire using a visual analogue scale to confirm the aroma. As explained in Triscoli et al. (2014), participants were asked to evaluate their desire on a scale from "not at all" (-10) to "very much" (+10). Furthermore, errors could occur when using the wrong denomination, even if the total was correct. Example: Asked for Rp 50.000, but the participant gave two Rp 20.000 notes and one Rp 10.000 note, when it should have been one Rp 50.000 note. Misidentifying the denomination of the money, for example, mixing up Rp 2.000 and Rp 20.000 notes. The participant incorrectly recounts the amount of money they have chosen before handing it over.

Spektrum Industri
Vol. 24, No. 2, 2026, pp. 268–288

3. Results and Discussion

Pre-experimentation is carried out to confirm that the participant criteria are met. Firstly, the eye sharpness test was carried out using a checkerboard and a Hess chart. This test is conducted to ensure that participants have uniform visual acuity when observing the given object or task. Visual sharpness is considered normal if participants can correctly recognize at least 80% of the patterns (Triscoli et al., 2014). Based on the test results, all participants meet the criteria, indicating good visual sharpness and eligibility to proceed to the following experimental stage. Next, a color-blindness test is conducted. This test uses the Ishihara Color Test method, which consists of a series of images with a number pattern or a hidden path formed by different-colored points. This test aims to identify whether participants have color perception disorders (Utama et al., 2016). Fig. 2 shows the process of conducting color-blind tests with male and female participants. The test results show that all participants can correctly identify numbers on the Ishihara card, so they are not considered to have color blindness.

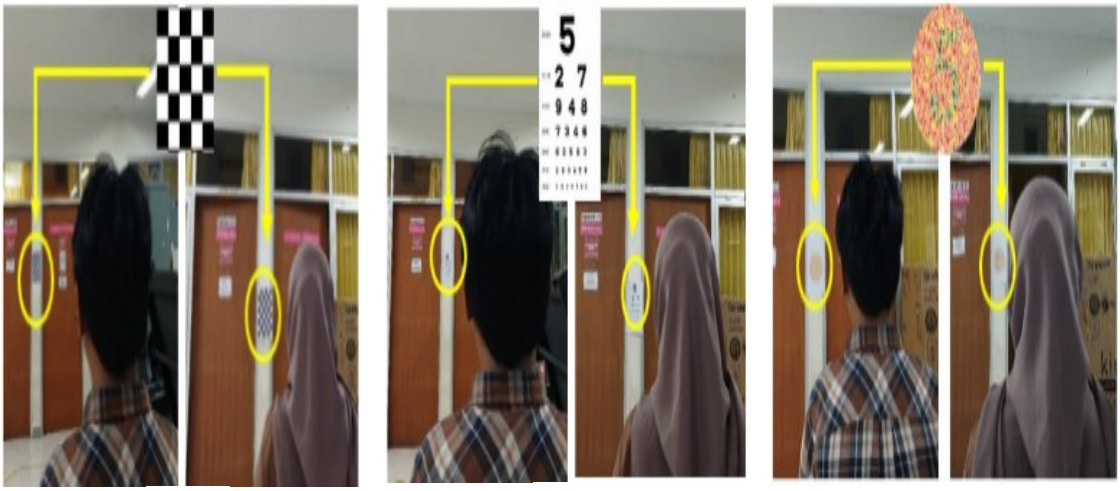


Fig. 2. Checkerboard (A), Hess chart (B), and color blindness (C) visual acuity tests

Table 4. Duration of participants counting money

No	Participant	Paper money	Duration (Second)
1			49
2	Male		68
3		100	64
4			72
5	Female		58
6			68

Table 5. Completely Randomized Design

No	Experiment Code	Light (lux)	Temperature (°C)	Aroma
1	A	150	24	Lemongrass
2	E	350	24	Lemongrass
3	H	350	26	Rosemary
4	F	350	24	Rosemary
5	G	350	26	Lemongrass
6	C	150	26	Lemongrass
7	D	150	26	Rosemary
8	B	150	24	Rosemary

