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A Randomized Controlled Study of the Colour of Light Exposure on Attention and Short Term Memory

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Abstract

Colours play an important role in stimulating the learning process of students, which ultimately would enhance their educational experiences. Hence, this study is conducted to determine the effects of exposure on different colours of light on attention and short-term memory among medical students. This randomized controlled trial was conducted among 90 medical students in private medical college in Malaysia, from June to August 2018. They were divided into three groups including blue, yellow and white light group (control group) with 30 participants respectively. Then, attention and memory tests were conducted. The data was analysed using software like Epi Info 7, GraphPad and Microsoft Excel. The mean of attention score percentage of yellow light group 80.7 (8.7) followed by control group 76.8 (9.4) and blue light group 72.1 (10.9) with P value of < 0.05 which is significant. On the other hand, the mean of memory score percentage of yellow light group 72.3 (16.4) is highest followed by control group 62.8 (18.5) and blue light group 57.5 (14.5) with P value of < 0.05 which is significant. In this study, the yellow light group had the highest mean scores compared to yellow light group and control group. Therefore, the yellow light is the most effective light used in improving performances of tasks requiring attention and memory by the students.

Keywords

Light Exposure, Attention, Memory, Randomized Trial

1. Introduction

The act or state of relating the mind to something is known as attention. Prior cognitive and neuroscientists have conducted researches on various issues which have impacts on the attention (Kim, 2010)[1]. The custom research focused on the interconnection between attention and human attitudes has been converted eventually into visual searching ability. Attention plays an essential role in combining primary visual features which is current wide consensus after several decades of extreme research on comprehending attention [2].

Memory refers to the mental series of processing, storing, and retrieving environmental information. Cognitive psychologists are still focus in investigating the relationship between the human cognitive system and the memorization process [3]. There are three reservoirs of memory which are the sensory memory, the long-term memory (LTM) and the short-term memory (STM). Recall and recognition are the two principals of memory retrieval. The data retrieved from the memory is recall whereas identifying someone or something that has been encountered before is known as recognition. The short-term memory functions as a scratch-card for the short time recall of information which has limited capacity and decays very rapidly. It will eventually guide to our long lasting memories as the temporary stored and processed information from the sensory memory is sent to the third stage, which is the LTM. STM can be strengthened by bits and chunks in which information from a continuous long sentence is breaking into point forms. There

are many factors affecting the apparent short-term memory. There are many factors affecting apparent short-term memory. The tendency of rehearsal shown to have access for the long-term memory storing [4]. Information overload also restricts the capacity of short-term memory [4]. Recall also depends on the frequency and format of the stimulus such as the word length and the syllable length [5]. STM is challenged with time limitation [5].

Colour is the most significant visual experience of human [6]. It is responsible for a powerful information passage to the human cognitive system and has been found to have vital role in improving memory performance [7]. Colour has been proven to have efficacious in many fields like learning and education, communication, marketing and more [8] as it is one of the major component to have impact on human's attention and attitude [9]. Colour assists in memorizing and increasing the level of attention. This is shown when coloured advertisements can attract people to read the advertisement up to 42% compared to the non-coloured advertisement [7].

There is more demands on outstanding academic performance in educational setting, where students utilize their cognitive abilities such as perceiving, paying attention, remembering, thinking and comprehending so as to excel in academic achievements [10]. There are various strategies in boosting the learning process and outcome. Colours play an important role in stimulating and motivating the learning process of students, in which will ultimately enhance their educational experiences. Hence, this study is conducted so as to determine the effects of exposure on different colours of light on short-term memory and attention among medical students.

2. Methodology

We conducted a randomized controlled trial to determine the effectiveness of blue colour light and yellow colour light towards attention and short term memory among medical students in a private medical college in Malaysia.

2.1. Study Setting, Study Time, Study Population

The study was conducted in a private medical college in Melaka, Malaysia where the population of students comprises MBBS, BDS and pre-university health science students (FIS student). The inclusion criteria was participants >18 year old, reported to be free from psychiatric, neurological, and substance use disorders (caffeine, alcohol and nicotine), and reported a sleep schedule of going to bed between 10pm and 1am the night before and waking up by 6am to 8am before they participated in the study. Some of the exclusion criteria were participants with colour blindness, suffered from migraine (previously and currently), posted for the night shift, had chronic medical conditions (long-standing diabetes mellitus, chronic hypertension and vertigo), chronic psychological disorders (Schizophrenia, depression, panic disorder and generalized anxiety disorder) or ophthalmological conditions (squint, diabetic retinopathy, glaucoma and cataract) and had acute medical conditions during the participation in this study.

