A Study on the Behavior of the heart under the Influence of Caffeine

Research Question - What are the heart effects caused by the daily consumption of caffeine?

1. Background

Caffeine is a drug, or a stimulant, consumed by millions of people worldwide. It is such a big part of life; people do not refer to it as a drug anymore. A statistic shows that Americans drink about 400 million cups of coffee per day, estimated to be 46 billion cups per year.[1]

I specifically chose this topic because caffeine is a massive part of my life, like others. It has kept me awake countless nights right before the exams. My mother always told me how it negatively affects my health, and I have read articles. This experiment will help deduce exactly how lousy caffeine is for human consumption.

1.1 More Background Information

To understand how caffeine affects the heart, we must know how it works first. As we know, the heart pumps blood through the veins and arteries. As the heart pumps blood, it produces a beat. This beat is monitored in minutes to give a reading which determines how fast your heart is beating. This reading is called beats per minute or bpm.

The pressure at which the blood is pumped through the arteries is measured. It is measured in millimetres of mercury or mmHg. Caffeine affects the adrenal glands; increasing the production of adrenaline increases the heart rate and blood pressure.[2]

2. Investigation

2.1 Aim

The experiment aims to find the relation between heart problems and caffeine. The investigation will determine the effects of caffeine on the heart and the long-term issues that come with it.

2.2 Hypothesis

The amount of caffeine consumed will affect the heart rate. The caffeine will cause the heart rate to peak, meaning the blood pressure will be higher than usual during this period. The higher the caffeine consumed, the longer the heart rate will stay at a peak. The high pressure will cause severe discomfort and long-term issues if consumption is continued over time.

2.3 Methodology

I conducted my investigation of the research question in the following ways:

1. To measure the heartbeat, I used a fitness tracker, the Amazfit Neo, to be exact. To make sure the readings from the watch were accurate, I wore a heart rate monitor and the watch simultaneously to see if they would give the same value. Results should be found in the 'Preliminary Experiments' section. The heart rate data collected from the watch was sent to an app called Zepp, which was then collected and analysed. An automated machine collects blood pressure data. I took readings every 5 minutes and averaged them to give a final reading. The readings were not plotted as they were similar in value. I collected the total time the blood pressure was abnormal instead. This is called peak time.

[1] "33 Fascinating Coffee Statistics for Every Coffee Lover - DisturbMeNot!." Accessed January 12, 2022. https://disturbmenot.co/coffee-statistics/.
[2] "Caffeine: How does it affect blood pressure? - Mayo Clinic." Accessed January 12, 2022. https://www.mayoclinic.org/diseases-conditions/high-blood-pressure/expert-answers/blood-pressure/faq-20058543.

2. The primary variable under investigation is the amount of caffeine intake, heart rate, and blood pressure. As caffeine takes hours to digest fully, I spread the experiment into three days for three levels of caffeine intake. Three experiments were done to determine the health effects of consuming each level of caffeine. Every morning, I'd start the experiment mid-day with a cup of coffee and maintain the same routine for the sake of the experiment. During mid-day, the blood pressure is normal, unlike mornings when the blood pressure is low. No rigorous activities were done to elevate the heart rate and mess with the results—any caffeinated beverages like sodas or any energy drinks.

3. As I will be experimenting on myself, I need to ensure I don't have any health problems interfering with the results. More to be found in the 'Preliminary Experiments' section.

2.4 Equipment

Table 1 – All Equipment Used

Equipment	Purpose
1 Fitness tracker	Track the heartbeats per minute.
3 250 ml mugs	Mix the coffee with the milk and make it easier for consumption.
An electronic weighing scale	Measure the weight of the coffee and the ounces of milk used.
Nescafe Gold Blend Coffee	Coffee used for the experiment.
1 Teaspoon	Mix the coffee with the desired solvent.
A bowl	A surface used to measure the weight of coffee on the scale.
Milk	Used as a solvent for coffee.
Automatic Pressure Machine	Used to measure blood pressure.
An oximeter	Used to determine heart rate for one of the preliminary experiments.

