Original Article

Investigating the Effects of Different Levels of Lighting on the Attention Index of Male and Female: An Experimental study

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Abstract

Aim: The aim of the present study was to evaluate the effects of different levels of lighting on the attention index of males and females under thermal comfort. **Materials and Methods:** To measure the effect of different lighting levels (200, 500, and 1500 lux) on attention index, Toulouse-Piéron Test was conducted in a chamber under thermal comfort condition (22°C, 45% RH). This study was conducted on 33 healthy students (17 males/16 females) with a mean (±standard deviation) age of 22.1 ± 2.3 years. The exposure time was 1.5 h. **Results:** The results indicated that the reduction in lighting level (200 lux) significantly decreased the attention index, speed, and accuracy of performance for both groups; however, this descending trend for the male participants was slightly higher than the female ones ($P < 0.05$). On the other hand, by increasing the lighting level (500 and 1500 lux), the attention index of the individuals was significantly improved under distracting and busy working environment ($P < 0.05$). **Conclusion:** The results of the present study demonstrated that the female participants showed better performance and lower mistakes in accuracy-demanded tasks. It was also found that, compared to the female participants, the attention level of the male participants was more easily affected. Furthermore, by increasing the lighting level, the distraction level among the female participants was lower than that of the males, and their ability to do dual tasks was significantly enhanced.

Keywords: Attention index, cognitive performance, lighting, Toulouse-Piéron test

Introduction

Proper lighting is one of the essential needs of the humans which might impact their physical, physiological, and mental behaviors, and adequate lighting levels should provide a background for visual performance under safe and healthy condition. Poor lighting conditions may affect the speed of work performance and sleeping quality and contribute to the work-related accidents.[1] It not only might have an adverse effect on the visual perception but also on the mental and physiological responses as well.[1,2] The results of numerous experiments suggest that higher light intensities (>2500 lux) can affect the human circadian physiology.[3] Since lighting is an important factor in our daily life, it can directly affect all dimensions of the human life. Tanner confirmed that "After food and water, light is the most important environmental inputs controlling the body functions."[4]

Although very limited studies have been performed to investigate the physiological effect of lighting on attention and focus, the participant of attention has been the focus for research and profoundly evaluated.[5] The results from a study indicated a higher complaint rate of employees whose jobs entailed high visual skills and attention and worked under general lighting design for which the number of complaints and dissatisfaction minimized by providing proper local lighting.[2]

More recently, literature has emerged that offers the evidence regarding biological, nonvisual, and mental effects of lighting on people.[6] Human performance is directly associated with profitability in the industrial environment. The performance-affected mechanisms are defined by the chain approach. Individual differences influence the effects of these

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mechanisms. Improving the lighting condition in the office has shown to exert a positive effect on employees' performance.[7]

Apart from the visual effects of light, its positive biological effects such as feeling healthy, alert, as well as having a pleasant mood, have been studied for 25 years in the field of medical and biological science.[7] De Kort and Smolders[8] and Scheer and Buijs[9] reported the effect of lighting on psychological-biological processes and demonstrated that participants exposed to abundant light were more alert and energetic than those exposed to lower illuminance levels. The results of one study revealed that error rate, reaction time, and the inability to think increased due to extreme mental fatigue, inadequate lighting, and low sleep quality.[10]

In addition to the physiological effect of lighting, the changes of cognitive functions were also reported. These changes can occur directly in the form of degradation of cognitive function due to a lack of sleep after circadian phase changes[11,12] or in an acute form such as the effect on consciousness.[13]

Recently, some studies have been conducted on the nonvisual effects of lighting such as acute melatonin suppression and circadian phase changes. The human visual system has high sensitivity at wavelengths of 460–480 nm, and a specific subset of retinal ganglion cells is involved in these effects.[3,14-16] Given that no specific study has been conducted into the effect of lighting on attention index under thermal comfort, the present study aimed to evaluate this issue.

Attention and focus are the basis for human activities such as intellectual and manual performance, the parameters which might be influenced by the environmental thermal conditions to a major extent. Thermal comfort can be defined differently. From a physiological point of view, thermal comfort is defined as a mental state that indicates the satisfaction of individuals with the thermal environment.[17] A search of the literature revealed few studies conducted on the effect of thermal comfort on attention index. The results obtained by Jaakkola *et al*. showed that room temperature was the most important parameter of indoor air to diagnose the symptoms of the sick-building syndrome (SBS) and dryness feeling, and therefore, controlling room temperature can improve the thermal comfort and reduce the SBS syndrome of office staffs.[18]