2.2. Sample Size, Sampling

A pilot study was conducted to estimate the actual sample size which 20 volunteers from batch 36 and batch 37 MBBS course were included. The students were randomized into 10 in blue light group and 10 in yellow light group.

The continuous data of our pilot study was taken to estimate the sample size using formula as shown below:

$$n_{trt} = (z_{1-\alpha/2} + z_{1-\beta})^2 [\sigma^2_{trt} + \sigma^2 con/r] / \Delta^2$$

$$r = n_{con} / n_{trt,} \ \Delta = \mu_{trt} - \mu_{con}$$

The output of the sample size calculation from n4 Studies:

For a randomized controlled trial with continuous outcome

Mean in a treatment group = 65.60, SD. in a treatment group = 9.83

Mean in a control group = 77.60, SD. in a control group = 10.86

Ratio (control/treatment) = 1.00

Alpha (α) = 0.05, Z (0.975) = 1.959964

Beta (β) = 0.20, Z (0.800) = 0.841621

Sample size: Treatments = 12, Controls = 12

However, we included a total of 90 students. We then used software Research Randomizer (http://www.randomizer.org) to divide them into yellow light group (n=30), blue light group (n=30) and white light group (n=30) as control.

2.3. Procedure and Data Collection

Three tables were prepared in three separate rooms where table lamps with white light, blue light and yellow light were placed on each table, labelled as table A, table B and table C. One assessor was allocated to table A, table B and table C respectively. To test for attention of the participants, the participants were provided individually with 5 sheets of papers with 2 pictures each [11-14]. Each participant was given 2 minutes to spot the 5 differences in each sheet. The time limit of 2 minutes to spot the differences was taken by using a stopwatch. The total amount of differences found was recorded. The participant was allowed to rest for 5 minutes before proceeding to the memory test. The participant was then provided with Paper 1 printed with 20 different words which were not related with each other [15]. Each participant was given 1 minute to memorise the 20 words printed on the paper. The time limit of 1 minute is taken by using a stopwatch. Paper 1 was collected back by the assessors from the participant and the participant was given resting time of 1 minute. After 1 minute of rest, the participant was provided Paper 2 which was blank. The participant was asked to write down as many words as he can recall from Paper 1 on Paper 2.

2.4. Data Processing and Data Analysis

The data was analysed using software such as Epi Info 7,

GraphPad and Microsoft Excel. The mean and standard deviation of the age and final score of the correct response from both tests were calculated for each group. On the other hand, we also calculated the frequency and percentage of gender and ethnicities. We used the ANOVA method to calculate the results of memory and attention tests as it is a one-way analysis of variance and we have three independent groups with one measurement. The comparison of results of memory and attention tests between the three groups were calculated using independent t-test method after adjusting the type 1 error. The level of significance was set at 95% CI (P value <0.05) for all results except for comparison of scores of blue light group, yellow light group and control group which use the Bonferroni adjustment P value < 0.0167.

1. White light group vs. yellow light group
2. White light group vs. blue light group
3. Yellow light group vs. blue light group

2.5. Ethical Consideration

All students' participations were voluntary and they were only allowed to participate in the research after giving informed consents. Students were informed that their academics will not be affected if they do not volunteer for the research. Student who participated in the research were assured that all the information will not be used in future studies or for other uses without informed consent. This research study was approved by the Research Ethics Committee of our college.

3. Results

The mean age of participants in the blue group was 23.0 (1.8), the yellow group was 23.0 (2.0) and in the control group was 22.8 (1.1). The participants of this study comprised of 36 males (40.0%) and 54 females (60.0%). In the blue colour group there were majority of Indian (46.7%) followed by Chinese (30.0%), Malay (16.7%) and other ethnicity (6.7). In the yellow light group there were (30.0%) for Malay, Chinese and Indian, while there were (10.0%) for other ethnicity. Meanwhile in the control group majority were Indian (53.3%) followed by Chinese (30.0%) and Malay (20.0%). (Table 1)

Table 1. *Baseline characteristics participants.*

Variables		Blue (n = 30) n (%)	Yellow (n = 30) n (%)	White (n = 30) n (%)	Total n (%)
Age (year)[a]		23.0 (1.8)	23.0 (2.0)	22.8 (1.1)	22.9 (1.6)
Gender	Male	14 (46.7)	12 (40.0)	10 (33.3)	36 (40.0)
	Female	16 (53.3)	18 (60.0)	20 (66.7)	54 (60.0)
Ethnicity	Malay	5 (16.7)	9 (30.0)	4 (13.3)	18 (20.0)
	Chinese	9 (30.0)	9 (30.0)	9 (30.0)	27 (30.0)
	Indian	14 (46.7)	9 (30.0)	16 (53.3)	39 (43.3)
	Others	2 (6.7)	3 (10.0)	1 (3.3)	6 (6.7)