2.5 Variables

Table 2 - Variables

	Named variable	Unit	Justification
Independent	Caffeine	Milligrams (mg)	The amount of caffeine is changed throughout the three experiments. The amount of caffeine changed influences the heart rate, making it an independent variable.

Dependant	Heart Rate	Beats per Minute (bpm)	The heart rate cannot be physically changed. It can be influenced by the amount of caffeine ingested. The heart rate readings depend on the amount of caffeine consumed. Therefore, heart rate is a dependent variable.
	Blood Pressure	mmHg	The blood pressure cannot be physically changed. It can be influenced by the amount of caffeine ingested. The readings depend on the amount of caffeine consumed. Therefore, blood pressure is a dependent variable.
Control	Time	Minutes	Time is the variable that stays constant throughout the experiment. The timeframe of the investigation is three hours.

2.6 Risk Assessment

Table 3 - Risk Assessment

Issue	**Justification**
Safety Issue	Caffeine is a stimulant drug that controls the heartbeat and can cause irregular heartbeat and bowel movements if taken in excessive amounts. As I will be experimenting on myself, this is a safety issue. To avoid any health issues, I conducted each experiment one day after the other to make sure the caffeine was properly digested, and the effect of the caffeine wore off. This also improved the accuracy of the experiment.
Ethical Issue	No ethical issues were taken into account.
Environmental Issue	No environmental issues were taken into account.

3. The Experiments

3.1 Preliminary Experiment

Preliminary experiments were done to avoid errors in the investigation performed.

3.1.1 Determining the Accuracy of the Fitness Tracker

As the data for this experiment will be collected using a fitness tracker, the accuracy of this data needs to be determined. To do that, I have used a pulse oximeter. A pulse oximeter was placed on the fingertip to determine the heart rate at the exact given time. The readings for the pulse oximeter need to be taken manually, unlike the fitness tracker that takes readings automatically and stores the data on my phone. Therefore, using the fitness tracker was a more convenient choice. Figure 1 shows the setup of the experiment.

Figure 1 - Preliminary Experiment

Chi-Squared Test:

A chi-squared test was conducted to see any significant difference between the accurate readings of a pulse oximeter and the fitness tracker. The pulse oximeter and the fitness tracker were worn on the same hand, and the readings were taken at an average of 5 minutes. The observed value will be the value given by the fitness tracker, and the expected value will be the one provided by the oximeter.

Null Hypothesis - The readings given by two sensors will give similar values.

Alternative Hypothesis - The readings given by the two sensors give significantly different values from each other.

	12:00 AM	**12:05 AM**	**12:10 AM**

Observed	77	81	76
Expected	77	80	75

	12:00	**12:05**	**12:10**
Observed frequency	77	81	76
Expected frequency	77	80	75
Difference	0	1	1
Positive difference	0	1	1
$(IO-EI)^2/E$	0	0.0125	0.0125
		X^2 value	**0.0258**

Degree of freedom = N-1 = (3-1) = 2

Critical Value = 5.991 for p = 0.05

Since the chi-squared value is a lot less than the critical value of 5.991, we can accept the null hypothesis and reject the alternative hypothesis.

3.1.2 The Check-Up

As mentioned before, I will be experimenting on myself. Therefore, I had a routine checkup with a doctor to ensure perfect health. The following checkup included -

1. A blood test.
2. Blood pressure check.

The blood test would determine if my body was in good condition, and the blood pressure check would decide if my heart was pumping blood at a healthy force.

Results:

My blood pressure was 110/70 mmHg, typical for a young adult. Therefore, I have no blood pressure problems interfering with the experiment's readings. The blood test is shown in Figure 2.

