Determining caffeine's effects on visual and verbal task performances as an indication of memory of 17 year old male and female students.

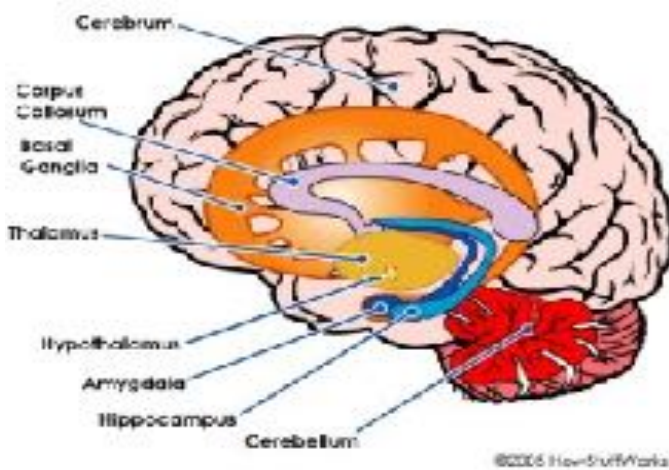Word Count: 4414 (with graphs)

TABLE OF CONTENTS:

1. Introduction:

The human brain is divided into the cerebrum, the cerebellum and the brain stem.

The cerebrum, being the largest part of the human brain and playing a significant role in **memory,** awareness, language and consciousness, is divided into four sections, named lobes, which are frontal lobe, parietal lobe, occipital lobe and the temporal lobe. As occipital lobe is associated with visual processing and temporal lobe is associated with recognition of memory and speech, this experiment observed the effects of caffeine in the *cerebrum.* The inner part of the temporal lobe, the medial temporal memory, includes the limbic system, which includes the hippocampus, providing memory (short- and long-term memory) processing.[1]

Figure 1: Human Brain and its components

Caffeine is the most common stimulant found in coffee, tea, chocolate and energy drinks. Researchers from Boston College and University of Arizona informed that 80% of the people all around the world daily consume caffeine. They reported that caffeine might influence memory by increasing general levels of arousal.[2] Researchers from Netherland stated caffeine has effects on cognitive functions, enhance vigilance and alertness.[3] Adenosine is a molecule in human body,

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[1] http://www.human-memory.net/types_short.html

[2] https://www.frontiersin.org/articles/10.3389/fpsyg.2016.01764/full

[3] http://digitalarchive.maastrichtuniversity.nl/fedora/get/guid:d785bdea-6cfb-485a-ad3d-49bca1f57768/ASSET1

when it binds to adenosine receptors causes exhaustion.[4] Caffeine act as inhibitors of adenosine receptors distributed throughout cerebral cortex so increase alertness and sustained attention. [5]

"Short term memory" involves the capacity of the brain to temporarily store an information for a small amount of time. The information gathered with short term memory will disappear as it has a limited capacity unless it is repeated mentally and physically in order to transfer that information from short term memory to long term memory. [6] "Long-term memory" is storing information over a long period of time. [7] Some researchers suggest that it is hard to find distinction between short term and long-term memory, with regard to this information "memory" term is used in this study.

With this extended essay, I observed the differences in cognitive skills and capacities of my peers at my school while testing the difference of awareness and capability to memorize visual and verbal tasks with caffeine intake.

I regarded this topic worthy of investigation, and conducted it specifically on seventeen-year-old high school students not only because I wanted to test this hypothesis myself, but also because coffee is a very common beverage which is consumed amongst students in order to maximize attention, success, and memory; and testing this common trend amongst students was a really interesting research topic.

The research question **"Does caffeine have an effect on visual and verbal performance task scores as an indication of memory of 17-year-old male and female students?"** aims to investigate whether caffeine alters brain's capacity to store and memorize information.

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4 https://sinirbilim.org/adenozin-reseptorleri-kahve/

5 https://www.sciencedirect.com/science/article/abs/pii/0304394082902907

6 http://memorise.org/brain-articles/memory-repetition-reinforcement

7 http://www.human-memory.net/types_long.html

2. Hypothesis:

Visual and verbal task performances of students will be altered positively after 250 mg of caffeine intake. The amount of caffeine (250 mg) was based on the research done by John Hopkins University, "They found that performance was better after the 200 mg dose, compared with the 100 mg dose, but there was no improvement after the 300 mg of caffeine, compared with 200 mg." Both placebo (Believing a treatment will work) and control groups(no caffeine) are designed to show psychological effects of caffeine consumption.

