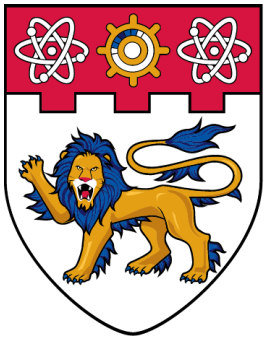


NANYANG TECHNOLOGICAL UNIVERSITY
SINGAPORE

HW0228 SCIENTIFIC COMMUNICATION II

ASSIGNMENT 2 - SCIENTIFIC REPORT

Tiviatis

Joey

Josephine

Shannon

2020/2021 Semester 2

RESEARCH TITLE:

Bored of Black Fonts? A study on the effects of different coloured fonts on undergraduates' concentration levels.

Bored of Black Fonts? A study on the effects of different coloured fonts on undergraduates' concentration levels.

ABSTRACT

This paper explores the effect of different coloured fonts on the concentration levels of undergraduates, focusing on the analysis of brainwave activity. 20 undergraduates across 5 different majors were selected with informed consent to participate in a test-based experiment. During the experiment, they were tasked to wear an electronic head device to measure their brainwave activity while completing the test. Results obtained from the experiment will be analysed based on the colour of fonts used, as well as socio-demographic factors such as the course of study and gender. The average of the results was calculated and evaluated with ANOVA statistical test to investigate whether the colours used have a significant impact on the results.

Overall, it was concluded that colours do not have a notable effect on the concentration levels of undergraduates. Although our study found that Participants in the Black control group reached a higher peak concentration on average during the tests, the difference compared to that of other colours is not distinguishable. Other factors such as the undergraduates' course of study, however, may have affected the effectiveness of this study due to the nature of their coursework. This study holds great significance as its potential findings can be utilised in educational settings to help improve the overall learning process of students in Singapore. With the incorporation of colour psychology, students may be able to concentrate better which in return, may increase their learning retention, helping them achieve a better learning experience as well as academic progress.

INTRODUCTION

Concentration is the ability to control and direct one's focus on a subject while excluding other unrelated thoughts in conformity with one's will.[1] The ability to focus effectively on the task while ignoring distractions is found to be one of the many factors that allow for better learning retention amongst students, with studies showing that students who concentrated while learning had higher academic achievement than those with poor attention while studying.[2] Consequently, concentration performance can be seen as a significant component in the effective learning of students. One such factor that may affect concentration performance in students would be the use of colours.

Studies have shown that colours have the ability to invoke certain emotions and influence perception in humans. When color is absorbed by the human eye, information is transmitted from the eye to the brain. The brain then releases a hormone which targets the cognitive functions of the body, including the emotions, mental clarity and energy levels. The psychological responses of the colors can be observed, with red being associated with negative notions like anger, violence and feelings of intensity, while blue with feelings of calmness, serenity and productivity.[3] With the unfolding of such colour studies, marketing strategies are often seen utilising colours to influence sales. For instance, red often appears on sale and discount banners as it is shown to be able to attract spontaneous customers.[4] Therefore, the ability of colours to influence the way people think and act can be incorporated in the same way for the learning of students.

According to various studies conducted on colour, colour was also found to have a clear advantage on visual memory. In a research done by Wichmann FA et al., participants tested in colour

conditions were reported to have performed 5-10% better in colour recognition tests than participants tested in black and white conditions.[5] Colour is believed to be the most crucial visual experience and may function as a powerful information channel to the human cognitive system to enhance memory performances. It thus has an untapped potential in educational settings which may better facilitate the learning process and improve cognitive abilities and concentration of students.

Although there have been many studies on the effect of colours, they were mainly centred on short-term memory recall.[6] Previous studies have also concluded that colours can cause changes in the alpha brain waves. Concentration is key to improving one's memory as attention is required to process and store new information. Despite concentration and memory being intricately linked, there has not yet been a study which primarily focuses on the effect of colours on concentration. Therefore, this study will take a closer look at the effect of colours in terms of font colour, on the concentration levels of students.

The purpose of this study is to first determine whether font colours affect the concentration of undergraduates of different majors in NTU, followed by evaluating which colour is the most optimal for concentration. In this study, concentration will be measured through the brain activities of the undergraduates where Electroencephalography (EEG) signals are extracted for analysis.

MATERIALS AND METHODS

Apparatus and Setting

The concentration test was sourced from The Athlete's Guide to Sports Psychology: Mental Skills for Physical People[7], which was used to develop the mental performance of athletes through concentration exercises. The 4 font colours selected for the test and their respective HEX codes are Black (#000000), Blue (#1167b1), Green (#008000) and Red (#ff0000). Blue, Green and Red were chosen based on various colour psychological studies[8] which indicated that Blue boosts productivity, Green promotes efficiency and focus while Red has a more stimulating effect on the brain. In this experiment, Black will be used as the control since most learning materials have a standard black font.

The test consists of a 15 cm square grid of 10 by 10 randomly placed numbers ranging from 00 to 99 displayed on an 11" iPad Air with an Apple Pencil. There were 4 sets of number grids with identical number placements but each with the different aforementioned font colours (Fig 1.1). To assess the brain activity of each participant, the Muse 2 EEG device was used during the test.