Figure 2 - Hematology Report

Tests are carried out by Sysmex XN-2000

Test	Result		Reference Values	
Total Count				
White Blood Cells	7.00	K/µL	4.23 - 11.00	K/µL
Neutrophil	4.20	K/µL	2.00 - 7.50	K/µL
Lymphocyte	2.10	K/µL	1.50 - 4.00	K/µL
Monocyte	0.42	K/µL	0.20 - 0.80	K/µL
Eosinophil	0.28	K/µL	0.04 - 0.40	K/µL
Basophil	0.00	K/µL	0.02 - 1.00	K/µL
Platelets	230.00	K/µL	150.00 - 450.00	K/µL
Differential Leucocyte Count				
Neutrophil%	60.00	%	40.00 - 70.00	%
Lymphocyte%	30.00	%	20.00 - 45.00	%
Monocyte%	6.00	%	02.00 - 08.00	%
Eosinophil%	4.00	%	01.00 - 04.00	%
Basophil%	0.00	%	00.00 - 01.00	%
Myeloblast/ Blast	0	%		%
Myelocyte	0	%		%
Atypical Cell	0	%		%
Red Blood Cells	5.69	million/dL	4.04 - 6.13	million/dL
Haemoglobin	16.40	g/dL	13.70 - 17.50	g/dL
HCT	50.31	%	37.70 - 53.70	%
MCV	88.40	fL	76.00 - 96.00	fL
MCH	28.80	pg	27.00 - 32.00	pg
MCHC	32.60	g/dL	32.00 - 36.00	g/dL
RDW-CV (%)	12.80	%	11.60 - 14.80	%
MPV	8.72	fL	9.40 - 12.40	fL
PCT	0.20	%	0.01 - 9.99	%
PDW	9.00	10 (GSD)	0.01 - 99.99	10 (GSD)
Reticulocyte	0.00	%	0.2 -2.0	%
ESR	05	mm in 1st hour (Westergren)	0 - 12	mm in 1st hour

As the test suggests, my blood renders a healthy amount of all components. Therefore, taking the readings can be considered accurate for a healthy young adult.

3.2 Control Experiment

I wore the fitness tracker for the control experiment for 12 hours, starting from 10 AM till 10 PM. I investigated to get a general idea of the resting heart rate and my heart rate throughout the day. I took it off for a few hours in the middle as my hands started to hurt from wearing the watch for too long. Figure 3 shows a graph of the beats per minute (bpm) throughout the day.

Figure 3 - Graph of the heart rate throughout the day

Results

Maximum Heart Rate	124 bpm
Minimum Heart Rate	40 bpm
Average Heart Rate or the Resting Heart Rate	70 bpm

3.3 The Main Experiment

I calculated the amount of caffeine I would consume and the amount of milk to dilute the coffee for the actual experiment. The milk does not reduce the caffeine or have any effect on it. I will then time when I drink the coffee until my heart rate, and blood pressure transcend back to normal. There will be three experiments in total.

3.3.1 Calculations

Before starting the experiment, the amount of caffeine consumed must be determined. The table below shows the amount of milk and caffeine ingested per experiment. For the first experiment, I took two teaspoons of coffee. According to the caffeineinformer, about 44mg of caffeine in each teaspoon rounds up to 88mg of caffeine. Therefore, 88mg of caffeine will be used for the first experiment. 176mg and 264mg will be used for the second and third experiments.

The milk used to consume the coffee will differ throughout the three experiments. The first experiment will contain 170ml or 6oz of milk, and the second and third experiments will have 12oz and 18oz, respectively.

3.3.2 The First Experiment

Table 4 - Details regarding the first experiment

Coffee Used	2g
Caffeine Used	88mg
Milk used	170ml or 6oz
Time of Ingestion	13:00

Observation

I took data of the first hour to determine the resting heart rate or the average heart rate before caffeine consumption. I consumed the coffee at 13:00, and its effects started showing around 13:14. The blood pressure and the heart rate increased at this time. The heart rate then increased average with a peak time, or the total time the blood pressure was at its highest, of 42 minutes. Graph 1 shows the results of the experiment. Summarised results can be seen in Table 5.