3. Method:

In order to test this research question, this experiment was conducted on 78 volunteer students aged 17 in a high school. An announcement was made to invite students. Among first comers 39 boys and 39 girls were included to study. These students were grouped into three, and were randomly assigned to groups.

The students were asked several questions with their signature in order to ensure their willingness to participate in the experiment (Given in the appendix 1). All of the subjects were handed out a questionnaire regarding their regular caffeine intake (how much caffeine in mg they consumed per day, the kind of coffee they preferred to drink, and when they drank it, the approximate time they spent on a sport per week, the possible allergies or diagnoses they had, if they were taking any medications, and the amount of sleep they had every day as well as their height, weight, gender and age. The students also signed a statement asking for their consent, and were informed to not consume a caffeinated drink or food.

The first group was given caffeinated coffee of 250 mg 40 minutes before the tests were done, (a lesson takes 40 minutes) caffeine shows peak performance 40 minutes after intake. The second group was given a same mass of decaffeinated coffee in order to act as a placebo group; and the third group was not given any caffeine containing beverages or foods as a control. The subjects

were also informed not to consume caffeine twenty-four hours before the experiment conducted as caffeine fully leaves the body after twenty-four hours.

The experiment consists of two stages: visual [8] and verbal [9] performance tasks.

Figure 2: Participants completing visual task.

Earlier on the day of the experiment, all of the subjects were informed earlier to bring either a pen or a pencil with them for the first stage of the experiment: visual performance task. After they arrived, they were informed to put their pen / pencil on the table and not touch it before told otherwise.

The participants were told to not turn the paper towards themselves until they were shown the 15 pictures. They looked at the pictures via slides, and the students were given 10 seconds to observe each picture on a single slide. After all of the 15 pictures were shown, the students were told to turn back over the paper with pictures and start marking the pictures they memorized in no particular order.

They had papers in front of them which included 10 of the pictures from the 15 pictures they were shown earlier and ten other pictures that did not appear on the list of pictures they were shown. Some of the other 10 pictures were almost identical to the ones shown previously in order to make it harder to distinguish the ones they saw before from the ones they did not. This method, also named as *pattern separation,* which triggers a deeper level of memory retention, also was an important factor when determining which group was better at distinguishing very similar visuals and to observe the effect of caffeine more accurately as pattern separation forces the brain to make a more

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[8] https://www.memorylosstest.com/free-short-term-memory-tests-online/

[9] https://www.ncbi.nlm.nih.gov/pubmed/18554731

complicated discrimination [10].

After they completed marking the pictures in front of them in 60 seconds, I took their papers from them and they watched the same slides again, and the same procedure was repeated for the second trial. The students completing their visual test can be seen above in figure 2.

 After both of the trials for the visual test was completed successfully, the subjects were given papers for the verbal performance task and were again told not to touch neither the paper nor the pen / pencil in front of them until they were told to do so. The subjects listened to the 15 words given in the appendix 3, and after listening, they wrote the memorized words down to the paper in front of them within 60 seconds. This procedure was repeated five times in order to not only observe short term memory, but also to observe the transformation of information from short term memory to long term memory by repetition. This process was completed in total silence in order to maintain the ideal environment to memorize the words and in order to prevent the words being said out loud. After the students completed this procedure for five times, they were asked to write their name on their papers, and then leave the laboratory. The data are collected and analyzed.

250 mg caffeine	Decaffeinated coffee	X
Caffeinated 13 M + 13 F	Placebo 13 M + 13 F	None 13 M + 13 F

VISUAL TASK

- Show 15 pictures.
- Wait 10 seconds to show each picture.
- Wait 60 seconds for subjects to mark remembered pictures out of 10.
- Repeat for the second trial.

250 mg caffeine	Decaffeinated coffee	X
Caffeinated 13 M + 13 F	Placebo 13 M + 13 F	None 13 M + 13 F

VERBAL TASK

- Make subjects listen 15 words.
- Wait 60 seconds for subjects to write remembered words out of 15.
- Repeat for 5 times.

