Effects of the Physical Work Environments to the Reaction Time of Students

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Abstract

Physical environments like noise, temperature, and illumination are frequently associated with students' participation and academic performance. This study aimed to identify the effects of the physical learning environment on the learnability and engagement of students during online classes. A total of 30 Grade 12 students from Mapúa University, during the academic year 2020–2021 were chosen as the correspondents. Survey questionnaires were provided to collect information from the respondents' demographic profiles as well as measures for the sources of the work environment such as the source of light, noise, and temperature. Furthermore, the student's reaction time was measured using the Stroop Test Experiment through CogLab: The Online Cognition Lab software, while the assessment of their physical learning environment was obtained using mobile applications. From the data gathered, the correlational analysis was used to evaluate the relationship of the independent variable (physical environment levels) to the dependent variable (reaction time). Subsequently, multiple regression analysis was used to determine the significant factor affecting the reaction time of students. Results showed from the correlation analysis that illumination and noise level have significant relationships to the reaction time of students, having p-value <0.0001 and Pearson correlation of -0.902 and 0.865 respectively. Moreover, it was found that illumination level was the only factor that significantly affects the reaction time the most (p-value<0.001).

1. Introduction

In 2014, Asiyai stated that a classroom's physical environment condition significantly affects the students' motivation to engage in classroom activities. It can influence students' behavior, attendance, health, enjoyment, and learning (Asiyai, 2014; Che Ahmad & Amirul, 2019). Cantrell (2019) also added that teachers should create a positive physical learning environment to make students feel emotionally and physically comfortable learning in the classroom. Otherwise, a poor, substandard classroom physical environment is just as detrimental to the students' learning as a bad curriculum (Hannah, 2013). Physical environments like noise, temperature, and illumination are frequently associated with the student's participation and academic performance. The learnability of students is physiologically and psychologically affected by these factors. According to Barth et al. (2014), poor workplaces were correlated with substandard ranges of students' aggression and academic focus. Edem et al. (2017) added that students and employees' productivity decreased because of poorly planned environmental workplaces as it resulted in no motivation and no work satisfaction. In the study of Gilavand (2016), noise pollution, inappropriate lighting, and temperature played a vital role in students' education quality. Ergonomically speaking, the design of learning environments is necessary to optimize human interaction with peers and improve academic and work resilience. Students are also seen to perform well in a lively workplace atmosphere where they feel safe, secure, and involved (Suleman & Hussain, 2014). There has been a significant number of studies that aim to identify the effects of physical environments, such as illumination, noise, and temperature, on a student's academic performance. However, those particular studies did not satisfy the statement of the problem of this research. The physical learning environment was different due to the COVID-19 pandemic; instead of researching students inside the classrooms, observations and assessments were done at home where the students are currently studying. The researchers made use of online forms (i.e., Google Forms), suitable in the current situation.

1.1 Objectives

Given this condition, this study evaluated the current physical work environment of students studying at home. The researchers described how physical work environments, such as noise, temperature, and illumination, affected the students' reaction time in an online setting. In line with this, the researchers conducted survey questionnaires, actual observations, and assessments to design an ergonomic work environment for students studying at home.

2. Literature Review

Within learning, spaces existed different environmental elements, with illumination, noise, and temperature is the most noticeable. The elements stated were factors that affect the students' learning capabilities as well as their engagement in and during classes, both physiologically and psychologically. These skills, learning capabilities, and engagement in classes assisted the student to easily accomplish their tasks at an effortless and fast pace while enabling them to participate at the same time. When the said skills are affected or impaired, changes were seen at a prominent scale by the results of their academic works or difference in a student's physical nature. With the majority of students today attending online classes, these environmental factors were more influential to them, with a higher chance of affecting their performance.