Graph 1 - Heart Rate after drinking 88mg of caffeine

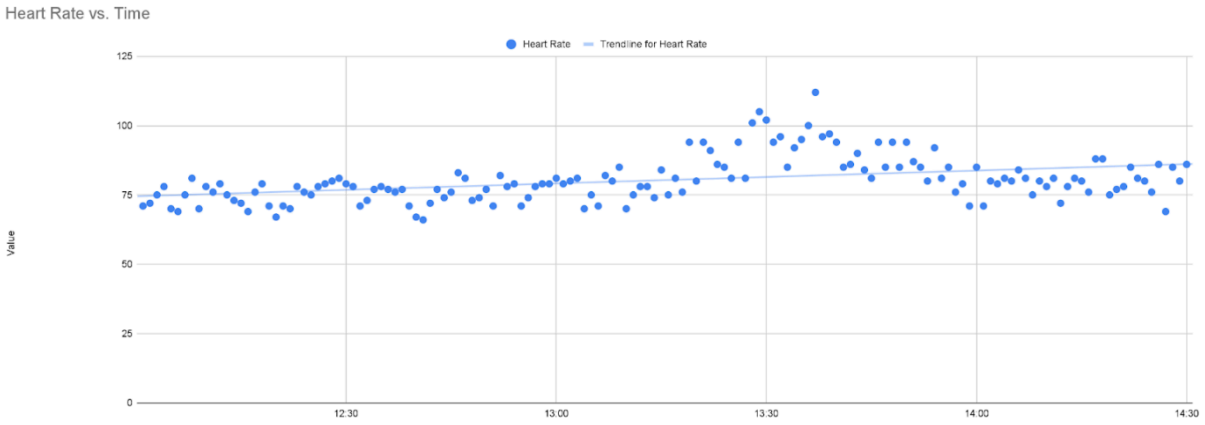

Table 5 – Results of The First Experiment

	Before Caffeine Consumption	After Caffeine Consumption
Average Heart Rate	75	82
Lowest Recorded	66	70
Highest Recorded	83	112
Blood Pressure	110/70	140/90
Total Peak Time	-	42 Minutes

3.3.3 The Second Experiment

Table 6 - Details regarding the second experiment

Coffee Used	4g
Caffeine Used	176mg
Milk used	340ml or 12oz
Time of Ingestion	13:00

Observation

Same as the first experiment, I took data of the first hour to determine the resting heart rate or the average heart rate before caffeine consumption. I consumed the coffee at 13:00, and the effects started showing around 13:15. The heart rate and the blood pressure then proceeded to have an increased average with a peak time, or the time the heart rate was at its highest, of an hour and 24 minutes, exactly double the amount of the first experiment. Graph 2 shows the results of the investigation. Summarised results can be seen in Table 7.