Figure 3 represents the summary of the experiment

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[10] https://hub.jhu.edu/2014/01/12/caffeine-enhances-memory/

4. Results and Analysis

NUMBER OF SUBJECTS	GENDER	CAFFEINATED		PLACEBO		NONE	
		TRIALS FOR VISUAL TASK					
		T1	T2	T1	T2	T1	T2
1	F	8	9	7	9	7	8
2	F	7	9	9	6	7	7
3	F	9	10	6	7	5	7
4	F	9	9	5	7	6	6
5	F	10	10	8	8	7	7
6	F	9	9	6	8	5	8
7	F	10	10	7	8	8	7
8	F	8	7	8	8	7	7
9	F	9	10	7	7	6	8
10	F	8	8	6	7	6	7
11	F	8	10	7	8	7	8
12	F	10	9	8	8	5	8
13	F	9	10	6	8	7	6
14	M	6	10	6	7	5	6
15	M	7	9	5	5	6	7
16	M	6	8	5	7	4	8
17	M	8	6	5	7	5	6
18	M	6	7	6	5	5	7
19	M	7	7	6	8	5	8
20	M	8	8	4	6	6	7
21	M	7	8	6	6	5	4
22	M	6	6	5	6	6	7
23	M	7	8	7	6	5	5
24	M	9	8	5	7	6	6
25	M	8	8	5	6	5	8
26	M	6	5	6	9	4	6

Table 1 showcases visual task results of male and female subjects according to their caffeine intake during the experiment. Results represents number of remembered pictures out of 10.

NUMBER OF SUBJECTS	GENDER	CAFFEINATED					PLACEBO					NONE				
		TRIALS FOR VERBAL TASK														
		T1	T2	T3	T4	T5	T1	T2	T3	T4	T5	T1	T2	T3	T4	T5
1	F	7	14	15	15	15	7	9	11	12	13	7	9	11	10	11
2	F	8	11	12	14	15	7	9	11	12	13	7	10	10	12	10
3	F	11	15	15	15	15	7	11	12	12	15	7	10	10	14	10
4	F	8	13	13	13	15	8	14	14	12	15	4	5	10	10	13
5	F	8	14	14	13	15	8	13	13	13	12	6	8	9	9	10
6	F	9	11	12	13	15	9	12	12	13	13	7	9	9	11	9
7	F	11	13	13	13	14	6	11	12	12	14	5	9	9	13	12
8	F	10	10	12	12	13	8	11	11	12	15	5	10	9	9	13
9	F	10	14	13	14	13	6	10	11	14	14	5	9	10	10	14
10	F	10	12	13	15	15	8	10	10	14	13	7	9	7	11	8
11	F	8	13	12	14	15	8	11	12	13	14	5	10	13	13	13
12	F	11	13	14	14	15	8	12	13	13	14	6	8	8	10	11
13	F	10	14	15	15	15	8	10	12	10	13	5	7	10	11	10
14	M	7	13	12	12	12	7	8	10	13	9	6	6	9	11	10
15	M	9	12	15	9	12	7	11	11	11	11	5	9	10	10	11
16	M	8	8	10	11	14	6	11	12	13	14	6	8	11	13	13
17	M	10	13	13	14	15	8	9	10	12	11	6	10	13	13	14
18	M	9	11	15	13	11	8	8	8	10	12	6	10	8	10	11
19	M	6	10	10	11	15	7	10	11	13	12	7	9	11	12	12
20	M	10	12	13	14	13	7	10	10	9	11	5	8	9	12	11
21	M	10	12	12	14	14	8	12	12	11	14	6	9	10	10	11
22	M	9	13	14	15	14	7	9	8	10	9	5	7	10	10	11
23	M	9	11	12	14	15	8	10	11	11	12	6	9	13	10	12
24	M	10	14	12	11	13	8	9	8	10	11	6	6	7	9	10
25	M	7	9	9	11	12	7	9	10	9	12	7	7	8	6	9
26	M	8	9	11	11	13	7	9	10	11	13	6	6	9	10	10

Table 2 showcases verbal task results of male and female subjects according to their caffeine intake during the experiment. Results represents number of words remembered out of 15.