Materials and Methods

Design

This experimental study conducted to evaluate the effect of different lighting levels (200, 500, and 1500 lux) on distraction rate in male and female students in 2015. All the tests were conducted in a chamber with controlled atmospheric condition. The dimension of the considered chamber was 3 × 4 m with a height of 2.8 m, which was adjusted by a control system equipped with a cooling-heating system. The chamber was designed in a way that no light (including the sunlight) could penetrate inside. A dark-colored table and chair were employed, none of which reflected light and did not contribute to any dazzling or glare. The ambient temperature and relative humidity inside the exposure chamber were maintained, respectively, constant at 22°C with 45 ± 5% during the tests.[6]

Participants

In the present study, 33 participants consisting of 17 males and 16 females (mean age = 22.1; standard deviation ± 2.3; age range of 19–26 years old) were selected randomly. The inclusion criteria were the aforementioned age range, having no visual problem and color blindness (the vision examination was conducted on participants with an optometrist). A NIDEK ARK-760 auto refractor (Nidek Co. Ltd., Tokyo, Japan) was used to measure the refractive error of each eye including myopia, hyperopia, presbyopia, and astigmatism. Clinically important myopia was defined as myopic SphEq of at least −1.0 diopter; clinically important hyperopia was defined as hyperopic SphEq of +3.0 diopters or more. Severe myopia was defined as myopic SphEq of at least −5.0 diopters. We also presented data with myopia defined as SphEq of at least −0.5 diopter. Astigmatism was defined as cylinder ≥ 0.25 diopter in the eye with a larger cylinder value.

Based on the medical records, participants had no history of taking cardiac, blood glucose lowering, antidepressants, tranquilizers, antihistamines, antiparkinsonian, and other medications; they had normal hearing thresholds, no cardiovascular disease, respiratory problems, and sleep disorders. On the other hand, the exclusion criterion was the unwillingness of a participant to continue the study. After the final selection of eligible individuals, all the tests were fully explained to the participants. Before beginning the tests, according to the university's ethics committee's approval, the informed consent of the participants was taken and documented.

Light conditions

In the present study, the test been done after some time of exposure to three levels of lighting (200, 500, and 1500 lux) were provided using fluorescent lamps (color temperature 4500 K). The lighting exposure levels before the trial were checked by a calibrated Hagner digital luxmeter (Model ECI).

Testing methods

To determine the effect of different lighting levels on participants' cognitive functions, Toulouse-Piéron Test (TPT) was utilized, and the efficiency of their work performance was determined under completing dual-task paradigm and distracting conditions. The participants rapidly marked all the symptoms similar to those on the top of the test sheets they were given while we were deliberately telling several preplanned jokes to distract them. To be tested, participants consecutively appeared in the chamber for 6 times (90 min each for each session).

The attention index of the participants was measured by TPT;[19] a test that has been widely used by physiologists during previous decades to calculate the concentration rate and determine some attentional and concentration disorders with a desirable validity. Considering the nature of this test, performing the Toulouse-Piéron entails high concentration and resistance against monotony. According to the psychologists, this test is an appropriate method to measure the individual's attention, and it is recommended for people aged 10 and above, as well as for each cultural level, since it is not a verbal test.[17]

In this regard, a paper with 1200 drawn squares on it (30 rows × 40 columns) was given to the participants. All these squares had referring lines in various directions and three target squares at the top of the paper. The aim of this sheet of paper was to identify the similar squares with targets among 1200 squares fast and accurately. The total time for performing the test was 10 min, in which similar squares with the target square were marked with "×". Two main factors are the number of signs marked correctly (the speed of performance), and the number of signs marked incorrectly (precision).

TPT function was compared to three dependent variables: the number of correct responses, the number of forgotten responses, and the attention coefficient. The number of correct answers was the number of characters correctly matched with the target squares. The number of forgotten responses refers to the number of correct squares contained in the sheet of paper but not marked by the participants. False answers were interpreted as the squares selected by the participants with no match with target square. The result was presented in the scale of 100 (the maximum attention rate).

In the scoring method, each well-marked square receives one positive score, and each of the false-marked and forgotten squares receives 0.5-point negative score. The sum of the positive and negative scores represents the overall performance of the participants.

Statistical analysis

The collected data were analyzed using SPSS Software, Version 20. One-way analysis of variance (ANOVA) was used to determine any statistically significant differences of attention index of the male and female participants in the studied lighting levels.

Results

Tables 1-3 present the mean attention index of the female and male participants under different conditions before being exposed to different lighting levels (200, 500, and 1500 lux) by statistical tests, independent *t*-test, and ANOVA.

Table 1 shows the average efficiency of the female and male participants before 1.5 h of being exposed to a lighting level of 200.

Table 2 shows the average efficiency of the female and male participants before being exposed to lighting level 500 lux.

Table 3 shows the average efficiency of the female and male participants before being exposed to lighting levels 1500 lux.