Graph 2 - Heart Rate after drinking 176mg of caffeine

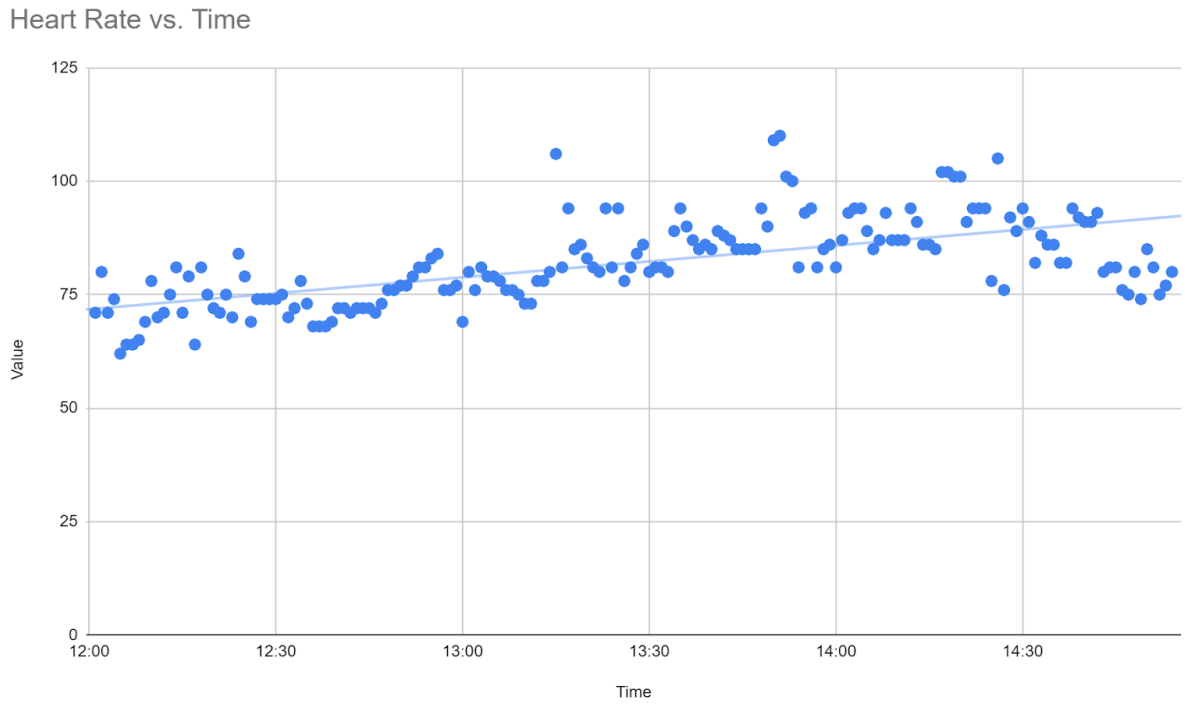

Table 7 – Results of The Second Experiment

	Before Caffeine Consumption	After Caffeine Consumption
Average Heart Rate	74	86
Lowest Recorded	62	73
Highest Recorded	84	110
Blood Pressure	110/70	140/90
Total Peak Time	-	1 hour and 24 minutes

3.3.4 The Third Experiment

Table 8 - Details regarding the third experiment

Coffee Used	6g
Caffeine Used	264mg
Milk used	510ml or 18oz
Time of Ingestion	13:00

Observation

Same as the first two experiments, I took data of the first hour to determine the resting heart rate or the average heart rate before caffeine consumption. I consumed the coffee at 13:00, and its effects started showing around 13:14. The heart rate and the blood pressure then increased average with a peak time, or the time the heart rate was at its highest, of two hours and 9 minutes. Graph 3 shows the results of the experiment. Summarised results can be seen in Table 9.