The next test assesses the ability to calculate money. Zhenjing et al. (2022) state that the standard time for completing manual calculations, 15 to 30 seconds, is categorized as adept; if longer, it is classified as not proficient. Table 4 shows the duration response used to calculate the cost of one pile of money (100 sheets). Male participants need a long time to count more than 30 seconds in a row: 49 seconds, 68 seconds, 64 seconds, whereas female participants also need more than 30 seconds: 72 seconds, 58 seconds, 68 seconds. The conclusion is that three male participants and three female participants are not proficient.



Fig. 3. Simulation of task completion for male and female participants

The simulation is conducted by measuring two response variables: the duration of task completion and the number of task-completion errors. Data collection was carried out using a Complete Randomized Design (CRD), with randomization implemented in Microsoft Excel. Randomization aims to minimize bias in the order of participants' treatment, so that the results obtained are more objective. The formation of treatments in the data collection process is shown in Table 5. Male and female participants collect data in accordance with the previously specified treatment sequence. Each participant undergoes all combinations of treatment, namely lighting, temperature, and aroma, under the set conditions. Fig. 3 shows one of the participants, male and female, when carrying out experimental tasks, namely sorting, selecting, and calculating banknotes according to the instructions displayed.

3.1. Task Duration Response

The fastest task durations for male participants were obtained with 150 lux lighting, a temperature of 24°C, and a lemongrass aroma of 243 seconds. Conversely, the longest task duration was achieved with 350 lux lighting, a temperature of 24°C, and a rosemary aroma, lasting 290 seconds. Meanwhile, the fastest task duration for female participants was achieved under 150 lux lighting, at 26°C, and with a lemongrass aroma, in 245 seconds.

Spektrum Industri
Vol. 24, No. 2, 2026, pp. 268–288

Table 6. Task duration response

Factor		Male		Female	
Light (lux)	**Temperature (°C)**	**Lemongrass**	**Rosemary**	**Lemongrass**	**Rosemary**
150	24	260	267	251	256
		254	257	262	256
		243	262	265	259
	26	263	272	245	260
		257	279	249	256
		272	278	264	261
350	24	262	290	266	266
		268	283	267	271
		267	283	263	270
	26	263	279	265	263
		280	287	255	276
		268	280	261	273

Note: all measurements are in seconds

Conversely, the longest task duration was obtained with 350 lux lighting, a temperature of 26°C, and a rosemary aroma of 276 seconds. Specifically, Park et al. (2013) explained that 150 lux lighting stimulates theta-wave activity associated with memory workload and attention, thereby increasing focus. Conversely, excessively high temperatures increase physiological and mental load, thereby prolonging task completion time (Li et al., 2023). Similarly, Doohan et al. (2023) reported that increased heat load affects reaction time, memory, and performance on the Stroop task, especially when accompanied by dehydration or prolonged work duration. Table 6 shows the response of task duration in male and female participants.

3.2. Response Number of Errors

The smallest number of errors (no error) was found in female participants in the interaction of 150 lux and a temperature of 24°C, as was the case with their interactions. Meanwhile, the most frequent mistakes among female participants occurred under 150 lux lighting, at 24°C, and with a lemongrass scent, with four errors. In male participants, the most common number of mistakes was one. Meanwhile, the most frequent errors occurred under 350 lux lighting at 24°C with the rosemary scent, with four errors. Errors often occurred among both male and female participants when they incorrectly recalculated the amount of money they had selected before handing it over and gave the wrong denomination as instructed. These results align with a study by Mostafavi et al. (2023) that found that lighting at 100–300 lux can reduce visual and cognitive load during detail-processing activities. In fact, high levels of lighting tend to cause glare and eye fatigue, which can lead to visual impairment. Table 7 shows the number of errors by gender.