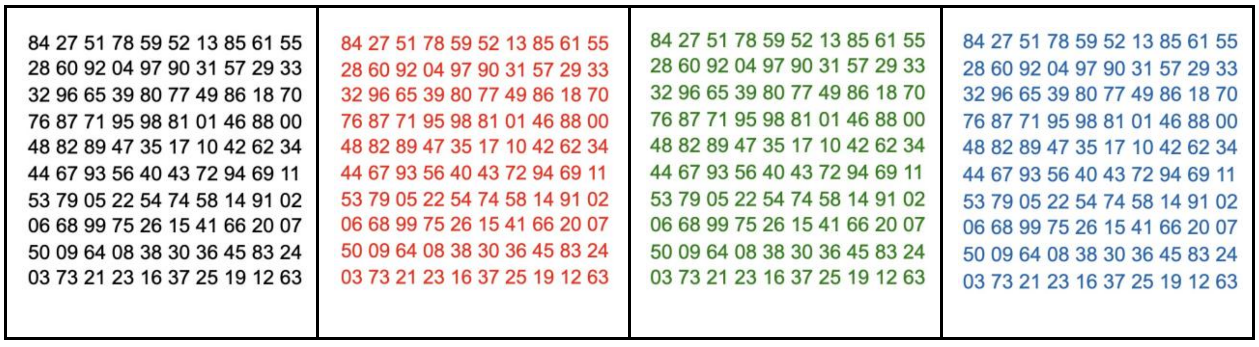


Fig 1.1 Concentration Test Number Grid

Participants

The study was conducted on 20 undergraduates majoring in 5 different majors in Nanyang Technological University in Singapore with their informed consent. None of the participants had colour deficiency. Each undergraduate was randomly assigned to one of the 4 sets of coloured number grids, with each set being tested on 5 participants. The control group consisted of 5 students while the remaining 15 were assigned to the coloured groups.

Procedure

The participants were instructed to wear a Muse 2 EEG device on their heads such that the electrodes are in contact with their skin, targeting the AF7, AF8, TP9, TP10 positions (Fig 1.3) of the brain.[9] Prior to the test, participants were briefed to cross out the numbers in ascending order starting from 00 within one minute. At the end, their highest crossed number will be recorded. Each participant was strictly monitored to ensure that the numbers were crossed in accordingly.

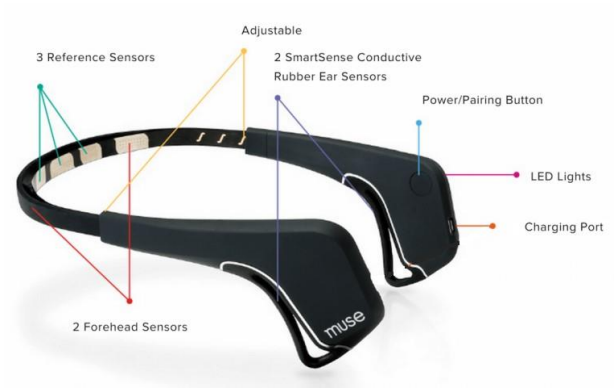


Fig 1.2 Muse 2 EEG Device

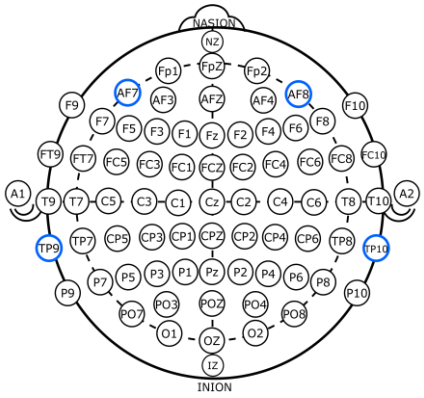


Fig 1.3 Positions of signal targets with respect to the brain

Data Processing

The Muse 2 EEG device was paired to the computer and electric waves from the human brain were sent actively into the BlueMuse application in microvolts. This electrical data underwent a lab streaming layer to allow collection of multiple data points, around 100 per second. During the experiment, a command line input was used to trigger an internal computer timer which records data into a CSV file (1 minute per experiment). A Python code was used to extract the numbers from the CSV file and cast a Fast-Fourier Transformation on the data to convert microvolts into Hertz (Hz). A graph was subsequently generated, and a frequency spectrum diagram was obtained. This diagram shows how often various frequencies occur, in which the frequencies can be further categorized into different bandwidths. Another diagram would be made using R programming language to plot out the summation of the occurrences of 5 different bandwidths: Gamma waves, Beta waves, Alpha waves, Theta waves and Delta waves. These 5 bandwidths would be compared to each other to understand the approximate concentration level

of the individual for their test.

RESULTS

A total of 20 undergraduates, aged 21.00 ± 1.12 years (95% CI) from 5 different majors, Data Science, Computer Science, Business, Medicine and Sports Science Management, completed the field experiment, of which 7 were males and 13 were females. Concentration levels of students during each colour test was compared based on the frequency of Gamma waves.

The brainwave activities of the participants are then assessed through the Muse 2 Device. An example of the frequency of brainwaves for a participant is reported as in Fig 2.

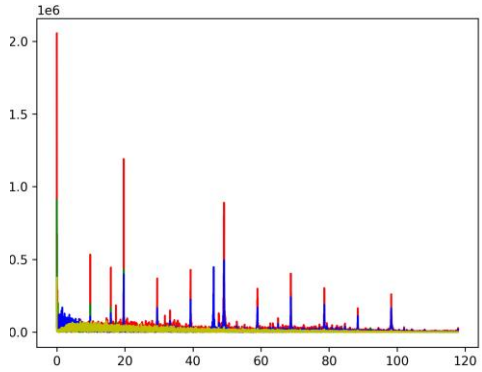


Fig 2. The frequency spectrum diagram displays the number of times a particular frequency of brainwaves is present in the undergraduate.

Fig 3. presents the average number of occurrences (average frequency) of the four different frequency bands present, in order of Gamma (>30 Hz), Beta (12-30Hz), Alpha (8-12Hz), Theta (4-8Hz) and Delta (0.5-4Hz) in the respective colour groups. To measure concentration, the Gamma band was isolated for comparison as previous research done on concentration have shown that the Gamma band was the most appropriate frequencies for the measurement of concentration.[10]

The average occurrence of Gamma waves frequencies emitted by the different colour groups are reported in Fig 4. There was a significant difference for participants in the Black control group and Blue colour group but not for those in the Red and Green colour groups. Gamma waves emitted by participants in the Black control group averaged at an occurrence frequency of

$5.369e^{7} \pm 2.4e^{3}$, Blue colour group at $4.233e^{7} \pm 2.2e^{3}$, the Red colour group at

$3.542e^{7} \pm 4.8e^{3}$and Green colour group at $3.271e^{7} \pm 5.3e^{3}$as reported in Fig 4.