	VISUAL TASK			VERBAL TASK		
	CAFFEINATED	PLACEBO	NONE	CAFFEINATED	PLACEBO	NONE
FEMALES AVERAGE	8,96	7,27	6,81	12,78	11,38	9,25
MALES AVERAGE	7,27	6,00	5,85	11,54	9,92	9,08
TOTAL MEAN	8,11	6,63	6,33	12,16	10,65	9,17
STD	1,20	0,94	0,77	1,13	1,02	0,93
SE	1,10	0,97	0,88	1,06	1,01	0,96

Table 3 shows descriptive statistic calculations of visual task and verbal task results of subjects

The mean results are calculated by taking two trials and dividing by two.

Standard deviation (STD) is a measure of the spread of found results by mean. The formula for STD is given below;

$$STD = \sqrt{\frac{\sum (x - \bar{x})^2}{N - 1}}$$

Standard error basically shows the variation in the distribution of mean.

$$SE = \frac{STD}{\sqrt{n}}$$
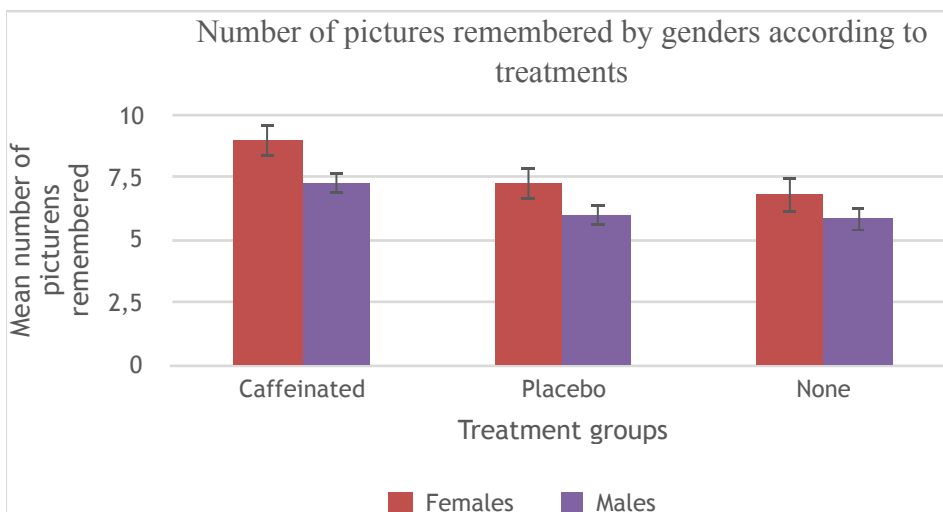
Graph 1 describes the difference of capability to memorize pictures according to caffeine intake. The error bars in the bar graph represents the standard error values of groups.
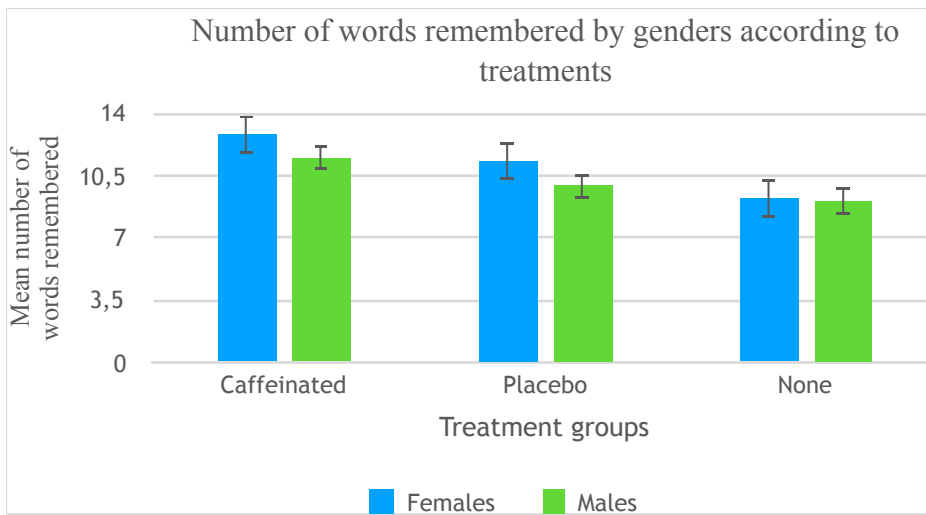
Graph 2 shows mean number of words remembered in five trials according to caffeine treatment. The error bars in the bar graph represents the standard error values of groups.

As there are 3 groups that should have compared, single factor ANOVA is used to determine whether first hypothesis (H_0) is true or not.