Table 7. Number of errors Response

Factor		Male		Female	
Light (lux)	**Temperature (°C)**	**Lemongrass**	**Rosemary**	**Lemongrass**	**Rosemary**
150	24	3	3	3	3
		3	2	4	2
		1	1	0	1
	26	2	2	2	1
		2	1	0	2
		1	1	2	2
350	24	1	2	1	3
		1	2	1	2
		2	4	2	3
	26	3	3	3	2
		1	3	1	3
		1	2	1	3

3.3. Independent sample t-test

The results of the independent-samples t-test were used to analyze the different influences of lighting, temperature, and aroma on both responses (task duration and the number of errors). Table 8 shows the results of the T-test for the three factors on task duration and errors in male and female participants.

Table 8. Independent sample t-test of responses

Factors	Task Assignment		Error	
	Male	Female	Male	Female
Light	-4.09**	-0.39	-0.58	-0.39
Temperature	-2.11*	0.59	1.56	0.59
Aroma	-4.47**	-2.01*	-1.36	-2.01*

Note: **p<0.01; *p<0.05

Consequently, differences in lighting levels (t=-4.09, p<0.01), temperature (t=-2.11, p<0.05), and aroma (t=-4.47, p<0.01) influenced the time to complete the task among male participants. Meanwhile, only the aroma level (t=-2.01, p<0.05) differed in the duration of task completion among female participants. On the other hand, only a difference in the number of errors by aroma level was found among female participants (t=-2.01, p<0.05). These results are consistent with previous research indicating that lighting, temperature, and aroma significantly influence cognitive performance and work effectiveness. Research by Park et al. (2013) showed that optimal lighting can improve the process of maintaining information in working memory. Meanwhile, Lan et al. (2022) found that an optimal temperature indicates a relaxed, comfortable state, which supports better thinking processes and concentration. Jahan et al. (2024) also, explained that optimal aroma factors can help increase concentration.

The effect of temperature was not statistically significant due to other factors affecting comfort and cognitive performance, such as humidity and air circulation. According to Dupont et al. (2023), if other environmental factors do not vary drastically, the effect of temperature on cognitive performance may be insignificant. Furthermore, it is closely related to the participant's ability to adapt to environmental conditions, and the intensity of interference from the three factors is insufficient to influence the number of errors. The study explained that suboptimal lighting test results can be caused by eye fatigue. Furthermore, Lan et al. (2022) demonstrated that when the temperature range is narrow, the difference is insufficient to produce significant changes. Moss & Oliver (2012) stated that the duration of exposure to aromas and the methods of distribution may not be optimal to produce substantial effects. Furthermore, ANOVA was used to analyze the impact of lighting, temperature, and aroma on the response variables of task duration and the number of errors made by male and female participants.

3.4. ANOVA Test of Task Duration Response

Based on the ANOVA, there was a significant effect of lighting, temperature, and aroma on task duration in male participants. The factors were lighting (F=27.05; p<0.01), temperature (F=8.41; p<0.05), aroma (F=31.10; p<0.01), and the interaction of lighting with temperature (F=6.73; p<0.05) (Table 9). This shows that the three factors, individually and in interaction, have a significant influence on the duration of task completion.

On the other hand, the interaction between lighting and aroma (F=1.04; p>0.05), as well as the combination of lighting, temperature, and aroma (F=1.41; p>0.05), showed no significant value. This means that the interaction between the three factors did not provide a different effect on the duration of task completion. Although each factor individually influenced the outcome, the combined effect of factors, especially those involving aroma, did not yield a statistically significant interaction. The lack of sufficient evidence of insignificance may suggest that aroma tends to act independently and does not always provide additional effects when combined with other environmental factors, such as lighting or temperature. This is in line with the findings of Herz (2009), who stated that responses to

Spektrum Industri
Vol. 24, No. 2, 2026, pp. 268–288

aroma vary significantly between individuals, influenced by personal experience, odor preferences, and current emotional states. A brief overview is provided in Table 9.

