

Original Research Article

Effect of Lighting on Concentration of Medical Students: A Randomised Controlled Trial

ABSTRACT

Aims: To determine the effect of lighting on concentration in college students.

Study design: Randomised controlled trial

Place and Duration of Study: Melaka-Manipal Medical College (MMMC), Muar Campus, Johor, Malaysia in July 2016.

Methodology: 50 students were randomly chosen and then assigned to intervention and control groups equally via randomisation. 41 students participated in this study. Participants of both groups were required to perform d2 Test of Attention and answer a structured questionnaire. The intervention group was placed in room with low luminosity while the control group was in a room with higher luminosity. Data were analysed using SPSS version 18.

Results: The intervention group had a mean score of 526.9 for concentration performance, which was lower than that of the control group at 615.3. The mean for error percentage of the intervention group was 0.10, whereas the control group had a lower mean of 0.03 for the same outcome. In general, the intervention group had significantly weaker concentration and more errors made as compared to the control group.

Conclusion: The results of this study highlight the positive effect of a higher lighting intensity has on concentration. Thus, it is recommended that educational institutes take into consideration the intensity of lighting as an important factor when setting up and designing their classrooms.

Keywords: Concentration, attention, d2 test of attention, light intensity

1. INTRODUCTION

Concentration is the ability to give one's attention or thought to a single object or activity at a time and is an important element to facilitate the learning process [1,2,3]. It is affected by both internal (random internal thought) and external factors (noise, lighting, emotions, colours and etc.) [4]. Thus, many studies were conducted in schools among the Western populations on the effects of external factors on concentration ability of students [5,6,7].

Lighting has been described as an agent in improving cognitive performance [8]. The importance of lighting for performance in humans is well established and many researches have indicated that lighting can affect people's mood and alertness [9,10,11,12]. Meanwhile, other studies have found that the degree of illumination is one of the modifiable factors to provide a more conducive and optimal environment for concentration [13,14].

These effects of lighting on human body make one wonder how lighting affects a student's concentration. While the literature available suggests that lighting can affect the ability to concentrate, most studies were conducted on young and school-going children [6,15]. Thus, this study was conducted to determine the effect of lighting on concentration among college students.

2. METHODOLOGY

In July 2016, we conducted this randomized controlled trial among medical students of Melaka-Manipal Medical College (MMMC) in Muar, Johor, Malaysia. MMMC was established in 1997 and is a leading medical education provider, the single largest contributor of doctors to the Malaysian healthcare system. Currently MMMC has two faculties namely the Faculty of Medicine (MBBS) and The Faculty of Dentistry

35 (BDS) while offering a pre-university course i.e. Foundation in Science Programme (FIS). MMMC has a
36 total of three campuses namely in Manipal, Melaka, and Muar, which house around 2000 students and
37 faculty in total [16].

38
39 We selected our study population which consisted of students from the Muar campus of MMMC. Using
40 the values $\bar{x}_1=206.89$, $\bar{x}_2=178.32$, and $SD=30.39$ from a previous similar study [6], we calculated the
41 minimum sample size of 18 (rounded up from 17.8) persons per arm using the following formula [17]:

$$42 \quad n = 2C/\delta^2 + 1, \quad \text{where } \delta = (X_1 - X_2)/SD \text{ and} \\ 43 \quad C = 7.84$$

44
45
46 The minimum number of participants for both arms was 36 persons. We proceeded by selecting a total of
47 50 students from the student population of 205 students via simple random sampling using a scientific
48 randomizer. We approached the selected students personally and obtained their consent. The inclusion
49 criterion was the willingness of students to participate whereas the exclusion criteria were unwillingness
50 to cooperate and not attending the session conducted.

51
52 We randomly assigned the 50 selected students equally into the intervention and control groups once
53 again using the scientific randomizer. To maintain the single-blinding characteristic, we only informed the
54 students that they belonged to either Group A (Intervention) or Group B (Placebo).

55 56 **2.1 Interventions**

57
58 Luminosity or lux (lx) is a measure of the overall illumination of a scene. One lux is equal to the intensity
59 of the light hitting a one metre squared object placed one metre away from a candle. The higher the lux
60 value, the greater the intensity of light falling on the scene [18]. We exposed the intervention group to low
61 degree of illumination i.e. low lux value. To achieve this, we selected a room and manipulated its lighting
62 by turning the lights on or off.