2.1. Physical Environment Factors that Affect the Learnability of Students

Lighting is an essential factor in the brain's capability to focus. Mott et al. (2012) and Gilavand (2016) stated that light is essential to the human condition and is universally understood. "By improving the natural lighting, students' intellectual ability and behavior, mental state, and moods are improved" (Shishegar & Boubreki, 2016; Arabi et al., 2018). Thus, a student's academic performance is greatly influenced by different levels of illumination inside the classroom (Arabi et al., 2018 as cited in Samani & Samani, 2012). In a study by Gilavand et al. (2016), it was mentioned that an individual's comfort within a space is affected by the quality and amount of light. Zannin and Marcon (2007) as cited in the study of Gilavand (2016) analyzed how various types of illumination such as warm white, cool white, and full-spectrum fluorescent have impacts on multiple variables (i.e. cognitive achievement, room pleasure). It was later found that with regards to the variables, there are no differences between all that was mentioned. It was concluded that warm or cool white is more preferable to the full-spectrum fluorescent. Vi Le et al. (2016) show that the mean illuminance level that is acceptable and suitable for the classroom is 300 lux above the recommended level.

Mott et al. (2012) studied the illumination affects the sleep, mood, concentration, attention, and academic performance of students. Artificial lighting systems cater to humans by dynamic lighting technology in their actualization, allowing varying lighting conditions per project. Either focus (6000K 100fc average maintained) or standard illumination is introduced to a total of 84 third graders. A high percentage of 36% is increased in oral reading performance through focused lighting than control lighting with a percentage of 17. No effects in the motivation, likely due to the younger age level of the respondents, were found. Samani and Samani (2012) claim that for any room that is designed for broadcasting presentation and practice or expected to help collaboration or individuals, good lighting is very critical. For reading or other visual tasks, a necessary and adequate lighting system is required.

Students spending most of their time at school compared to any other building except their homes emphasizes the importance of a comfortable indoor thermal learning environment (Zomorodian et al., 2016 as cited in Chiu et al., 2017). According to Singh et al. (2018), the quality of the thermal environment influences a student's performance and well-being. Several studies found that the thermal comfort of students is related to their productivity, and it is becoming a requirement in institutions to allow students to learn efficiently (Hamzah et al., 2018). A review of 81 research articles showed that students were not satisfied with their indoor thermal learning environment (Singh et al., 2018).

2.2. Physiological Effects of a Poor Work Environment

According to Suleman and Hussain (2014), students are predicted to work well in a positive classroom atmosphere where they feel safe and wanted. In 2014, Suleman and Hussain conducted a study where they used a pre-test and post-test technique to determine the impacts of a classroom's physical environment on the academic scores of secondary school students. The results show that a classroom with pleasing surroundings has a positive outcome on the scores of secondary school students; the students of the experimental group performed better in comparison to the students of the control group. The research suggests that classrooms must be well-organized, equipped, and facilitated (Suleman & Hussain, 2014). Meanwhile, mediocre classroom environments were often linked with student aggression, peer relations, and focus (Barth et al., 2004).

It is possible to think of the working world simply as the place where people spend their time the most. Several properties in work environments can influence both physical and psychological well-being. There were three kinds of things considered. It has been shown that different facets (i.e., heat, noise, and lighting) directly and indirectly affect different psychological processes (Briner, 2014). Edem et al. (2017) argued that the productivity and efficiency of employees will decrease because of poorly designed work environments. In addition, it affects their morale and could give rise to low motivation and no work pleasure. It is a challenge to provide a safe work environment for workers and students to ensure health, quality, productivity, and good results.

Poor working light conditions are factors that can lead to depression, especially for students striving to have good grades. Temperatures such as humidity and airflow, also have a major impact on students' outdoor and indoor studies. Thermoregulatory indicates that temperature can cause an overlap of mood regulation, and may be linked and irritated by the weather and individual mood (Boker et al., 2008). According to Melamed et al. (1992), noise exposure can also lead to irritation, somatic complaints, and depression of students. Noise irritation is often correlated with students' noise sensitivity. There are proven ties between notable problems in the physical environment that can lead to stress and a broad scale of mental state issues.