Table 9. ANOVA test of duration

Factors	DF	Male			Female		
		Adj SS	Adj MS	F-Value	Adj SS	Adj MS	F-Value
Light	1	2.725.7	2,725.7	27.05**	1.568	1.568.00	26.54**
Temperature	1	847.3	847.35	8.41*	68.06	68.06	1.15
Aroma	1	3.133.7	3,133.7	31.10**	364.5	364.50	6.17*
Light * Temperature	1	678.3	678.35	6.73*	2.72	2.72	0.05
Light *Aroma	1	105.1	105.12	1.04	93.39	93.39	1.58
Temperature *Type of Aroma	1	39.0	39.01	0.39	242.00	242.00	4.1*
Light * Temperature * Aroma	1	141.7	141.68	1.41	5.56	5.56	0.09
Error	64	6.448	100.75		3.780.89	59.08	
Total	71	14.118.90			6.125.11		

Note: **p<0.01; *p<0.05

Furthermore, in response to females, lighting affected task duration by (F=26.54; p<0.01) and aroma by (F=6.17; p<0.05). This means there is a significant difference in task duration across variations in lighting levels and aroma types. Meanwhile, the temperature factor did not show a considerable effect individually (F=1.15; p>0.05). The temperature had no significant impact, either individually or in combination with other factors. However, there may be an undetected effect, as the temperature used in the experiment was within a thermal range that did not significantly interfere with performance. Lan et al. (2022) explained that when the temperature range is narrow, the difference is insufficient to produce significant changes.

The ANOVA test results show that lighting significantly influences task duration for both males and females. There is insufficient evidence that the number of errors has a significant effect, so it is possible that specific light intensities can increase or decrease concentration, according to the results of research by Boyce (2022), which states that optimal lighting and appropriate lighting design can contribute to comfort and work motivation, which can indirectly affect concentration and performance. For the temperature variable, a significant effect was observed only in male participants, whereas no significant effect was observed in female participants. This is likely because women's bodies tend to have a wider temperature tolerance, so temperature changes in the 24–26°C range do not significantly affect their work performance.

A study by Lan et al. (2010) supports this, stating that women tend to feel comfortable over a wider temperature range than men, who are more sensitive to changes in workspace temperature. This study is in line with Greenfield et al. (2023), who report innate differences in thermal sensation between men and women, in which women's initial vasomotor response to environmental stress and changes in blood flow contribute more to increased thermal awareness. Meanwhile, the combination of temperature and aroma for the female's task completion time, and of lighting and aroma for the female's error counts, produced significant results. Women may be more responsive to combinations of environmental variables, as Andreucci et al. (2021) found that women exhibit greater physiological reactivity to combinations of sensory stressors.

3.5. ANOVA Test Response Error

Based on the ANOVA results for the lighting, temperature, and aroma variables on the response of errors in both genders. However, aroma significantly influences error in females. Lighting factors (F=0.35 in male and F=0.16 in female, where p>0.05), temperature (F=2.49 in male and F=0.37 in female, where p>0.05), and aroma (F=1.9; p>0.05 in male but F=4.06; p<0.05 in female). There were interactions among lighting and temperature, lighting and aroma, temperature and aroma, and among the three factors: lighting, temperature, and aroma.

Table 10. ANOVA test of the number of errors

Factors	Male				Female		
	DF	Adj SS	Adj MS	F-Value	Adj SS	Adj MS	F-Value
Light	1	0.50	0.50	0.35	0.22	0.22	0.16
Temperature	1	3.56	3.56	2.49	0.50	0.50	0.37
Aroma	1	2.72	2.72	1.9	5.56	5.56	4.06*
Light * Temperature	1	1.39	1.39	0.97	2.00	2.00	1.46
Light *Aroma	1	5.56	5.56	3.88	4.50	4.50	3.29
Temperature *Type of Aroma	1	0.50	0.50	0.35	0.22	0.22	0.16
Light * Temperature * Aroma	1	0.22	0.22	0.16	1.39	1.39	1.02
Error	64	91.56	1.43		87.56	1.37	
Total	71	106.00			101.94		