63 The room we chose had 16 light bulbs arranged in sets of 2 light bulbs. The bulbs used were Panasonic
64 energy saving bulbs (Model no: FL40SS.D/36), each of which had a power of 36W and gave off light with
65 a luminosity rating of 2600 lumens and colour temperature of 6500K [19]. We selected a room without
66 windows and sealed off the glass panels on the doors to eliminate natural light from entering the room.

67 We only kept two sets of lights (4 bulbs) switched on during the intervention session in which the
68 recorded luminosity measurement at desk level was 15 lx. For the control group, we turned all the lights in
69 the room on to produce a measured luminosity of 450 lx at desk level. We measured the luminosity in the
70 rooms using a phone-based digital lux meter application called 'Lux Meter' that had been found to
71 produce accurate readings in another study [20].

72 **2.2 Outcome**

73
74 We measured the ability to concentrate of subjects under different lightings using the d2 Test. The d2
75 Test measures processing speed, rule compliance, and quality of performance, thus allowing for a
76 neuropsychological estimation of individual attention and concentration performance [22]. The reliability of
77 the test has been proven to be very high, and the validity of the technique has been documented by a
78 number of research studies, as evident by the internal consistency of the total number of items processed
79 ranging from 0.84 to 0.98 along with a test-retest reliability of 0.87 [21,22].

80
81 The d2 Test consists of 14 rows, each containing 47 characters; giving a total of 658 items. Ten different
82 characters are used in the d2 Test, which are made up of combinations of the letters "d" and "p" with one
83 to four dashes, which are in turn arranged either individually or in pairs, above or below each letter. The
84 subjects were required to scan across the rows from left to right to identify and to mark all items

85 consisting of “d’s” with two dashes. The subjects were asked to work as quickly as possible without
86 making mistakes. The processing time per row was set at a 20 seconds, which we timed using a
87 stopwatch. At each 20-second interval, we instructed the subjects to shift to the following row regardless
88 of whether the current row had been completed or not. The total administration time for the d2 Test was
89 four minutes and forty seconds. We administered the test in groups consisting of four to eight subjects.
90

91 From the d2 test sheets, we were able to obtain several scores namely, (1) Total Number of Items
92 Processed (TN), which was the number all items that were processed, both relevant and irrelevant ones;
93 (2) Raw Score of Errors (E), which was the sum of all mistakes in the forms of errors of omission (number
94 of relevant items that were missed, E1) and errors of commission (number of irrelevant items that were
95 marked, E2); (3) Percentage of Errors (E%) which was the proportion of errors (E) out of total number of
96 items processed (TN); (4) Total Number of Items Minus Error Scores (TN-E). From these calculated
97 scores, we managed to derive two other test scores which were (5) Total Number of Items Minus Double
98 of Error Scores (TN-2E); and (6) Concentration Performance (CP), which was derived from the number of
99 correctly crossed out relevant items (d2) minus the errors of commission (E2) [23].
100

101 Upon completion of the d2 test, participants were required to answer a two-part self-administered
102 structured questionnaire. We collected sociodemographic data in Part 1 of the questionnaire which
103 included age, gender, birth order, monthly allowance, number of meals per day and number of hours of
104 sleep per day. In Part 2, we included questions that assessed various perceptions of the participants
105 towards their experience during the session. Part 2 consisted of four sections, A, B, C, and D. Section A
106 contained five items that assessed how well the participants had understood the test. Section B contained
107 eight items to assess how the participants felt during the test in the particular conditions of the room.
108 Examples of the items asked in this section included if they felt comfortable in the room and if they
109 experienced headaches due to the conditions of the room. Section C contained seven items that asked
110 participants about their perception on their respective performances in the test. These include items about
111 their ability to think clearly and their evaluation of their own alertness during the test. Lastly, section D
112 contained two items regarding the opinion of participants on the test whether they felt it was organised
113 and suitable.
114