Table 1: Comparison of mean and standard deviation of total performance score, before exposure to 22°C temperature and light 200 lux

Test steps	Mean		SD		*P**	*P***
	Female	Male	Female	Male		
Normal work	52.06	49.91	2.20	3.01	0.02	<0.001
Double work	48.31	46.84	0.92	1.74	0.005	
Normal work	51.75	50.70	2.3	2.8	0.25	
Distraction conditions	48.9	47.7	0.6	1.11	0.001	
Normal work	51.7	50.5	1.9	1.92	1.00	

*Due to the normal distribution of data, independent *t*-test for compare gender was used, **Due to the normal distribution of data and homogeneity of variance, ANOVA was used. SD: Standard deviation, ANOVA: Analysis of variance

Table 2: Comparison of mean and standard deviation total performance score, before exposure to 22°C temperature and light 500 lux

Test steps	Mean		SD		*P**	*P***
	Female	Male	Female	Male		
Normal work	50.93	50.29	2.2	2.1	0.40	<0.001
Double work	41.6	37.2	2.8	1.9	0.001	
Normal work	52.5	52.2	1.7	1.8	0.68	
Distraction conditions	45.5	38	1.7	2.1	0.001	
Normal work	51.5	52.4	4.3	1.6	0.42	

*Due to the normal distribution of data, independent *t*-test for compare gender was used, **Due to the normal distribution of data and homogeneity of variance, ANOVA was used. SD: Standard deviation, ANOVA: Analysis of variance

As shown in the tables, before the exposure to different lighting levels, the female participants had significantly higher mean attention and efficiency than the male participants under different conditions such as performing work under normal condition (at this stage, each person selects and marks the squares from the first page according to the pattern at the top of the page for 3 min. During the 2-min break, people placed the test papers upside down so that the squares were not in front of their eyes), dual-task paradigm, and distraction ($P < 0.05$).

Furthermore, the ANOVA shows the significant difference between the overall mean of the participants' attention index under the three working conditions ($P < 0.05$). The results from the Tukey test also indicate that the attention index has a higher mean in normal conditions, distraction, and dual-task, respectively.

Tables 4-6 compare the means of efficiency and attention index in different working conditions after exposure to lighting levels of 200, 500, and 1500 lux. As the tables show, the mean attention index of the female participants when performing dual task and under distracting conditions is significantly higher than that of male ones ($P < 0.05$). However, no significant difference exists between the male and female participants during normal conditions of working ($P > 0.05$). The results of ANOVA and Tukey's *post hoc* test also indicate that the overall performance or attention index is significantly improved in normal, distracting, and dual-task conditions, respectively.

Table 4 shows the average efficiency of the female and male participants after being exposed to lighting level 200 lux.

Table 5 shows the average efficiency of the female and male participants after being exposed to lighting level 500 lux.

Table 6 shows the average efficiency of the female and male participants after being exposed to lighting level 1500 lux.

Furthermore, based on the comparison of the means of individuals before and after exposure, it seems that participants had better performance scores before exposure to 200 lux compared to the postexposure to this level of lighting. However, the comparison of the mean of the different stages of the TPT before and after exposure to the 500 and 1500 lux levels showed that the attention index of individuals in postexposure situations was significantly improved.

Discussion

To analyze the possible impact of lighting levels on the male and female participants' attention levels, TPT was employed. The results showed that the males' attention levels were more considerably influenced than female participants while performing dual task and working under distracting conditions. In addition, the attention indexes of the female participants

Table 3: Comparison of mean and standard deviation total performance score, before exposure to 22°C temperature and light 1500 lux

Test steps	Mean		SD		*P**	*P***
	Female	Male	Female	Male		
Normal work	51.6	50.1	2.1	1.8	0.04	<0.001
Double work	41.3	36.2	2.8	1.6	0.001	
Normal work	53.7	53.6	1.4	0.8	0.85	
Distraction conditions	43.9	38.9	3.4	3.8	0.001	
Normal work	52.09	52.3	1.6	1.7	0.63	

*Due to the normal distribution of data, independent *t*-test for compare gender was used, **Due to the normal distribution of data and homogeneity of variance, ANOVA was used. SD: Standard deviation, ANOVA: Analysis of variance

Table 4: Comparison of mean and standard deviation total performance score, after exposure to 22°C temperature and light 200 lux

Test steps	Mean		SD		*P**	*P***
	Female	Male	Female	Male		
Normal work	50.4	49.6	1.5	1.9	0.22	<0.001
Double work	37.3	32.9	1.4	1.9	0.001	
Normal work	50.1	49.7	1.6	1.8	0.55	
Distraction conditions	42.9	41.9	1.9	2.1	0.17	
Normal work	52.4	51.1	1.8	1.9	0.057	