H_0: There is not any difference between caffeinated group's visual task results, placebo group's results and none groups' results.

H_1: There is difference between caffeinated group's visual task results, placebo group's results and none groups' results.

These hypothesis statements are evaluated by the P-value. If the found value is less than a = 0,05, H_0 will be rejected and H_1 will be verified.

Anova: Single Factor for visual task

SUMMARY

Groups	Count	Sum	Average	Variance
Caffeinated	26	211,5	8,134615	1,451154
Placebo	26	172,5	6,634615	0,891154
None	26	192	7,384615	0,801154

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	29,25	2	14,625	13,95754	7,03E-06	3,118642
Within Groups	78,58654	75	1,047821			
Total	107,8365	77				

Table 4 shows visual task ANOVA results between caffeinated, placebo and control group

The P-value is found as 7,03E-06which is less than a = 0,05; so H_0 statement is rejected and **H_1** is proved that there is statistically significant difference between caffeinated group's visual task results, placebo group's results and none group's results supporting the hypothesis and the base of this research.

Anova: Single Factor for verbal task

SUMMARY

Groups	Count	Sum	Average	Variance
Caffeinated	26	316,2	12,16154	1,276862
Placebo	26	276	10,61538	1,033354
None	26	238,2	9,161538	0,864062

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	117,0369	2	58,51846	55,30563	1,75E-15	3,118642

Within Groups	79,35692	75	1,058092
Total	196,3938	77	

Table 5 shows verbal task ANOVA results between caffeinated, placebo and control groups

The P-value is found as 1,75E-15 which is less than a = 0,05; so H_0 statement is rejected and H_1 is proved that there is statistically significant difference between caffeinated group's verbal task results, placebo group's results and none groups' results.

5. Discussion

The table 3 indicates that caffeine had a positive effect on the cognitive ability of both of the sexes and that caffeine does improve memory since the results of the placebo group was almost identical to the no caffeine group.

As seen in table 1, the average number of pictures remembered by *both* of the sexes in two trials combined differed from caffeinated, and no caffeine groups. The average picture memorized was 8.13 for the students who drank the 250 mg caffeine, whereas the number was 7.38 for those who did not drink it. Therefore, a 9% of increase was observed. The group that was given decaffeinated coffee (the placebo group) memorized an average of 6.6 pictures, almost 19% less than the ones who drank coffee.

From the results of this experiment, it has been found that teenage female subjects appear to have a better cognitive ability to memorize visuals compared to their opposite sex peers (Graph 1 and 2). Regardless of the caffeine intake of the subjects, female subjects showed a better ability to memorize the pictures they were shown. Several research studies have suggested that women have a better cognitive ability than men due to the difference of hormones released in the body of each sex. It has been supported that estrogen and estradiol levels play a significant role in memory as they regulate mood and cognitive function. The data gathered from this test was supported by this argument as girls had significantly better results with or without caffeine intake. For the first trial of the visual test conducted, average pictures memorized from a female subject appeared to be 8.96. On the oth-

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er hand, the average number of pictures memorized by male subjects was observed to be 7.27. Same trend occurred in the no caffeine group, with the average number of pictures being recalled correctly by female subjects was 7.27 whereas males was 6.00. As a result, females showed a better performance in memorized pictures compared to boys. The results of the verbal test showed a similar trend as the females that either drank caffeinated or decaffeinated coffee memorized more pictures in all of the trials   then males. On the other hand, the male group which did not drink coffee performed better than females without caffeine, a trend which did not appear on the visual test. The female "none" group performed less on the 1st, 3rd, and 5th trials. This observation is the only data in this experiment that did not give the expected results. I believe the causes of such error could be the unequal amount of sleep each participant had, the time they spent on sports, or their body index. (details will be discussed in the "limitations and error improvement' part)

What I have also observed from the results I have gathered from this research was that the subjects at the caffeinated group were more likely to identify the previously viewed images from the similar visuals they did not see before. The importance of this phenomena, pattern separation, is described by the John Hopkins University researcher Yassa as "*If we used a standard recognition memory task without these tricky similar items, we would have found no effect of caffeine, however, using these items requires the brain to make a more difficult discrimination—what we call pattern separation, which seems to be the process that is enhanced by caffeine in our case.*" during a similar research regarding caffeine's effect on cognitive ability.