Physical environments such as illumination, noise, and temperature play a critical role in the students’ engagement and academic performance. Studies show that these factors dramatically affect students’ learning outcomes in different learning environments. Noise pollution and inappropriate lighting and temperatures cause loss of focus, exhaustion, and discomfort to students. Lewiski (2015) argued that classroom features should not be destructing or upsetting.

2. Methods

This research used a quantitative - experimental design utilizing the correlation and regression technique. A quantitative design is performed in a more structured setting that enables the researchers to control the study variables and objectives (Rutberg & Bouikidis, 2018).

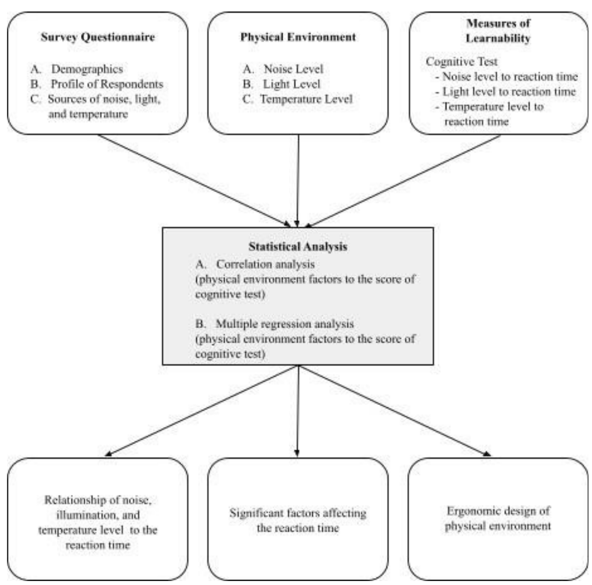

Figure 1. Conceptual framework

As shown in Figure 1, survey questionnaires were provided to collect necessary information from the respondents' demographics, profile, and source of light, noise, and temperature. The physical environment (i.e., noise, light, and temperature) levels were measured using meter applications. Furthermore, cognitive tests were conducted to measure the participants' physical environment levels to their reaction time while taking the test. From the data gathered, correlational analysis and multiple regression were utilized to evaluate the relationship of the dependent variable (reaction time) to the independent variable (physical environment levels) and to predict events from current data and knowledge (Curtis et al., 2016). Significant factors affecting the reaction time must be recognized to create an ergonomic design of physical environment appropriate levels.

Since the study was experimental, the participants came from the Senior High School Department of Mapúa University - Intramuros Campus. Only 30 Grade 12 students from the IS214 class, during the academic year 2020 – 2021, were gathered. Because the study requires a lot of directives, collecting data from 30 respondents within the same class will be more practical for the researchers' convenience.

3. Data Collection

A survey questionnaire was administered through online forms (i.e. Google Forms). The questionnaire is designed to describe the respondents' demographic and identify its corresponding aspects of the physical environment like noise, light, and temperature. Moreover, the profile of the respondents (i.e. respondent's hours of study, area of study, etc.) was collected to help evaluate the results (making comparisons across groups), generalize the findings, and make comparisons in replications, literature reviews, or secondary data analyses (American Psychological Association, 1994 as cited in Sifers et al., 2002). The questions are curated to have a better understanding of the purpose of the research using the data gathered from it.

The learnability of students was measured using the Stroop Test Experiment on CogLab: The Online Cognition Lab. The respective test consists of 48 slides with single words, 24 of which the font colors and word names are different, and 24 in which the font colors and color names match. The participants needed to identify the color of the font, rather than the word name itself, as quickly as possible. The experiment executed three trials in the morning, afternoon, and evening to measure the variability of data. Each experiment had a 2 to 4 minutes interval. Simultaneously, the assessment of their physical learning environment (i.e., noise, light, and temperature) was obtained during every Stroop Test Experiment through the use of mobile applications. The estimated time on each Stroop Test experiment was 30 minutes. In 1935, Stroop observed that participants had a hard time identifying the font colors that are different from their word names even though participants were told to disregard the word names. The Stroop effect happens when the font color identification is affected by its word names (Pang et al., 2020).