115 We utilised a Likert scale response format with responses ranging from “strongly disagreeing” to “strongly
116 agreeing” and scores ranging from “1” to “5” respectively. For each item that was worded negatively, we
117 reversed the score accordingly. Then, we summed up the responses for each of the four sections. A
118 higher total score in section A meant that the participants had a higher understanding of the test, while in
119 section B, a higher total score meant that the participants felt the conditions of the room had no effect on
120 them. In section C, a higher total score meant that the participants performed well according to their
121 subjective perception. Lastly, a higher total score in section D showed the participants felt the test was
122 suitable.
123

124 **2.3 Data Processing and Analysis**

125

126 We processed the data using Microsoft Excel and then proceeded to data analysis using SPSS version
127 18. We presented our data using frequencies and percentages as well as means and standard deviations
128 in a tabulated form. We used unpaired t-test statistical analysis for the outcomes in the intervention and
129 control group which were the scores of d2 Test and scores of Part 2 of the questionnaire. The level of
130 significance was set at 95% (P value $<.05$).
131

132 **2.4 Ethical Approval and Consent**

133

134 We were granted approval to conduct the study by the Research Ethics Committee of Melaka-Manipal
135 Medical College in the month of July 2016. We also obtained written permission from the administrative of
136 Melaka Manipal Medical College (Muar Campus) for the use of their premises to conduct the study. All
137 the students were voluntary participants of the study and had given their written consent. We also
138 assured the confidentiality of all data collected during this study.
139

140
141 **3. RESULTS**

142
143 The total number of participants was 41 participants, among which the mean age was 22.9 years with
144 standard deviation of 0.53. The majority of the participants were females, constituting 58.5% of the
145 participants. In terms of ethnicity, the largest group was Malay who made up 39%, followed by Chinese
146 and Indian, who accounted for 26.8% and 24.4% respectively. Others indigenous groups made up the
147 remaining 9.8%. Descriptive statistics of all participants in the study are shown in Table I.
148

149 **Table I: Descriptive statistics of basic variables among participants**
150

Variable	Values
Age (Mean ± Std Deviation)	22.9 ± 0.53
Gender	
Male	17 (41.5%)
Female	24 (58.5%)
Ethnicity	
Malay	16 (39.0%)
Chinese	11 (26.8%)
Indian	10 (24.4%)
Others	4 (9.8%)

151
152
153 By comparing the sociodemographic characteristics between the intervention and control groups, the
154 mean age of the intervention was 23.0 years, which is found to be higher than 22.8 years of the control
155 group. In terms of gender, there were 11 (52.4%) males in the intervention and 6 (25.0%) of them in the
156 control group. In this study, Malays constituted the highest percentage in control group (52.4%) followed
157 by the Chinese (19.1%), Indians (14.3%) and others (14.3%). In the intervention group, both the Chinese
158 and Indians made up 35% of the group followed by Malays (25%) and others (5.0%). However, the
159 differences between the intervention and control group in terms of age, gender and ethnicity were not
160 significant. Details are tabulated in Table II.
161

162 **Table II: Comparison of sociodemographic characteristics between intervention and control**
163

Variable	Values		P value
	Intervention	Control	
Age (Means ± SD)	23.0 ± 0.51	22.8 ± 0.53	.26
Gender			
Male	11 (55.0%)	6 (28.6%)	.09
Female	9 (45.0%)	15 (71.4%)	XX
Ethnicity			
Malay	5 (25.0%)	11 (52.4%)	Reference
Chinese	7 (35.0%)	4 (19.1%)	.13 ~
Indian	7 (35.0%)	3 (14.3%)	.11 ~
Others	1 (5.0%)	3 (14.3%)	.99 ~