Note: *p<0.05

There was insufficient evidence that these physical work environment factors were driven by other factors, such as work speed, comfort level, or concentration, rather than directly affecting accuracy or the number of errors. This aligns with the findings of Andreucci et al. (2021), who found that lighting affects productivity and comfort, with no difference in the number of errors. Likewise, research by Young et al. (2015) shows that work performance, including error and accuracy levels, is influenced not only by physical environmental factors but also by non-environmental factors such as mental workload, training, and work experience. The ANOVA results for the number of errors are shown in Table 10.

3.6. Post Hoc Test Response Task Duration and Error

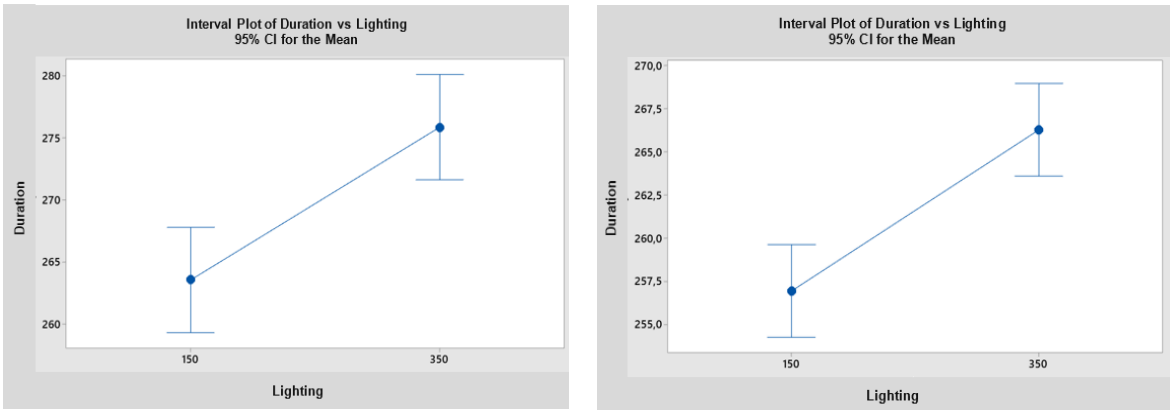
Based on the ANOVA, variance in task duration was found between male and female participants; therefore, a further test (post hoc test) was conducted. According to Young et al. (2015), the Tukey test is used to compare factor levels in detail after a significant effect is found in the three-way ANOVA. Table 11 shows the results of the Tukey test, in which differences in factor levels influencing task duration between male and female participants are lighting and aroma. Meanwhile, temperature differences only apply to male participants. Furthermore, only temperature influences error in female participants.

Table 11. Tukey test for duration and error

Level	N	Duration				Error			
		Male		Female		Male		Female	
		Mean	Grouping	Mean	Grouping	Mean	Grouping	Mean	Grouping
Lighting									
350	36	275.86	A	266.278	A	N/A	N/A	N/A	N/A
150	36	263.56	B	256.944	B	N/A	N/A	N/A	N/A
Temperature									
350	36	273.14	A	N/A	N/A	N/A	N/A	N/A	N/A
150	36	266.28	B	N/A	N/A	N/A	N/A	N/A	N/A
Aroma									
350	36	276.31	A	263.861	A	N/A	N/A	2.25	A
150	36	263.11	B	259.361	B	N/A	N/A	1.69	B

The results of the Tukey test for male participants can be described as in Fig. 4(A), where at 150 lux lighting, the average task completion was 263.56 on cognitive load (task), where performance in concentration was stable, so that participants were able to maintain performance efficiently. At 350 lux lighting, with an average duration of 275.86, participants performed better. On the other hand, Fig. 4(B) shows the distribution of female participants under 150 lux lighting, where the average task completion was 256.94 seconds; this condition is likely to provide a more conducive atmosphere for increasing focus and concentration during task completion, compared to 350 lux lighting, with an average of 266.28 seconds.