From the trend shown (Fig 4), we can conclude that the type of font colour used in the experiment may have some effect on the concentration of the participants, with the Black control group (n=5) faring the best in terms of the average frequency of Gamma waves emitted, although the results will be further examined and discussed with limitations in mind.

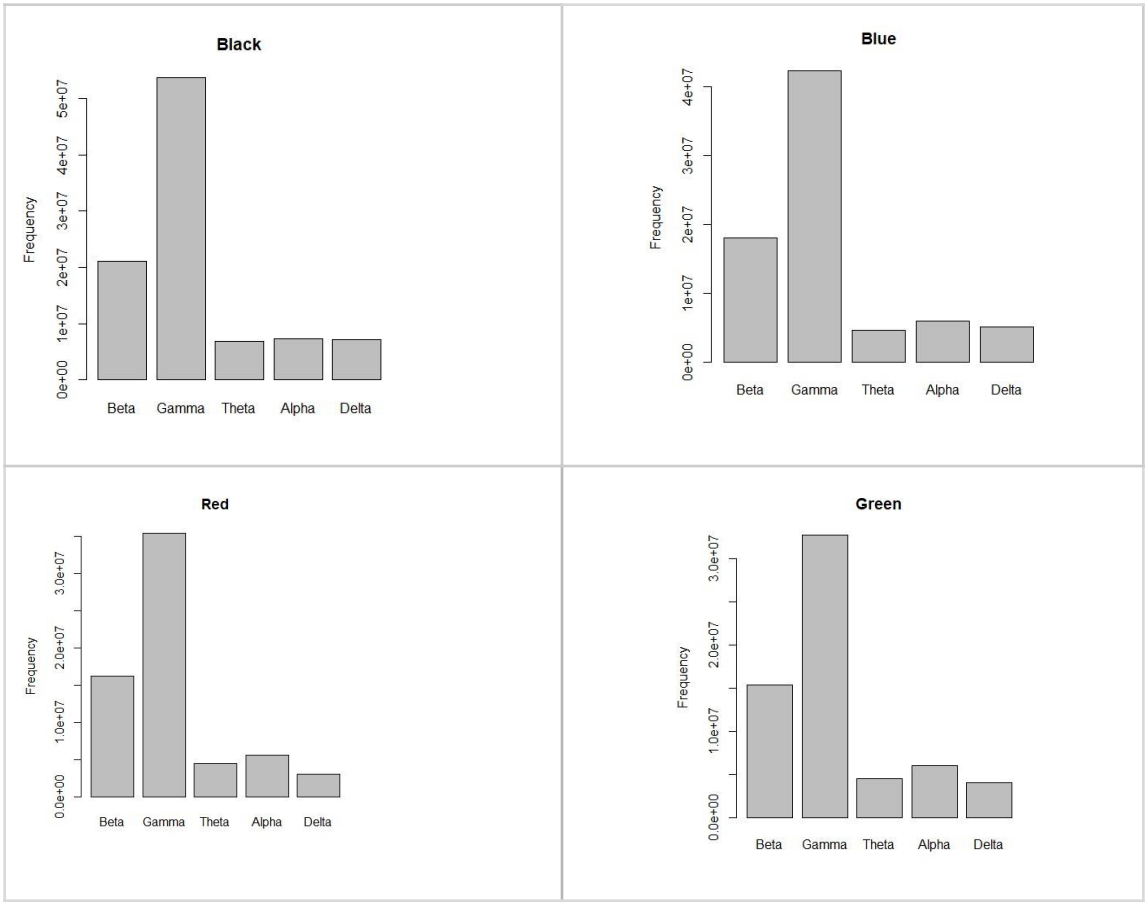


Fig 3. Results of the average frequency of the 5 different frequencies band for respective colour groups

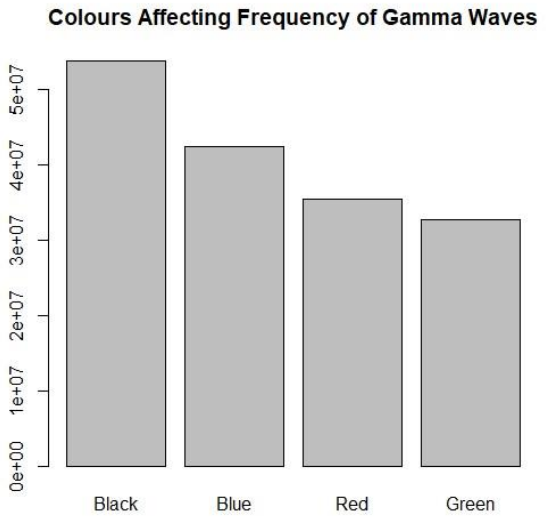
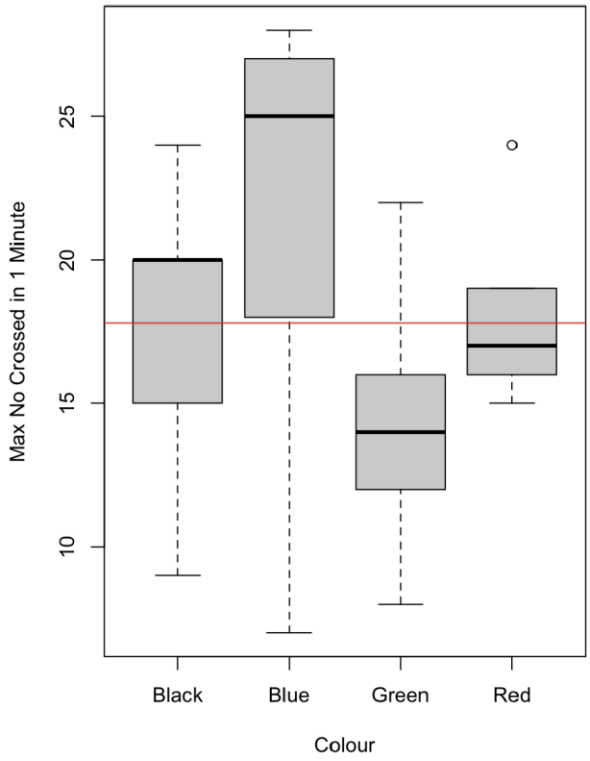