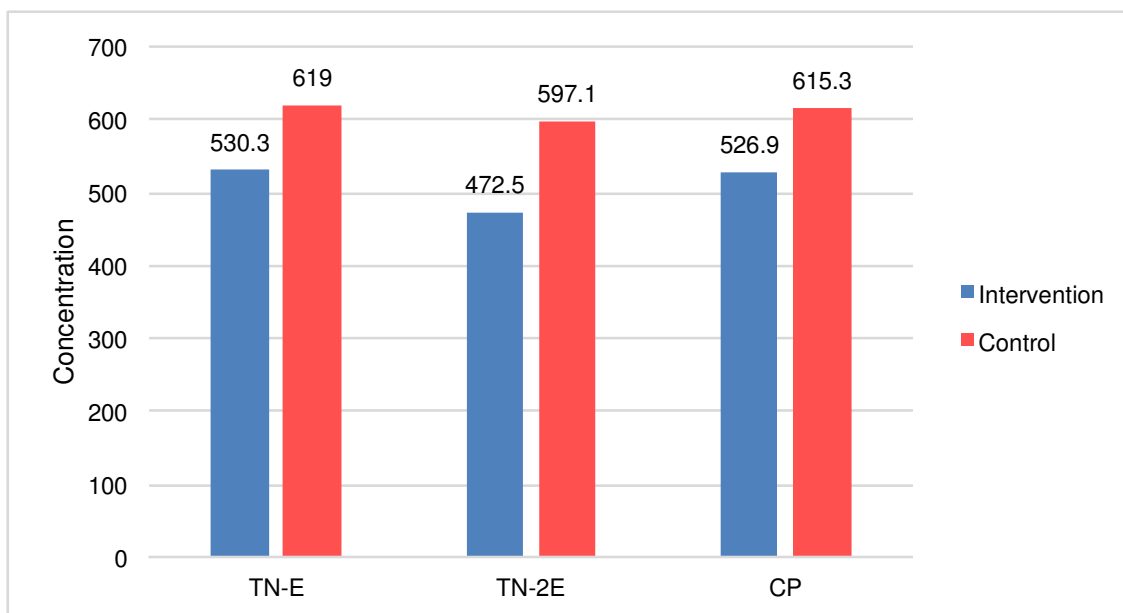
164
165 ~ Fisher exact test was used since expected cell count <5
166

167 From the scores of the d2 test, the intervention group had means of 530.3 and 472.5 for TN-E and TN-2E
 168 respectively, which were significantly lower than the control group with means of 619.0 and 597.1
 169 respectively. The intervention group had a mean score of 526.9 for concentration performance, which
 170 was also lower than that of the control group at 615.3. Other than that, the mean for error percentage of
 171 the intervention group was 0.10, whereas the control group had a lower mean of 0.03 for the same
 172 outcome. In general, the intervention group had weaker concentration and more errors made as
 173 compared to the control group. The significant differences in scores between the intervention and control
 174 groups are depicted by Table III and Figure I.

175 **Table III: Quantitative comparison of outcomes of the d2 test between intervention and control**
 176 **groups via independent t-test**
 177

Outcomes		Mean (SD)	t test	P value
TN-E	Intervention	530.3 ± 71.8	-5.15	< .001*
	Control	619.0 ± 31.9		
TN-2E	Intervention	472.5 ± 95.6	-5.44	< .001*
	Control	597.1 ± 42.8		
CP	Intervention	526.9 ± 71.1	-5.19	< .001*
	Control	615.3 ± 31.6		
Error %	Intervention	0.10 ± 0.06	4.83	< .001*
	Control	0.03 ± 0.03		

179 * Significant finding, (P value <.05)
 180
 181
 182



183 **Figure 1: Comparison of concentration test scores among Intervention and Control**
 184

185
 186 After correcting for the confounders, namely gender, age, ethnicity and the number of hours of sleep
 187 the students had the day before the RCT, the intervention group was found to have a significantly lower
 188 level of concentration performance (CP), as compared to the control group as shown in Table VI.
 189
 190
 191
 192

193 **Table VI: Multiple linear regression analysis of lighting intensity on concentration performance**
 194

Variables	Unstandardised Coefficients	t-test	P value	95% Confidence Interval		
				Lower Bound	Upper Bound	
(Constant)	631.33	1.41	.17	-277.38	1540.05	
Intervention	-87.45	-4.18	<.001*	-130.01	-44.89	
Gender	3.50	0.17	.87	-38.20	45.20	
Age	-2.26	-0.12	.91	-40.36	35.84	
Ethnicity	Malay	38.80	1.15	.26	-29.79	107.39
	Chinese	31.23	0.88	.39	-40.89	103.35
	Indian	19.94	0.53	.60	-56.82	96.69
Number of hours of sleep	0.30	0.03	.97	-17.68	18.27	