As can be seen by the graph above (graph 2) the students in the caffeinated group memorized more words compared to the placebo and the no caffeine groups. From the results of the verbal test, I have observed that there was a slightly less difference between the number of words remembered by female subjects and male subjects compared to the difference in the number of pictures remembered. However, I noticed that as more trials were done on the participants, more words were memorized (storing information via repetition and forming long term memory). I noticed that in both of

the sexes, the highest amount of words remembered was in the final trial of the caffeinated group. This supported my argument that caffeine enhances cognitive ability, having advantages in both long and short term. I also noticed that, being the greatest among other groups, the performance differed in both sexes. Female students who participated in the caffeinated group appeared to memorize 12.78 words in average, while the average number in the male subjects was 11.54. This test too, supported the argument that caffeine enhances cognitive capacity in both sexes and that females tend to have a better memory than males.

6. Sources of Error & Improvements (Limitations) and Strengths:

In this experiment several errors were encountered. The students did not get the same amount of sleep, one of the greatest factors to have consequences on memory and processing information according to several research. In order to get the most accurate results, students could be asked to get the same amount of sleep the day before the experiment was conducted.

Another factor that could have affected the results is I have observed that some students spent at least two hours playing sports whereas some did not play sports at all. An article regarding exercise's positive effects on memory which was published in Harvard Health Publishing bolstered this argument, *"Indirectly, exercise improves mood and sleep, and reduces stress and anxiety. Problems in these areas frequently cause or contribute to cognitive impairment."* Therefore, in a further experiment on this topic, participants who devote the same time for a sport per week could be used.

Thirdly, the students listened to the words for the verbal test in the laboratory in which the students were surrounded with their peers, rather than listening to them individually. Even though the students were asked to stay silent, it was very difficult to maintain the silence during the entire experiment. This may have blocked the students from hearing the words correctly and they may have had to pay extra attention to hear the words and the students could easily look over their peers' papers to see their answers.

Even though all of the students were under the same curriculum which is taught in English, none of the students were native English speakers, making it harder to memorize words in another language rather than their native language. This could be improved by testing this research question on students who are native English speakers.

More students could be included in each group to get accurate results. Other memory tests could be used to collect data to be more specific for short- and long-term memory. Increasing masses of caffeine could be used in a design to find the most effective mass of caffeine.

In spite of the limitations I discussed above, I also had strengths which enhanced the results of my experiment. I tried to gather as much seniors as possible in order to maximize the accuracy of the results. The number of students in all 3 groups (caffeinated, placebo, none) were equal. All of the students were of 17 years of age in order to keep the age factor constant.

7. Conclusion:

From this experiment, it can be concluded that caffeine has a positive effect on adolescents of both genders as 250 mg of caffeine intake has resulted in a better visual and verbal memorization, therefore enhancing performance. It has been observed that both female and male students were affected positively by caffeine consumption, and the placebo group used in order to test the psychological effects of caffeine scored relatively similar to the no caffeine (control group) while the students reached their peak performance with caffeine.

Short term phenomenon explains why students who participated in this research were very easy to forget the visuals in the visual memory task and replace them with different objects. Also, the transformation of information to long term memory by repetition is also supported by how students showed an increasing and positive correlation with the number of times they have listened to the words and the amount of words they have memorized and wrote down correctly in verbal tasks.

Several research studies have suggested that women remember things faster, more accurately and in great detail than men, having an overall more developed memory than men and that girls have supe-

riority in cognitive skills compared to boys.[11]   this argument too has been tested with this research

as girls were observed to remember more and remember more accurately compared to their opposi-

te sex peers, and scored better both in the visual and the verbal tests.

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[11] https://www.medicalnewstoday.com/articles/313998.php

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Appendix 1 : Extended Essay Survey used on Subjects:

*Your name will **appear** in this research.*

Your Name:

Class:

Gender:

Age:

Height:

Weight:

Are you currently involved with any type of sports? If you are, approximately how many hours a week do you spend on it?

Do you have a chronic allergy, disorder, or disease of any kind?

Is there a medication of any type or reinforcement that you take regularly? (ex: vitamins, antidepressant, ADHD, insomnia…)

Approximately how much caffeine do you consume coffee in a regular day ?

During what time of the day do you prefer to drink coffee?