Spektrum Industri
Vol. 24, No. 2, 2026, pp. 268–288



(A) **(B)**

Fig. 4. Interaction plot of the interval of lighting on duration for male **(A)** and female **(B)**

These results are in line with Park et al. (2013), who found that 150-lux lighting can increase theta-wave activity associated with memory workload and attention, reflecting increased internal focus and work efficiency. Meanwhile, Fig. 5 shows that the average task duration for male participants at 24°C was 266.28, which was faster than at 26°C (273.14). A cooler environment likely helps maintain comfort and prevent heat-related declines in concentration. This condition aligns with Lan et al. (2022), which states that a temperature of 24°C can increase parasympathetic activity (the body's nervous system) in a relaxed, comfortable state, supporting better thinking processes and concentration.

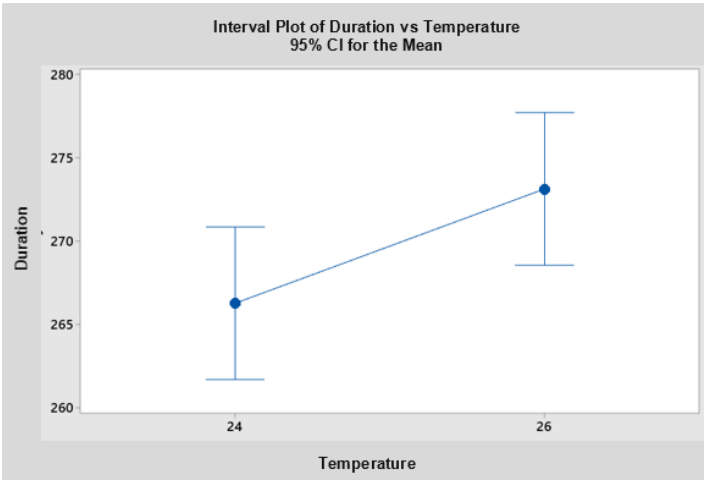
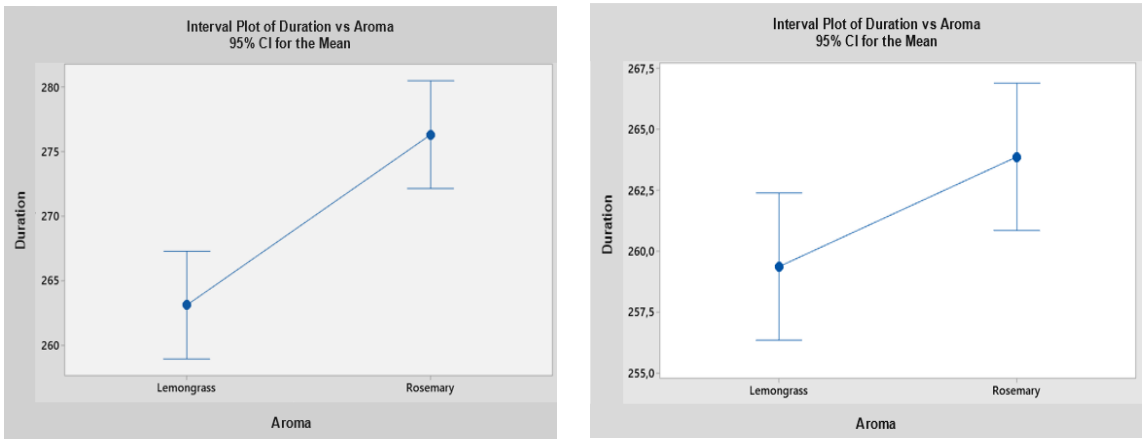


Fig. 5. Interval plot of temperature on the duration of completion for males

On the other hand, Fig. 6(A) shows that, for male participants, the aroma of lemongrass can reduce the completion time to only 263.11 seconds. This means the aroma has a relaxing effect that can reduce sympathetic activity and increase calmness, thereby improving cognitive performance during task completion. In contrast, rosemary requires an average duration of 276.31 seconds, which is not suitable for monotonous tasks that require high accuracy. This is in line with Jahan et al. (2024), who found that lemongrass can increase mental relaxation while enhancing alertness and concentration.