195 * Significant finding, (P value <.05)
 196

197 From the same table, a prediction model can be generated, which enables the estimation of the
 198 concentration performance of a student, as shown in the equation below:
 199

200 Concentration Performance = 631.33 - 87.45(Intervention) + 3.50 (Male) - 2.26(Age)
 201 + 38.80(Malay) + 31.23(Chinese) + 19.94(Indian)
 202 + 0.30(Hours of sleep)
 203

204 For example, the concentration performance score in d2 test under exposure to illuminance of 15 lx of a
 205 24-year-old Malay female, who had 8 hours of sleep the night before, would be 530.84.
 206

207 The statistical analysis of perception of participants towards various aspects of the RCT session is shown
 208 in Table V. In this table, a higher mean score is indicative of a more positive outcome whereas a more
 209 negative outcome would be indicated by a lower mean score. Regarding comprehension of the test
 210 conducted, the control group averaged at 16.7 whereas the intervention group averaged at 19.5. The
 211 control group also found the room conditions to be more favourable, giving a mean score of 30.3,
 212 compared to the intervention group, which had a mean score of 24.6. As for their performance, the control
 213 group had more positive perception with a mean score of 22.3 compared to the intervention group which
 214 scored 19.6. With regards to the suitability of the test, there was no significant difference between the two
 215 groups.
 216

217 **Table V: Statistical analysis of perception towards various aspects of RCT session**
 218

219 *

	Perception towards		Mean ± SD	t-test	P value
220 Sig	Comprehension of Test	Intervention	19.5 ± 3.6	2.45	.02*
		Control	16.7 ± 3.8		
222 ant	Room Condition	Intervention	24.6 ± 5.1	-3.13	.003*
		Control	30.3 ± 6.5		
224 ng,	Performance	Intervention	19.6 ± 3.7	-2.57	.01*
		Control	22.3 ± 3.1		
226 valu	Suitability of Test	Intervention	8.5 ± 1.4	0.95	.35
		Control	8.0 ± 1.6		

227 e
 228 <.0
 229 5)

230
 231 **4. DISCUSSION**
 232

233 The intervention group, which underwent the d2 Test in the room with lower light intensity, had a
 234 significantly lower mean TN-E as compared to the control group in higher light intensity. TN-E is the total
 235 number of item processed minus both errors of commission and omission, and is a measure of quantity of
 236 work completed after correction for errors [24]. It provides a reliable correlation between accuracy and

237 speed of performance [25]. TN-2E is another similar parameter, which doubles the error score, to correct
238 for total performance [26]. Thus, the results for both TN and TN-2E imply that subjects in the control
239 group, who were exposed to light of higher intensity, were faster and more accurate in completing the
240 task, thus giving a higher productivity.

241
242 In addition, the intervention group had lower score for concentration performance, as compared to the
243 control group. Concentration performance takes both accuracy of performance and coordination of speed
244 into account. It is the most reliable measurement of concentration as it is not sensitive to extreme scores
245 due to incidental coincidences [25]. In other words, the control group, which performed the d2 test in light,
246 had higher level of concentration than the intervention group.

247
248 On the other hand, the intervention group had a higher error percentage than the control group. Error
249 percentage is a measure of inhibitory control, rule compliance, carefulness and quality of performance in
250 general [25]. Hence, the control group, with a lower mean score for percentage of errors, indicated that
251 the subjects had better accuracy and attention level, hence higher quality of task performed [24,25].

252
253 The results of d2 Test thus show that the subjects who were exposed to higher light intensity had a higher
254 level of attention and concentration as compared to subjects who performed the same task under lower
255 light intensity, as in accordance with results of a few similar researches [6,27]. Light is said to be the most
256 important environmental input, after food and water, in controlling bodily functions [28]. Other than a
257 strong enabler for visual performance, light also regulates mood, focus, motivation, concentration and
258 alertness, thus increasing productivity [29,30].