Figure 4. Results of the comparison of average Gamma waves emitted by the 4 different colour groups

Table 1 presents a statistical summary of the results of the Concentration Test by Colour. Fig 5. is a visual representation of Table 1 in Boxplot. It is revealed that participants who took the Blue test fared the best in contrast to those of the Green test, who performed the poorest. As referenced from Table 1, the overall average of the maximum number crossed in 1 minute is 17.80±6.10. Participants of the Blue test averaged at 21.00±8.75, while those of the Green test averaged at 14.40±5.18. The ANOVA test (Fig 6) (p = 0.426 > 0.05) revealed that there is



not enough evidence to support the claim that the mean of all the colour groups were different. Thus, the mean of the maximum number

Fig 5. Boxplot of test results across colours

crossed within a minute were not significantly different throughout the colour groups.

```
> summary(aov(sc$Max.No.Crossed.in.1.Minute~sc$Colour))
            Df Sum Sq Mean Sq F value Pr(>F)
sc$Colour    3  110.0   36.67   0.982  0.426
Residuals   16  597.2   37.32
> pairwise.t.test(sc$Max.No.Crossed.in.1.Minute, sc$Colour, p.adjust.method = "none")

        Pairwise comparisons using t tests with pooled SD

data:  sc$Max.No.Crossed.in.1.Minute and sc$Colour

      Black Blue Green
Blue  0.39  -    -
Green 0.42  0.11 -
Red   0.88  0.48 0.34

P value adjustment method: none
```

Fig 6. ANOVA test results across colour

Colours	Average of Max No Crossed in 1 Minute	StdDev of Max No Crossed in 1 Minute
Black	17.60	5.77
Blue	21.00	8.75
Green	14.40	5.18
Red	18.20	3.56
Grand Total	**17.80**	**6.10**

Table 1. Results of Concentration Test across colours

Based on our results (Table 2), female participants tend to perform better with an average of 18.23 ± 5.40 for the test compared to their male counterparts with an average of 17.00 ± 7.64.

Table 3 reveals that average maximum numbers crossed in 1 minute among all participants across the different courses is highest among the Medical students. Medical undergraduates had the highest average maximum number crossed in a minute at 24.75 ± 3.59.

Gender	Average of Max No Crossed in 1 Minute	StdDev of Max No Crossed in 1 Minute
F	18.23	5.40
M	17.00	7.64
Grand Total	**17.80**	**6.10**

Table 2. Results of Concentration Test across gender

Course	Average of Max No Crossed in 1 Minute	StdDev of Max No Crossed in 1 Minute
BUS	14.50	1.73
CS	18.25	1.71
DSAI	20.40	4.72
MED	24.75	3.59
SSM	8.00	1.00
Grand Total	**17.80**	**6.10**

Table 3. Results of Concentration Test across different majors

DISCUSSION

In this study, Electroencephalography (EEG) is used to measure the concentration levels as it is a noninvasive and safe method to record brain activity. The brain activities are represented by the the frequency bands of the EEG signals, namely the Delta band (0.5-4 Hz) for deep sleep and waking, Theta band (4-8 Hz) for the state of consciousness, inspiration and deep meditation, Alpha band (8-12 Hz) for relaxation without attention, Beta band (12-30Hz) for active thinking and attention and lastly the Gamma band (>30Hz), which is produced during intense concentration and active problem solving[11]. Therefore, Gamma band is the most appropriate frequency band that will be investigated in the experiment.

As higher concentration levels are associated with a higher occurrence of Gamma waves, findings indicated that the highest concentration levels of the participants were attained by participants in the Black control group, faring with the highest average occurrence of Gamma waves at $5.369e^{7}$ followed by Blue, Green and Red. The evidence of the impact of font colour on concentration can be observed through the Boxplot (Fig 5) results as well, with Blue achieving a significantly higher average of maximum numbers counted. Although the average maximum number counted for the colour groups were proven to not be as disparate at 10% significance level, the observations can be conclusively tied to one another. Font colours like Blue and Black increase readability[12] which in return may increase concentration, while other colours like Red may pose a distraction[13], thus adversely affecting the concentration level of the participants.

The Boxplot (Fig 5) illustrates that participants fared the best for the Blue test, which may be due to the calming effect[14] of the colour Blue, which enabled participants to remain calm, focused yet mentally stimulated as they searched the numbers in ascending order. On the other hand, although red is a stimulating colour that is bright and attention grabbing, red has been often associated with negative undertones which induces panic[15]. As a result, participants in the Red group performed less favourably than other colours as expected, as participants may feel stressed and distracted by the bright and jarring text. Unexpectedly, the results of participants in the Green test fared the worst despite studies showing that the color exhibits a calming effect, which can improve one's reading ability and comprehension.[16] These unanticipated results could be attributed to how green is associated with the relaxing attributes of nature and other natural surroundings, which might lead to participants being too relaxed and thus zone out of their focus. Furthermore, the shade of Green chosen may have been more difficult to read and other external
factors like the preferences of the participants may contribute to this inconsistency.