[a] Mean (SD)

Based on the marks of attention score percentage between the three groups calculated using ANOVA, the mean of blue light group is 72.1 (10.9), yellow light group is 80.7 (8.7) and the control group is 76.8 (9.4). The P value is <0.05 which is significant. (Table 2)

Table 2. *Comparison of mean attention score percentage between blue (n-30), yellow (n=30) and white (n=30) light exposure.*

Groups	*N*	Attention Score Percentage (%) Mean (SD)	*F*-statistics (df_1, df_2)[b]	*P*-value[b]
Blue light	30	72.1 (10.9)		
Yellow light	30	80.7 (8.7)	5.8 (2, 87)	0.0043
White light	30	76.8 (9.4)		

[b] One-way ANOVA

Based on the memory score percentage between the three groups calculated using ANOVA, the mean of blue light group is 57.5 (14.5), yellow light group is 72.3 (16.4) and the control group is 62.8 (18.5). The P value is <0.05 which is significant. (Table 3)

Table 3. *Comparison of mean memory score percentage between blue (n-30), yellow (n=30) and white (n=30) light exposure.*

Groups	*n*	Memory Score Percentage (%) Mean (SD)	*F*-statistics (df_1, df_2)[b]	*P*-value[b]
Blue light	30	57.5 (14.5)		
Yellow light	30	72.3 (16.4)	6.1 (2, 87)	0.0031
White light	30	62.8 (18.5)		

[b] One-way ANOVA

As for the comparison of attention score percentage between yellow light group and control group, the mean difference of yellow light group vs control group is 3.9 with P value of >0.0167. For the memory score percentage, the mean difference of yellow light group vs control group was 9.5 with P value of >0.0167. (Table 4)

Table 4. *Comparison of memory score percentage and attention score percentage between yellow (n=30) and white (n=30) light exposure.*

Variable	Mean (SD)		Mean difference (95% CI)	*P*-value[c]
	Yellow light n=30	White light n=30		
Attention Score Percentage	80.7 (8.7)	76.8 (9.4)	3.9 (-0.8, 8.5)	0.1034
Memory Score Percentage	72.3 (16.4)	62.8 (18.5)	9.5 (0.5, 18.5)	0.0394

[C] Post-hoc analysis with Bonferroni corrections; (P<0.0167 is significant)

As for the comparison of attention score percentage between blue light group and control group, the mean difference of blue light group vs control group was -4.7 with P value of >0.0167. For the memory score percentage, the mean difference of blue light group vs control group was -5.3 with P value of >0.0167. (Table 5)

Table 5. *Comparison of memory score percentage and attention score percentage between blue (n=30) and white (n=30) light exposure.*

Variable	Mean (SD)		Mean difference (95% CI)	*P*-value[c]
	Blue light n=30	White light n=30		
Attention Score Percentage	72.1 (10.9)	76.8 (9.4)	-4.7 (-9.9, 0.6)	0.0811
Memory Score Percentage	57.5 (14.6)	62.8 (18.5)	-5.3 (-13.9, 3.3)	0.2189

As for the comparison of attention score percentage between yellow light group and blue light group, the mean difference of yellow light group vs blue light group was 8.5 with P value of <0.0167. For the memory score percentage, the mean difference of yellow light group vs blue group was 14.8 with P value of <0.0167. (Table 6)

Table 6. *Comparison of memory score percentage and attention score percentage between yellow (n=30) and blue (n=30) light exposure.*

Variable	Mean (SD)		Mean difference (95% CI)	*P*-value[c]
	Yellow light n=30	Blue light n=30		
Attention Score Percentage	80.7 (8.7)	72.1 (10.9)	8.5 (3.5, 13.6)	0.0014
Memory Score Percentage	72.3 (16.4)	57.5 (14.6)	14.8 (6.8, 22.8)	0.0005

Based on the feedback from participants, the percentage of participants having headache in blue light group during/after the test was 16.67%, in yellow light group was 3.33% and in control group was 3.33%. The relative risk of blue light group with control group was 5.0 with 95% CI of 0.6 to 40.3, P value >0.05 and Chi square of 3.0 while for yellow light group with control group was 1 with 95% CI of 0.1 to 15.3, P value >0.05 and chi square of 0. (Table 7)