(A) **(B)**

Fig. 6. Interval plot of aroma on duration for male **(A)** and female **(B)**

On the other hand, Fig. 6(B) shows that the average distribution of lemongrass aroma of 259.36 seconds by female participants can create a more stable and focused mental state during task completion, compared to the scent of rosemary, with an average of 263.86 seconds. These results are in line with research by Sriraksa et al. (2018). The calming effect and increased concentration from the lemongrass aroma help reduce cognitive load, enabling participants to complete tasks more accurately. Fig. 7 shows that the lemongrass scent had the potential to cause 1.69 errors in female participants, compared with the rosemary scent, which had an average of 2.25 errors. These results are in line with Sriraksa et al. (2018), who found that inhalation of lemongrass oil can improve concentration and memory quality and provide a psychologically calming effect.

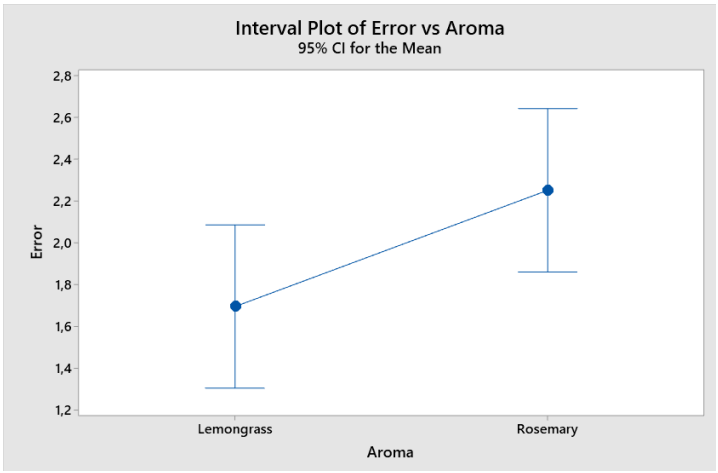


Fig. 7. Interval plot of aroma on the number of errors for females

3.7. Proposed Improvements to Physical Work Environment Parameters

After ANOVA and Tukey tests, significant differences among factor levels were found in several treatment combinations. To determine the optimal physical work environment conditions, the average (mean) values for each treatment were compared for both task duration and the number of errors. This approach is consistent with the method used in the study by Kazemi et al. (2018), who compared lighting conditions and recommended cool-color-temperature LEDs as the optimal condition based on the highest mean value after statistical analysis. Dianat et al. (2013) also explained that the use of the average (mean) value as the basis for determining optimal work environment parameters is supported by the results of statistical tests that show significant differences between

Spektrum Industri
Vol. 24, No. 2, 2026, pp. 268–288

factors, as well as the suitability of the mean value with the perception of responses to the best conditions in the work environment. Test results show that 150 lux lighting yields a shorter task duration than 350 lux, both in males (263.56 < 275.86 seconds) and in females (256.94 < 266.28 seconds). Therefore, 150 lux is recommended as a lighting intensity that better supports work efficiency. A study by Mostafavi et al. (2023) showed that lighting at 100–300 lux significantly reduces visual and cognitive load during detail-processing activities. Lighting that is too high tends to cause glare and eye fatigue, while lighting that is too low can reduce visual accuracy. The adjustment to 150 lux is equivalent to a lamp power of 6 watts/m² and is in accordance with standard workspace requirements.