*Due to the normal distribution of data, independent *t*-test for compare gender was used, **Due to the normal distribution of data and homogeneity of variance, ANOVA was used. SD: Standard deviation, ANOVA: Analysis of variance

Table 5: Comparison of mean and standard deviation total performance score, after exposure to 22°C temperature and light 500 lux

Test steps	Mean		SD		*P**	*P***
	Female	Male	Female	Male		
Normal work	50.9	50.3	1.6	1.7	0.34	<0.001
Double work	44.4	41.3	2.5	2.2	0.001	
Normal work	52.2	51.8	1.7	1.9	0.50	
Distraction conditions	49.7	45.8	1.7	1.1	0.001	
Normal work	52.9	52.8	1.6	1.4	0.91	

*Due to the normal distribution of data, independent *t*-test for compare gender was used, **Due to the normal distribution of data and homogeneity of variance, ANOVA was used. SD: Standard deviation, ANOVA: Analysis of variance

Table 6: Comparison of mean and standard deviation total performance score, after exposure to 22°C temperature and light 1500 lux

Test steps	Mean		SD		*P**	*P***
	Female	Male	Female	Male		
Normal work	52.03	52.4	1.9	1.9	0.51	<0.001
Double work	52.4	49.02	1.8	0.8	0.001	
Normal work	52.5	52.5	1.7	3.6	0.99	
Distraction conditions	52.2	50.7	1.6	1.6	0.01	
Normal work	52.9	53.1	1.6	1.6	0.76	

*Due to the normal distribution of data, independent *t*-test for compare gender was used, **Due to the normal distribution of data and homogeneity of variance, ANOVA was used. SD: Standard deviation, ANOVA: Analysis of variance were significantly higher than male under the intense lighting level. This result would therefore support the notion that "Women are more capable than men in multitasking."

In the present study, the thermal comfort condition was set particularly since it can improve the attention index and enhance the learning process.[17] Wyon *et al*. reported that the performance of male participant's was significantly impaired under dual-task condition at 28°C, while female participant's performance was not affected by thermal condition in the same situation.[20]

Mott *et al*. indicated that lighting was extremely important for all aspects of human life.[4] Moreover, they found that quality of lighting and color temperatures were effective parameters in the learning process, while they had no effect on concentration and motivation.

The present study results were in agreement with those of Smolders *et al*. indicating that the participants exposed to 1000 lux lighting level were less sleepy and happier than those exposed to 200 lux lighting.[21]

Maierova *et al*. found that self-selection of lighting in the workplace might have a positive effect on the biological and cognitive function of individuals and health, mood, and performance of the participants in performing difficult tasks in bright and self-selected lighting conditions were better than dim light conditions, while the comfort level of individuals was the best in self-selected conditions. They also mentioned that improvement in behavior increased by increasing the lighting levels.[22] Moreover, the present research results were consistent with those obtained by Halpern showing that the consciousness of male participants in performing interrupting activities was lower than that of women during performing the same mental activity.[23] In addition, the results of our study were in contrast with those of Casal *et al*.[24] which showed no significant difference response in the response time and attention between the male and female participants. The reasons for this discrepancy can be explained as the following: (a) the type of task an individual was performing during the cognitive test has been different in majority of studies and (b) the characteristics of the situation of introducing the task (duration, thermal comfort conditions, lighting intensity, application of an additional task, etc.) have been dissimilar.

Some differences exist in brain anatomy and processing of the males and females which accounts for behavioral difference between them. Several studies have indicated that the females could perform a verbal task better than the males, while the males are usually good at doing spatial tasks.[25]

In this study, individuals' attention index and accuracy and speed of performance were reduced under 200 lux lighting level, dual task, and distraction. By increasing the lighting level from 500 to 1500, the attention index, accuracy, and speed of performance of individuals were also significantly improved under dual task and distraction (in the present study, the number of correct answer represented higher speed of performance, and the number of false or forgotten answers exhibited the accuracy). These findings were in agreement with those of Thakkar *et al*.[26] indicating the flexibility of women in performing high-accuracy demanded activities compared to men. We had limited information about previous studies into the difference between genders in terms of speed and accuracy of performing the work. Several previous studies of error reduction did not show any significant differences in terms of gender,[27-29] but these studies were unable to identify subtle differences.

Conclusion

The results of the present study showed that, after 1.5 h of hard working, individuals' efficiency was increased by increasing the lighting intensity. Therefore, it is likely that it will be fairly cost effective for individuals to perform only a certain task at a given time and under low-light intensity.

Further studies are required to expand our knowledge about the effect of different lighting levels on male and female participants' attention levels under thermal comfort.

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Ethics code

The ethics code of this research is: IR.MUI.REC.1394.3.586.

Conflicts of interest

There are no conflicts of interest.

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