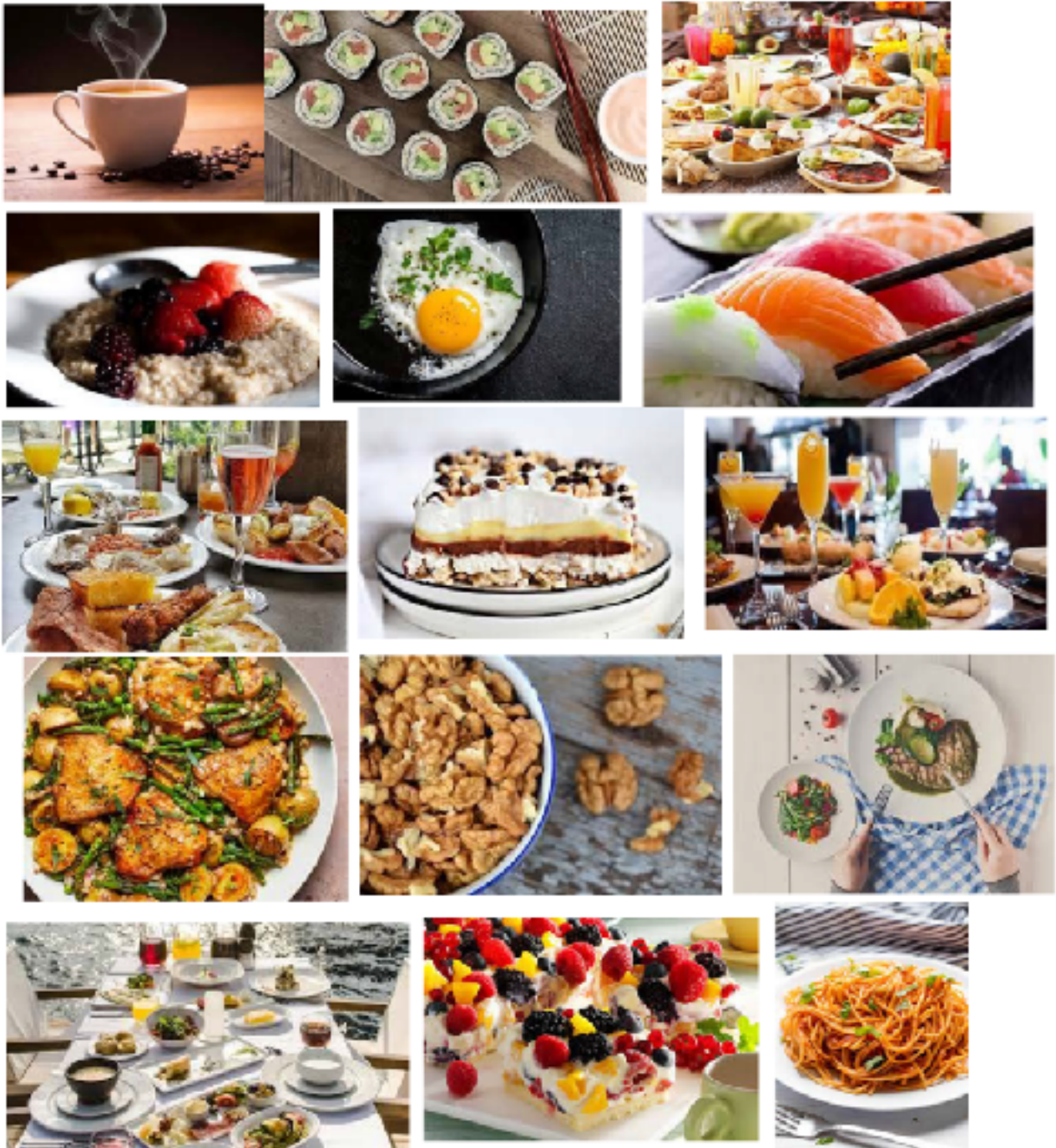**What type of coffe do you usually consume?**

Approximately how many hours of sleep do you have each night?

*I confirm that my participation in the research regarding **"caffeine's effects on memory"** is voluntarily.*

Name:

Signature:

Appendix 3: The Words Used In the Verbal Test

1. **Executive**

2. **Millitary**

3. **Bud**

4. **Infirmary**

5. **Equipment**

6. **Goal**

7. **Wedding**

8. **Mother**

9. **Lake**

10. **Instrument**

11. **Window**

12. **Novel**

13. **Howl**

14. **Prisoner**

15. **Fire**