The results gathered from the Stroop Test experiment and the measured levels of noise, temperature, and illumination were using statistical analysis. The correlational analysis was to determine the relationship of student's learnability (reaction time) to the noise, temperature, and illumination level. The higher the correlation, the stronger the relationship of the variables; on the other hand, the lower the correlation, the more the variables are hardly related to each other (Franzese & Luliano, 2019). Subsequently, multiple regression analysis was used to determine the significant factors affecting the learnability of students. Based on the latter analysis results, an ergonomic design was developed by determining the appropriate level of noise, light, and temperature that are conducive to the learning of students.

4. Results and Discussion

4.1. Graphical Results

4.1.1. Average Illumination

The respondents were asked by the researchers to record their illumination level using lux-measuring applications. To ensure data accuracy, the participants were instructed to record three trials of their data in each given period. And the average of the collated illumination levels for the morning, afternoon, and evening is as follows: 17.86 lux, 21.54 lux, and 15.78 lux. It can be concluded that the respondents' illumination is more likely to be at peak during the afternoon than the morning and the evening, with the evening's illumination level having the lowest lux recorded as shown in Figure 2.

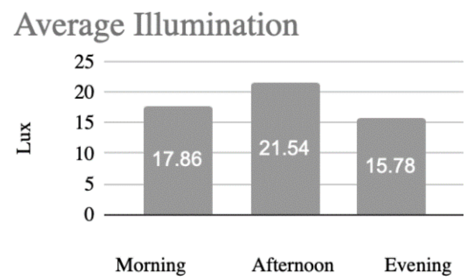

Figure 2. Students' average illumination

4.1.2. Average noise

The noise levels were measured in decibels (dB). In Figure 3, the average noise recorded by the participants in the morning, afternoon, and evening were 52 dB, 54 dB, and 50 dB, respectively. According to Yale Environmental Health and Safety (n.d.), 50 dB is equivalent to the sound of a household refrigerator. While anything above 80 to 90 dB may result in loss of hearing at prolonged exposure. It is concluded that the average noise recorded by the participants is at a normal range.

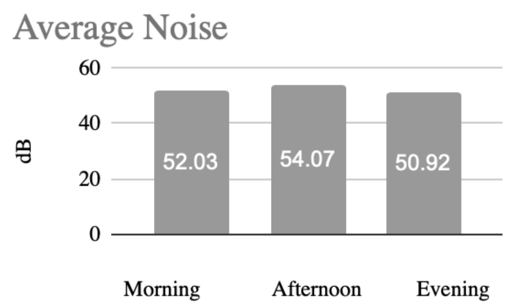

Figure 3. Students' average noise

4.1.3. Average temperature

The average temperature measured by the respondents was 27.20℃ in the morning, 27.75℃ inthe afternoon, and26.90℃ in the evening. The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) (2004) suggests that temperatures at home and school should be between 23℃ and 26℃ to maintain the students' productivity and engagement in classes. The results are shown in Figure 4.