Table 7. *Association between blue (n-30), yellow (n=30) and white (n=30) light exposure and headache status.*

Variable		Headache during/after the test *n* (%)	No headache during/after the test *n* (%)	RR (95% CI)	Chi-square	*P*-value
Colour of light exposure	Blue light	5 (16.667)	25 (83.333)	5.0 (0.6, 40.3)	3.0	0.0852
	Yellow light	1 (3.333)	29 (96.667)	1 (0.1, 15.3)	0	1.0
	White light	1 (3.333)	29 (96.667)			

Based on the feedback from participants, the percentage of participants having dizziness in blue light group during/after the test was 10.00%, in yellow light group was 3.33% and in control group was 6.67%. The relative risk of blue light group with control group was 0.5 with 95% CI of 0.1 to 2.9, P value >0.05 and Chi square of 0.6 while for yellow light group with control group was 0.5 with 95% CI of 0.03 to 5.2, P value >0.05 and chi square of 0.4. (Table 8)

Table 8. *Association between blue (n-30), yellow (n=30) and white (n=30) light exposure and dizziness status.*

Variable		Dizziness during/after the test *n* (%)	No dizziness during/after the test *n* (%)	RR (95% CI)	Chi-square	*P*-value
Colour of light exposure	Blue light	3 (10.000)	27 (90.000)	0.5 (0.1, 2.9)	0.6	0.4288
	Yellow light	1 (3.333)	29 (96.667)	0.5 (0.03, 5.2)	0.4	0.5536
	White light	2 (6.667)	28 (93.333)			

Based on the feedback from participants, the percentage of participants having blurring of vision in blue light group during/after the test was 13.33%, in yellow light group was 3.33% and in control group was 0%. The Chi-square of blue light group was 4.3 with P-value of 0.0384 while the Chi-square value of yellow light group was 1.0 with P-value of 0.3132. (Table 9)

Table 9. *Association between blue (n-30), yellow (n=30) and white (n=30) light exposure and blurring of vision status.*

Variable		Blurring of vision during/after the test *n* (%)	No blurring of vision during/after the test *n* (%)	RR (95% CI)	Chi-square	*P*-value
Colour of light exposure	Blue light	4 (13.333)	26 (86.667)	-	4.3	0.0384
	Yellow light	1 (3.333)	29 (96.667)	-	1.0	0.3132
	White light	0 (0)	30 (100.000)			

Based on the feedback from participants, the percentage of participants having knowledge of exposure of different colour of light can affect memory and attention was 53.33% for blue light group, 50.00% for yellow light group and it was 43.33% for control group. The Chi-square value was 0.4 with P-value of >0.05. (Table 10)

Table 10. *Association between blue (n-30), yellow (n=30) and white (n=30) light exposure and knowledge status.*

Variable		Knowledge of exposure of different colour of light can affect memory and attention *n* (%)	No knowledge of exposure of different colour of light can affect memory and attention *n* (%)	Chi-square	*P*-value
Colour of light exposure	Blue light	16 (53.333)	14 (46.667)		
	Yellow light	15 (50.000)	15 (50.000)	0.4	0.8368
	White light	13 (43.333)	17 (56.667)		

Based on the feedback from participants, 63.33% of them in blue light group felt distracted to perform tasks under the blue light exposure, 33.33% in yellow light group and 26.67% in control group. The chi-square value was 7.8 with P-value of <0.05 which is significant. (Table 11)

Table 11. *Association between blue (n-30), yellow (n=30) and white (n=30) light exposure and distraction to perform tasks under light exposure in this study.*

Variable		Distracted to perform tasks under light exposure in this study *n* (%)	Not distracted to perform tasks under light exposure in this study *n* (%)	Chi-square	*P*-value
Colour of light exposure	Blue light	19 (63.333)	11 (36.667)		
	Yellow light	10 (33.333)	20 (66.667)	7.8	0.0205
	White light	8 (26.667)	22 (73.333)		

Based on the feedback from the participants, 33.33% of them in blue light group felt anxious while performing the task under the blue light, 30.00% in yellow light group and 26.67% in control group. The chi-square value was 0.1 with P-value of >0.05. (Table 12)

Table 12. *Association between blue (n-30), yellow (n=30) and white (n=30) light exposure and anxious status.*