The temperature factor in male participants showed better results at 24°C (266.28 seconds) than at 26°C (273.14 seconds), with the most significant difference observed in male participants. Lower temperatures within the ideal range tend to increase work speed and minimize errors. These results are from Lin et al. (2025), which showed that temperatures in the range of 21–25°C improve cognitive performance and work speed during patterned activities. It is still within the ideal range, as specified in the Decree of the Minister of Health of the Republic of Indonesia Number 1405/Menkes/SK/XI/2002 (Kepmenkes RI No. 1405/MENKES/SK/XI, 2020), namely 23–28°C. However, among female participants, a temperature of 24°C was associated with a faster completion time, though the difference was not significant. Lemongrass aroma consistently resulted in a faster mean task duration and fewer errors than rosemary, both in males (263.11 < 276.31) and in females (259.36 < 263.86). This suggests that lemongrass has a positive effect on focus and calmness during work. Research by Sriraksa et al. (2018) corroborates the test results ($p < 0.05$) and reports that inhaling lemongrass aroma significantly improves short-term memory, thereby enhancing performance on repetitive tasks.

This effect was more pronounced in male participants for task duration and in female participants for accuracy or the number of errors. This indicates that aroma stimuli are more effective at influencing women's mood and accuracy while working. Higher olfactory sensitivity is observed in women, as reported by Herz (2009), who found that women exhibit stronger emotional and cognitive responses to aroma stimuli than men do. This occurs because neurological and sensory differences generally exist between the sexes, such as those in the laterality of amygdala activity, sensitivity and discrimination in vision processing, and neuronal cell death (apoptosis) pathways (Reschke et al., 2014). Furthermore, a meta-analysis by Sorokowski et al. (2019) showed that women generally outperform men in olfactory ability. Based on statistical test results and mean performance values, the combination of 150 lux lighting, a temperature of 24°C, and a lemongrass scent is recommended as the optimal physical work environment. This combination can accelerate task completion and reduce the risk of errors, especially among female participants. Although not all significant results were found in every group, this recommendation remains within the standard range of work comfort. It is suitable for repetitive numerical tasks, such as those performed by bank tellers.

3.8. Research Implication

This study provides insights into managing the physical work environment to enhance optimal worker productivity. Optimization parameters: This study designed an optimal parameter design considering multiple responses using a Completely Randomized Design (CRD). Optimal factor level results can serve as a reference for setting the physical work environment. Determining the factor levels for response duration and number of errors yielded different parameters. These results indicate that when partial response references are used, field treatments also differ. The presence of insignificant factor level combinations indicates the insensitivity of the conditioned factors. The differences in results in treatment units based on gender indicate the need for attention to conditioning the physical work environment based on gender.

4. Conclusion

Lower illumination and temperature, as well as exposure to lemongrass aroma, resulted in shorter work times. Lemongrass not only led to faster task completion than rosemary but also reduced errors, especially among female participants. The optimal conditions for the physical work environment are 150 lux of illumination, 24°C, and a lemongrass aroma. The implications of this study are that attention to lighting and the provision of aroma stimuli are needed for bank work environment design. This can stimulate cognitive ergonomics and studies on manual work system development. This combination can be applied to create a work environment that supports productivity and cognitive work efficiency for both men and women. Limitations and Future Research: This research has a small sample size. Then, the results have limited generalizability since the laboratory conditions do not fully reflect a real-world work environment.

Author Contribution: All authors contributed to this paper. The design of the methodology, data analysis, and interpretation was performed by Author 1. The laboratory experiment and data collection analysis were led by Author 2. Preparing the discussion and conclusions was managed by Author 3. The review writing and final text approval were supported by Author 4. All authors read and approved the final paper.

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Declaration of AI-Tool Usage: AI-assisted tools were used to support manuscript proofreading, verify the consistency of variables and mathematical notation, and check reference formatting. All outputs were reviewed and verified by the authors, who take full responsibility for the accuracy and integrity of the final manuscript.

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