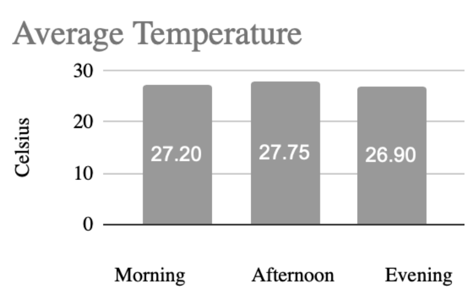

Figure 4. Students' average temperature

5.1. Numerical Results

5.1.1. Result of Analysis of Variance

Analysis of Variance (ANOVA) was used to determine if there are significant differences in the work environment measurements of the respondents particularly the noise level, temperature level, and illumination level. Based on the result of the one-way Analysis of Variance (ANOVA), the data suggests that there is no significant difference in the noise level based on time of day (morning, afternoon, evening) having a p-value> 0.05. The results may have been affected by the respondents' location differences, which produce different noise levels. This is similar to the study of Xie et al. in 2011, in which they have found no significant relationship between the environmental noise levels and the students' academic achievement and suggested that the environmental noise levels may not have been a suitable indicator of overall noise levels compared to previous studies that showed significant correlation. For the illumination level, there is a significant difference based on time of day (morning, afternoon, evening) having a p-value < 0.05. The result of the interval plot proves that the illumination level in the evening is significantly lower compared with the illumination level in the afternoon. Additionally, the illumination level in the afternoon was greater than evening due to sunlight. Based on data for the temperature level, there is a significant difference based on time of day (morning, afternoon, evening) having a p-value of < 0.05. This means that the temperature level in the evening is significantly lower compared to the temperature level in the afternoon. Thus, studying in the evening, if not in the morning, is more comfortable than studying during the afternoon. According to Abassi et al. (2019), this is because the human brain functions better when it is in a slightly cool temperature rather than at a humid or cold temperature. The summary of the results is shown in Table 1.

Table 1. Summary of Analysis of Variance (Physical Work Environment)

Factors	Variables	F-Value	p-value	Remarks
Physical Work Environment	Noise	1.92	0.164	Not significant
	Illumination	4.91	0.008	Significant
	Temperature	5.69	0.004	Significant

Similarly, a significant difference in the reaction time of respondents based on demographics was also analyzed such as age, gender, duration of the study, area of study, and time of day. For the age factor, it shows that there is no significant difference in the reaction time based on age having a p-value > 0.05. All ages that are in the scope of the study didn't affect their reaction time. Similar to the study of Gottsdanker (1982), it was found out that there was no significant difference in simple visual reaction time between the ages of 15 to 20, but the sample size was limited. Interestingly the study used random intervals ranging from 5 to 20 seconds, which did not allow for extensive planning. In conclusion, the evidence provided by the reaction time does not support any hypothesis of general slowing of the movement and senses of the respondents according to their respective ages. For gender, the data suggests that there is no significant difference in the reaction time based on gender having a p-value >0.05. This means that the gender of the respondents has little to no effect on their reaction time. Compared to a study conducted by Karia et al. (2012), the visual reaction time of male respondents was lesser than the of female respondents. For the duration of the study, it shows that there is no significant difference in the reaction time based on the duration of the study having a p-value > 0.05. Based on research conducted by Nonis & Hudson (2010), it was stated that the duration of the study had no effect nor related to the performance of the students, rather the student's study habits and their behavior have resulted in a relationship between the two variables. For the area of study, it shows that there is no significant difference in the reaction time based on the duration of the study having a p-value > 0.05. Following this, the plot shows that the distance between the data on each area of the study shows that any possible change of factor will have minimal to unnoticeable effect on the reaction time. And lastly, for the time of the study, it shows that there is a significant difference in the reaction time of students based on time of day (morning, afternoon, night, midnight), having a p-value <0.05. Therefore, the null hypothesis will be rejected, and the alternative hypothesis will be accepted. The result of the interval plot proves that the reaction time of students studying at night is significantly higher than the reaction time of students studying in the morning, afternoon, and midnight. The participants were given a time frame of 3 hours at each time of the day; From 6:00 pm to 9:00 pm, 8:00 am to 11:00 am, 1:00 pm to 3:00 pm, and 12:00 am to 3:00 am at midnight. It can be inferred that the illumination and temperature level affect the reaction time of students. The summary of the results is shown in Table 2.

Table 2. Summary of Analysis of Variance (Reaction Time)

Factors	Variables	F-Value	p-value	Remarks
Reaction Time	Age	2.01	0.153	Not significant
	Gender	-0.82 (T-value)	0.421	Not significant
	Duration of study	0.07	0.930	Not significant
	Area of Study	0.27	0.762	Not significant
	Time of Day	11.80	0.000	Significant

5.1.2. Result of Correlation Analysis

A correlation analysis was conducted to measure the strength of the relationship between two or more variables which include the dependent and independent variables. In this research, the reaction time of the students was considered as a dependent while the three physical environmental factors served as the independent variable. The result of correlation analysis shows the factors that have a significant relationship to the reaction time were illumination level and noise level having a p-value less than 0.05. Since the Pearson correlation value of illumination level is -0.902, the relationship of this factor to the reaction time is strongly negatively correlated. It means as the illumination level decreases, the reaction time of students increases. On the other hand, since the Pearson correlation value of noise level is 0.865, it proves that the relationship of this factor to the reaction time has a strong positive correlation. This means that as the noise level increases, the reaction time of students also increases. Moreover, it can be inferred from this analysis that for the students to decrease the reaction time, it is suggested to expose the students to a higher illumination level and lower noise level to become productive and quick to respond. The result is shown in Table 3.