Variable		Feeling anxious while performing the task under the light exposure *n* (%)	Not feeling anxious while performing the task under the light exposure *n* (%)	Chi-square	*P*-value
Colour of light exposure	Blue light	10 (33.333)	20 (66.667)		
	Yellow light	9 (30.000)	21 (70.000)	0.1	0.9474
	White light	8 (26.667)	22 (73.333)		

4. Discussion

The main objective of this study is to determine the effectiveness of different colours of light (blue, yellow and white) exposure towards attention and short term memory among medical students in Melaka Manipal Medical College. The yellow light and blue light were compared with a control group (white light). Based on the attention score percentage, the yellow light group obtained the highest mean score among the three groups, while the blue colour group is the lowest. In reference to the results of this study, it is proven that using yellow colour light is more effective in paying attention compared to using blue colour light. Therefore the yellow colour light is a more favourable light that should be implemented during the lecture classes with the lecture slides being projected which in our context is the ability to spot all differences from pictures. The short term memory was also tested during this study where the mean score percentage of the yellow light group is the highest, followed by the control group. The blue light group obtained the lowest mean memory score percentage among all three groups. In reference to the results of this study, it is proven that using yellow colour light is more effective in memorization compared to using blue colour light as the participants in

yellow colour light group obtained the highest memory score percentage out of the three groups. Therefore the yellow colour light is a more favourable light that should be implemented on memorizing important points from textbooks which in our context is the ability to memorize 20 words given in 1 minute time. Based on study, a comparison of blue light and yellow light in mental arousal and performance conducted by Kyungah Choi and Hyeon-Jeong Suk, two researchers at the Korea Advanced Institute of Science and Technology (KAIST) in South Korea, they proved that using blue light can increase alertness [16] but decrease performances of the subjects. The findings confirm the Yerkes-Dodson Law [17], an observation stated more than a century ago by psychologists Robert Yerkes and John Dodson. The law says there's a curvilinear relationship between mental arousal and performance. Tests on the Yerkes-Dodson law suggests people perform at their best when their state of mental arousal is intermediate which is reached at 6500 K which is represented by blue light. This means that blue light will make us too alert and decrease performance from optimal baseline [18]. According to a research conducted by Anna on the memory consolidation affected by light, blue light exposure could be implemented during memory training for elderly individuals, or it could be used selectively by students to improve memory for important test material. In addition, exposure to blue wavelength light from natural sun exposure may have similar beneficial effects on memory; however future research will be necessary to investigate whether the results from this study are also found in such naturalistic settings [19].

The positive mean difference value of the comparison between the yellow light group and control group indicates that the yellow light group is more effective in doing task requiring attention and memorization compared to control group in this study. However, the positive mean difference value of the comparison between the blue light group and control group indicates that the blue light group is less effective in doing task requiring attention and memorization when it is compared with control group. Lastly, the positive mean difference value of the comparison between the yellow light group and blue light group indicates that yellow light group is more effective among the two interventions in doing task requiring attention and memorization. Based on a previous research published in the journal Proceedings of the National Academy of Science (PNAS), researchers found that the orange light which has a similar wavelength with yellow light in our research had a substantially stronger impact on the prefrontal cortex of the participants – the part of brain responsible for higher order cognitive function [20].

When we focused on the participants' conditions like headache and dizziness during and after the test with awareness towards the effect of different colour of light exposure on memory and attention, there is no significant difference between the three groups of blue, yellow and white lights. This is because yellow and white lights are commonly used in daily activities. There is significant difference of blurring of vision in participants under blue light exposure during or after the test compared to yellow light and control group. The participants exposed to blue light are more significantly distracted to perform the task compared to yellow and white light. Distractions comes in many forms, which can be vibrant colors, lights and loud sounds. The more these appear in our surroundings, the more likely our attention is caught [21]. In the current study we wanted to observe different colours of light exposure influencing the performance of the participants. Blue light strained the eye more than yellow and white lights. The eyes require more effort to focus on blue sharply as it scatters more widely within the eye and more likely to be focused in front of the retina, causing us to be

slightly out of focus [22]. There is no significant difference in the anxiousness while performing the task among the participants under the blue, yellow and white lights exposure as good instructions and explanations were given to all participant before the task was conducted.

5. Conclusion

In conclusion, yellow light exposure is the most significant colour compared to the blue light exposure and control group. In addition, the yellow light exposure does not cause headache, dizziness and blurring of vision. Yellow light is also less distracting and causing less anxiousness. This proves that yellow colour light exposure is the most effective colour in performing tasks requiring short term memory and attention which can be useful for all medical students to perform better in their educational purposes.

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