259
260 A sound explanation to the findings of our research would be the effect of bright light exposure during
261 daytime on subjective sleepiness of the subjects in control group, whereby light of higher intensity
262 effectively replenished the subjects' energy and reduced their feeling of fatigue, thus improving their
263 sustained performance and increasing their productivity [31,32,33,34]. Studies had shown that higher
264 illuminance is more arousing than lower illuminance, both cortically and behaviorally, due to the waking
265 effect of higher light intensity on the central nervous system [35,36]. Indeed, light-induced improvement in
266 subjective alertness was found to be linearly related to responses in the posterior thalamus [37]. These
267 resulted in subjects in the control group having a higher level of concentration when compared to the
268 intervention group.

269
270 Another plausible theory that explains the relationship between light intensity and the level of
271 concentration of our subjects involves the role of melatonin, a hormone which has the highest plasma
272 level in the human body during the peak of rest phase of human rest activity cycle [38]. It has been
273 hypothesized that melatonin attenuates the suprachiasmatic nucleus-dependent mechanisms responsible
274 for promoting and maintaining cortical and behavioral arousal at particular times in the circadian cycle,
275 thus causing a depressant effect upon arousal, attention and motor activity [27,38]. This explains the
276 lower level of concentration among subjects in the intervention group, who were exposed to light of lower
277 intensity. Contrarily, exposure to sufficiently bright light could hypothetically increase alertness due to
278 decreases in circulating and CNS melatonin levels [32]. In fact, a study in the USA showed that variations
279 in lumination within the range of typical, ambient, room light of 90 to 180 lux could have a significant
280 impact on subjective alertness, which is a dose-response relationship that had been positively correlated
281 with the degree of melatonin suppression by light [27,39].

282
283 Along with the results of the test, we also found significant differences between the subjective perception
284 of the intervention and control group with regards to various aspects of the experiment. The test was
285 found to be more comprehensible to the intervention group participants compared to control group
286 participants. This is surprising as it had been noted in previous studies that students cannot focus and
287 were sleepy when they are in a poor lighting environment, thus causing their comprehensibility and
288 performance to be affected [40]. One plausible theory would be the decrease in visual input in lower light
289 intensity had enabled the intervention group to focus more on the sense of hearing, thus enabling them to
290 understand the instructions better.

291

292 We also observed that the control group felt better and less affected by the conditions of the room
293 compared to the intervention group. This suggests that good lighting can create a calm atmosphere
294 without an oppressive feeling [41]. Furthermore, adequate light level can prevent visual discomfort such
295 as excessive straining of the eye or squinting which can lead to headache [42,43].

296
297 Another significant finding was in term of their subjective personal performance. The control group felt
298 they had performed better compared to the intervention group whereas participants from the intervention
299 group had reported that they were more relaxed, and were able to think more clearly and experienced
300 increased concentration level. This may be due to the good lighting, which had provided motivation for the
301 participants to perform better [40]. Another explanation is that visual performance is generally improved
302 when people can see the task clearly.[44].

303
304 There are a few limitations in our study that should be addressed for more reliable results. Our study had
305 only investigated light as a single factor affecting students' concentration. Among the limitations there
306 could be the presence of other factors such as stress that may have an adverse effect on the ability to
307 concentrate. This was because participants were selected from five different clinical posting groups and
308 may be exposed to varying amount of stress. Personal problems could be another possible source of
309 stress [45]. Another limitation was that we were unable to acquire a lux meter due to the limited resources
310 [20]. The age of the light bulb was also a limitation as older light bulbs may be worn out and this
311 corresponds to lower lumen values [46]. Another limitation was that we only took into account the
312 intensity of lighting but did not look into other aspects of lighting such as glare and temperature. Also, the
313 students were told to wear their respective visual aids during the vision but their visual acuity was not
314 tested.

315
316 As such further research into this subject may be directed towards the possible effects of the temperature
317 of lighting, glare as well as the effects of natural lighting on the ability of a student to concentrate.

318

319 **5. CONCLUSION**

320

321 The findings of this study highlight the positive effect of a higher lighting intensity on a student's
322 concentration. Thus, it is recommended that educational institutes take into consideration the intensity of
323 lighting as an important factor when setting up and designing their classrooms in order to ensure that the
324 concentration levels of students are not negatively affected.

325

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