Table 3. Summary of Correlation Analysis

Factors	Variables	Pearson correlation	p-value	Remarks
Reaction Time	Noise	0.865	0.000	Significant
	Illumination	-0.902	0.000	Significant
	Temperature	-0.012	0.950	Not significant

5.1.3. Result of Regression Analysis

A regression analysis was also performed to identify the factors that affect the reaction time of the students the most. Based on the result of regression analysis, it shows that the only factor that significantly affects the reaction time of students is illumination level having a p-value less than 0.05. However, the regression equation shows the effect of all factors on the reaction time of students. According to the results, as the reaction of students increases by 1, the illumination level reduces by 10.07. The summary result is shown in Table 4.

Table 4. Summary of Regression Analysis

Term	Coefficients	SE Coef	T-value	P-value	VIF
Constant	-136	655	-0.21	0.836	
Illumination	-10.07	2.69	-3.74	0.001	3.50
Noise	4.91	3.03	1.62	0.117	3.51
Temperature	40.2	22.2	1.81	0.081	1.03

5.2. Proposed Improvements

Based on the results, it is recommended that students install additional LED lighting fixtures with a luminance level between 300 to 500 lux around the work area, provide additional fans or A/C units with its horsepower proportional to the room size to achieve an ideal temperature between 19 to 26 degrees Celsius, and keep the noise levels below 90 dB to avoid interference with the students' learnability and engagement during classes. Furthermore, the researchers recommend future researchers, who aim to conduct a similar study, execute the experiments face-to-face and inside the classrooms rather than online. This is due to the presence of external factors, such as time difference, location, and internet speed, which put several limitations to the study. The slight difference in these factors may have altered the ideal results. Moreover, due to the restrictions of COVID-19, the researchers were mandated to observe a controlled group where the number of respondents is limited. Thus, future researchers are recommended to gather more participants to strengthen their thesis. Professional measuring instruments are also recommended to yield more accurate data during the measurement of noise, illumination, and temperature levels. Furthermore, future studies shall use a different test to measure the learnability and engagement of students since the Stroop Test experiment is only used to measure the reaction time.

6. Conclusion

The study identified the relationship of noise, illumination, and temperature level to the learnability of students, assess their physical working environment and determine the factor that significantly affects students' reaction time. The only factor that significantly affected the reaction time of students was the illumination level, having a p-value less than 0.05. Additionally, a significant difference was found in the reaction time of students based on time of day. The reaction time of students' studying at night was also relatively higher than those students studying in the morning, afternoon, and midnight. The analysis showed that as the level of illumination decreases, the reaction time of the student's increases. In light of this, the relationship of illumination level to the academic performance of students was strongly negatively correlated, having a Pearson value of -0.902. While the noise level increases, the reaction time of students increases as well, having a strong positive correlation with a Pearson value of 0.865. Although illumination and noise level were the only ones having a significant relationship with the reaction time, based on the ANOVA test, the temperature level has an effect on the students' reaction time based on the time of day with a p-value less than 0.05. The findings suggested that only the illumination and noise levels have a significant effect on the students' reaction time. Thus, students during online classes need to have good lighting and a relatively quiet physical learning environment to maintain a low reaction time.

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Menzelaius Craig A. Villanueva is currently a Grade 12 STEM student of Mapua University. A kind and determined student that dreams of graduating and obtaining a Bachelor of Science in Chemical Engineering. He has been a volunteer in some local donation programs and donation drives for previous typhoon that the Philippines experiences.

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