On the other hand, according to previous studies on the effect of colours on memory,[17] despite indications that some colours might have a stronger positive effect on memory, it was concluded that such findings were insufficient to prove the effect of colours on memory in general. Similarly, our results reinforce such studies as seen from the ANOVA statistical test. After careful calibration of the brainwaves statistics and the maximum number crossed during the test, results have shown that Black had the best overall performance in our study. On that account,
Black may potentially be the most optimal colour to promote concentration. However, the ANOVA results showed that the difference between the statistics in comparison to the other colours were

not notable, which indicated that the different participants fared similarly in spite of the colours. Thus, although Black was concluded to be the most optimal colour, it must be recognised that the experiment conducted may have several flaws which led to the insignificant results.

The results obtained may have been biased and offset by other underlying reasons that may have affected the findings of concentration levels of the participants during the field experiment. External factors like the amount of sleep, energy level, preference and background of the participants may have influenced their cognitive functions, thereby contributing to disparity in the findings.

For instance, participants who major in Medicine were observed to have performed better than participants from other courses. Such findings could be attributed to the type of training that they undergo during the course of their study. Medical students are expected to have a high level of attention and concentration due to the nature of their work, and therefore may have a better gauge and control of their concentration compared to participants from other majors. As a result, Medical undergraduates may be expected to perform better in such concentration tests, regardless of the different coloured fonts.

LIMITATIONS

Potential limitations of the current study includes the asymmetric distribution of male and female participants and the small sample size (n = 20). Due to time constraints resulting in a small sample size, there may be biases due to the heavy reliance on the performance of a small group of participants. The lack of males may have resulted in a skewed distribution of the results which

may not be a fair representation of the whole male population. Participants from the different majors were also unevenly distributed, with some majors having only two to three participants. Such limitations may have led to less significant observations, and the reliability of the results would be better with the application of stratified sampling to ensure an even distribution.

Furthermore, to maintain the simplicity of the EEG experiment, the EEG device Muse 2 was used. The lower amount of electrodes present in Muse 2 as compared to medical grade EEG also meant that it is very susceptible to noise, especially from electrical pulses resulting from eye movement, forehead and jaw movement. Such noise would result in the lack of accuracy of the brain wave measurement results. The presence of electronic devices in the testing room which were used to connect to the EEG device for data collection may have also emitted
electromagnetic waves which can interfere with the readings.

That being said, future research should be done with a larger sample size and a more even distribution of both genders and majors to obtain a representative result. Furthermore, future researchers may also use a more meticulous approach that accounts for external factors together with more accurate EEG devices that can accurately extract values from the brainwaves.

CONCLUSION

With regards to pioneer research on colours and memory, our study builds on its sentiments to further explore the broader effect of colours, primarily on concentration. In view of the potential of font colours being a visual tool to grab students' attention, our study focuses on the effect of different coloured fonts on the concentration levels of undergraduates. Hence, our study seeks to

determine if font colours make a significant difference on concentration levels and to find out the most optimal colour for concentration from the results.

Our results have shown that there is a slight effect of each colour on the concentration of students, however it was concluded that the extent of the effects were not significant enough to warrant its influence on one's concentration. Therefore, a more meaningful outcome may be obtained upon further studies conducted given the following recommendations. Studies can focus on investigating with a larger sample size and apply a stratified sampling to ensure an even distribution of the subjects for a representative result. In order to obtain more accurate EEG data for analysis, state-of-the-art EEG devices with greater precision can be used whilst ensuring a low noise environment. Hence, future research may be able to uncover new discoveries about colours which can be meaningful in today's educational settings.

Nevertheless, the study has provided insight on the possibility of colours having the potential in influencing the mind's ability to concentrate. Although there are limitations to this study, the use of colours cannot be undermined in educational settings. Colours have been utilised in many instances to keep students engaged and make learning more intriguing. Studying such colour psychology on the effect of concentration may produce interesting findings that can help improve the overall learning performance and experience of students.

With the infusion of technology into educational settings in Singapore, as illustrated in the recent news regarding all secondary school students having their own personal digital learning devices

by 2028[20], there has been a growing trend of paperless education utilizing electronic devices such as iPads. Many students have made the switch to writing notes on their tablet devices which gives them access and options of choosing the colour of fonts they can write or type in. As such, students are able to discover more efficient ways of studying with colours to strategise their studies.

Learning facilitators can also utilise the findings from this study to provide learning materials in colours that may prove to be the most optimal in promoting the concentration of students when they read the materials, not limiting themselves to plain black and white themes.

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Appendices

Participants Information

SN	Participant ID	Course	Year of Study	Age	Gender	Colour	Max No Crossed in 1 Minute
1	#500	DSAI	2	21	F	Black	24
2	#501	DSAI	2	20	F	Blue	25
3	#502	CS	2	20	F	Red	19
4	#503	DSAI	2	21	F	Green	14
5	#504	DSAI	2	20	F	Red	17
6	#505	MED	2	21	F	Blue	27
7	#506	MED	2	20	F	Black	20
8	#507	DSAI	2	20	F	Green	22
9	#508	CS	1	21	F	Red	16
10	#509	MED	2	21	M	Blue	28
11	#510	MED	2	21	M	Red	24
12	#511	BUS	2	20	F	Green	16
13	#512	BUS	2	21	F	Black	15
14	#513	SSM	1	19	F	Blue	7
15	#514	SSM	2	23	M	Green	8
16	#515	SSM	2	22	M	Black	9
17	#516	BUS	2	23	M	Green	12
18	#517	BUS	2	21	F	Red	15

19	#518	CS	2	23	M	Blue	18
20	#519	CS	2	22	M	Black	20

-

Individual Bar Graph for the different colours

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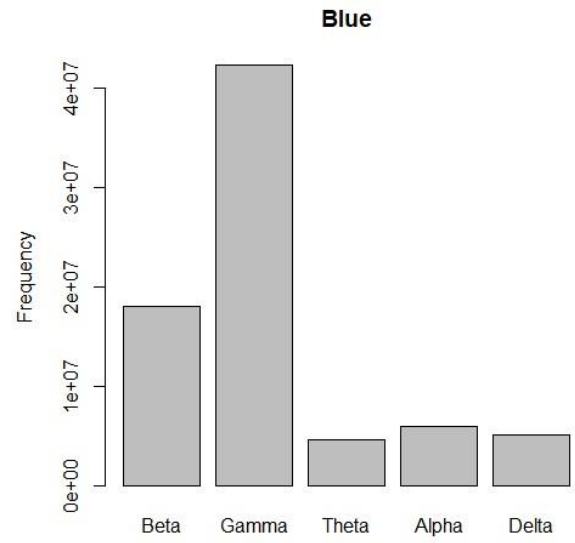
<td> 
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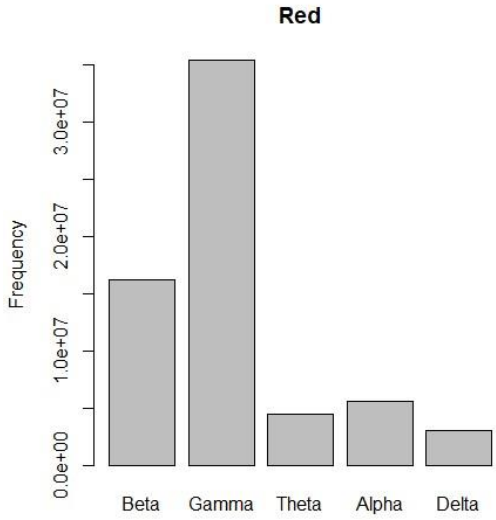
<td> 
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<tr>
<td>Average Brainwave bands of participations in the blue colour group = 42338735</td>
<td>Average Brainwave bands of participations in the red colour group = 35420465</td>
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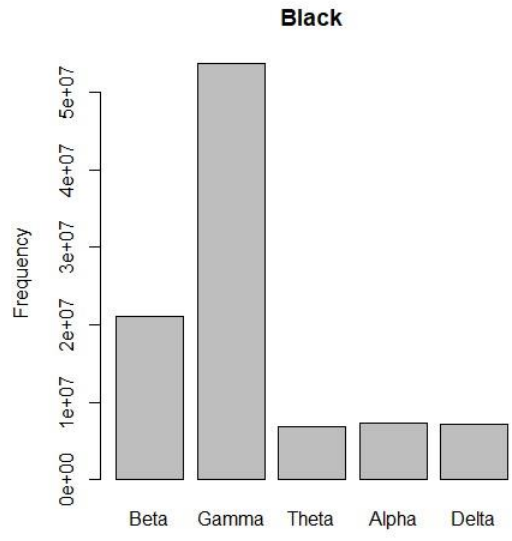
<td> 
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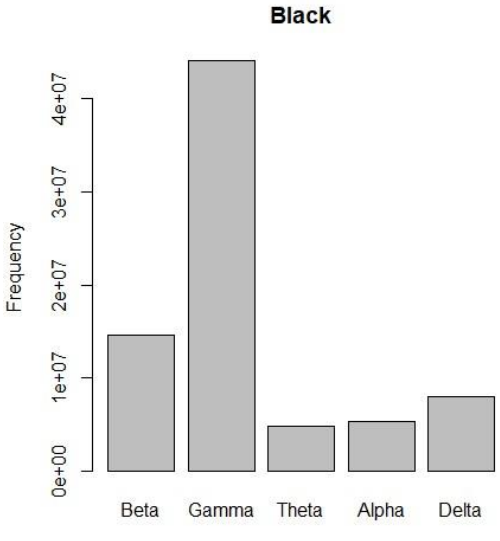
<td> 
</td>
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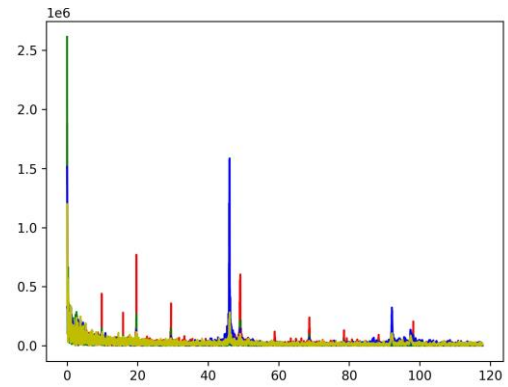
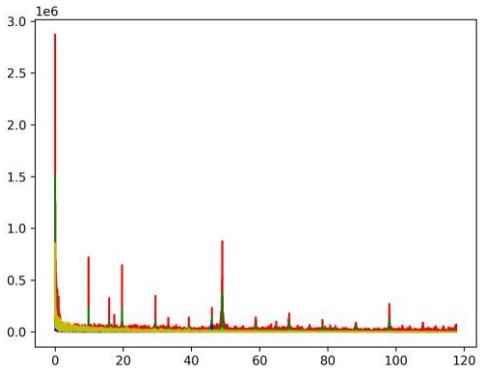
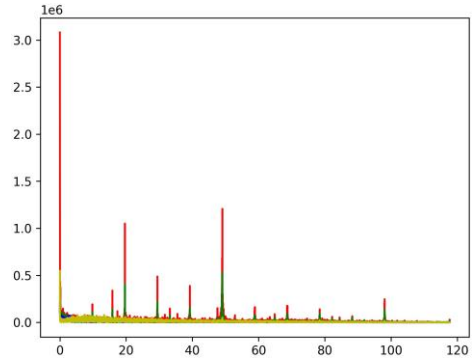
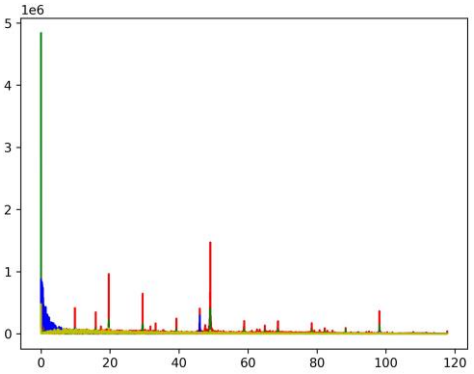
Average Brainwave bands of participations in the green colour group = 53689273	Average Brainwave bands of participations in the green colour group = 44047316

Frequency Spectrum diagram based on brainwave of participants: Red Group



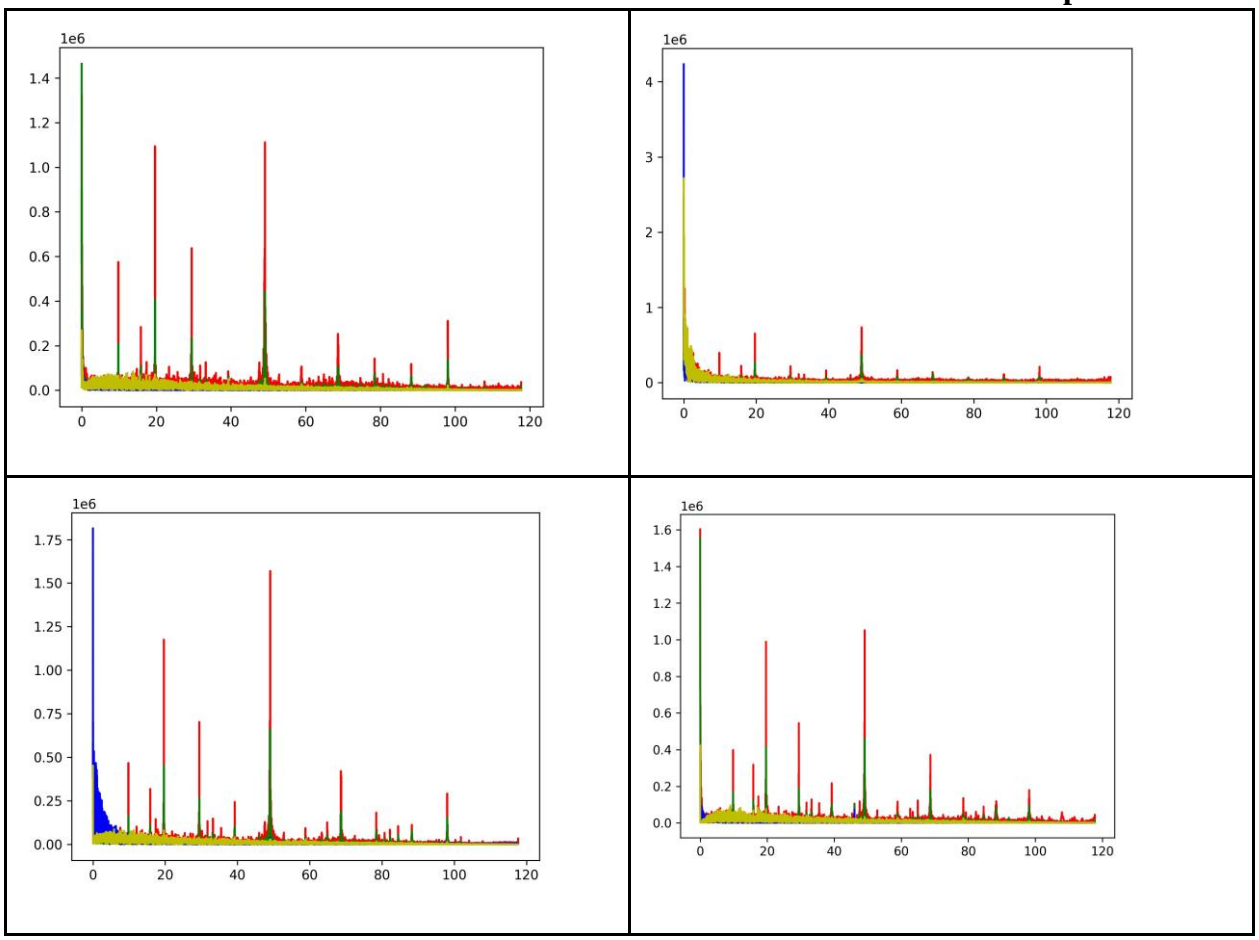




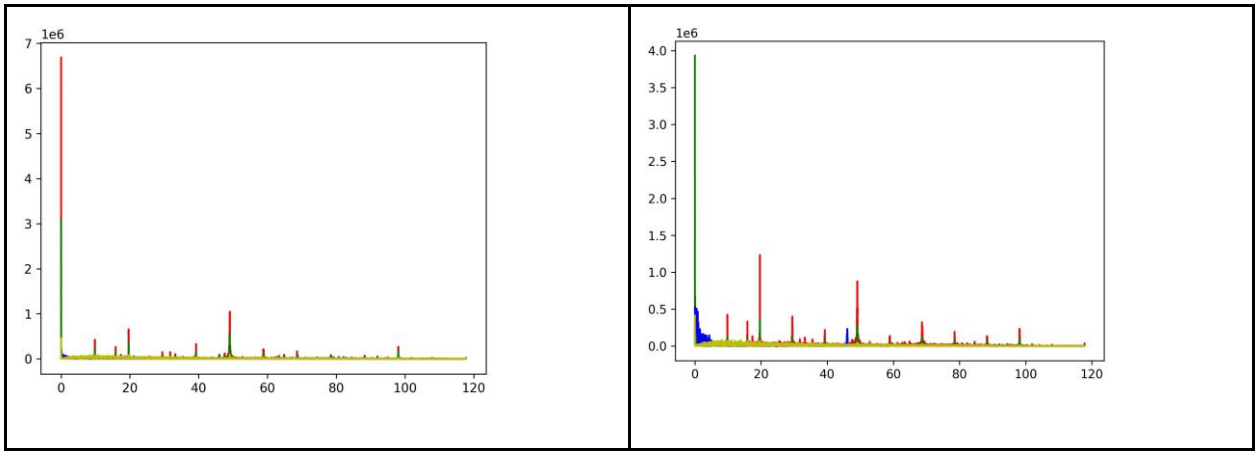


Frequency Spectrum diagram based on brainwave of participants:

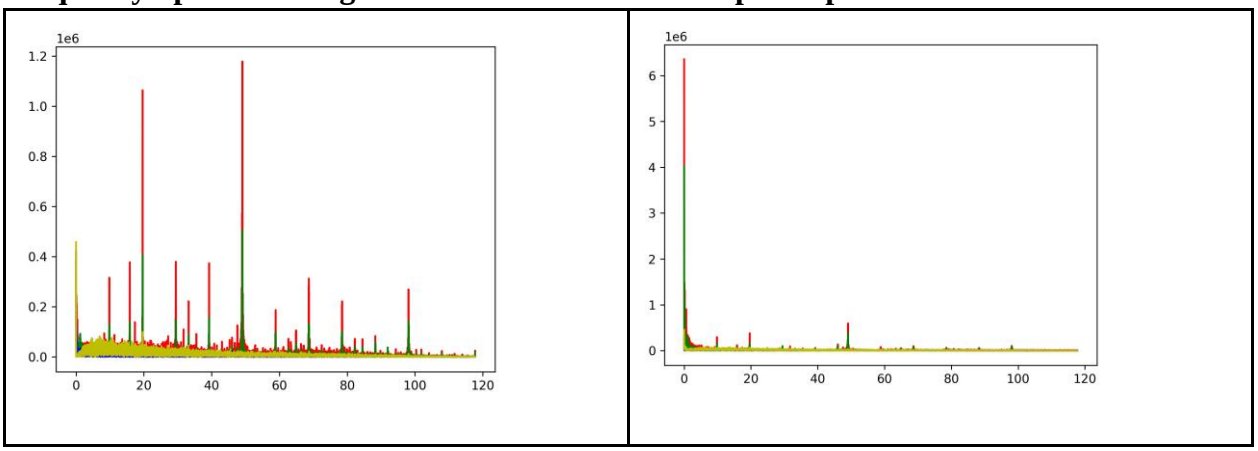
Blue Group



Green Group



Frequency Spectrum diagram based on brainwave of participants:



Black Group

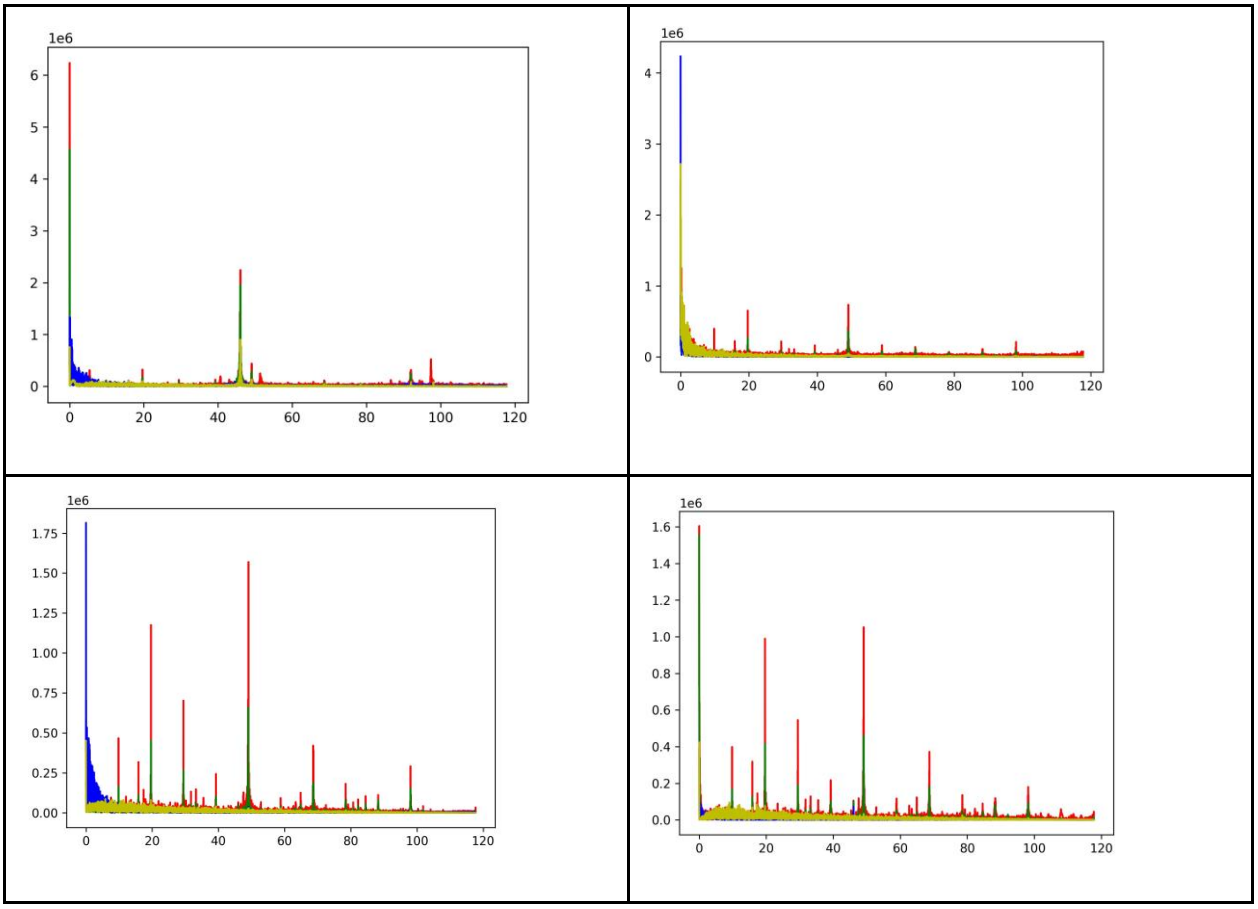


Image 1. Group member Shannon monitoring participant during Concentration Test

Image 2. Male participant wearing Muse 2 device taking Red Concentration Test