Graph 3 - Heart Rate after drinking 264mg of caffeine

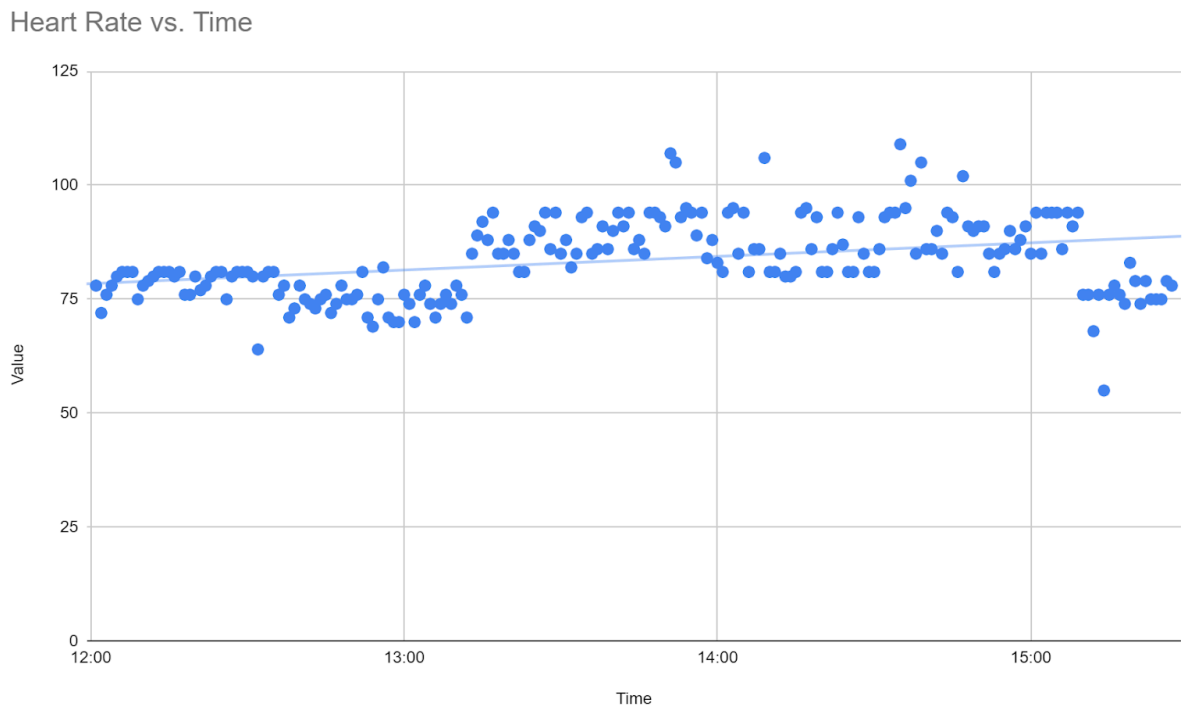

Table 9 – Results of The Third Experiment

	Before Caffeine Consumption	After Caffeine Consumption
Average Heart Rate	77	88
Lowest Recorded	64	70

Highest Recorded	82	109
Blood Pressure	110/70	140/90
Total Peak Time	-	2 hours and 9 minutes

4. Analysis

4.1 Long term effects of caffeine

As mentioned before, I conducted three different experiments with three different levels of caffeine to cover the demographic. Some people like to drink one cup of coffee, some like to drink two, and some drink three. To cover all the bases, I experimented three times with different levels of caffeine. This section will be divided into people who drink one cup a day and people who drink more than one cup a day.

People Who Drink One Cup of Coffee a Day

People who drink one cup of coffee a day roughly intake 50mg of caffeine. This level of caffeine ingested does not have any detrimental effects on the heart. An article from Insider stated that it's rather beneficial to have one cup of coffee per day. Having a cup a day can reduce heart failure.

According to Insider, researchers took data from three studies including 21,00 adults and concluded that it lowers heart failures from 5% to 12%.[3]

People Who Drink More Than One Cup of Coffee a Day

In a new study, moderate coffee drinkers (three cups a day) increased their risk of heart attack by drinking a cup of coffee by 60%.[4] As mentioned before, caffeine triggers the adrenal glands to produce more adrenaline and increase heart rate[5]; this differs from person to person as caffeine can interact with different receptors in the brain.[6] Having blood pressure often can cause heart attacks. The arteries get damaged by becoming less elastic. This will reduce blood flow and the oxygen levels at heart, causing heart diseases and eventually a stroke or a heart attack.[7] The caffeine levels under investigation were 88mg, 176mg, and 254mg. Starbucks' most popular drink is their Vanilla Latte[8] which contains 150mg of caffeine in 16oz.[9] Meaning this elevates the blood pressure by approximately over an hour. Therefore, if caffeinated beverages are routined, it can deteriorate their health long-term.

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[3] "Drinking at least one cup of coffee a day may help prevent heart failure." Accessed January 12, 2022. https://www.insider.com/drinking-1-cup-of-coffee-a-day-prevent-heart-failure-2021-2.
[4] "Coffee May Trigger Heart Attack - WebMD." Accessed January 12, 2022. https://www.webmd.com/heart-disease/news/20060815/coffee-may-trigger-heart-attack.
[5] "Caffeine: How does it affect blood pressure? - Mayo Clinic." Accessed January 12, 2022. https://www.mayoclinic.org/diseases-conditions/high-blood-pressure/expert-answers/blood-pressure/faq-20058543.
[6] "Does coffee raise blood pressure, and should I drink it regularly?." Accessed January 12, 2022. https://www.medicalnewstoday.com/articles/does-coffee-raise-blood-pressure.
[7] "High Blood Pressure Symptoms and Causes | cdc.gov." Accessed January 12, 2022. https://www.cdc.gov/bloodpressure/about.htm.
[8] "Top 10 Most Popular Starbucks Drinks Ranked | On The Table." Accessed January 12, 2022. https://blog.mybalancemeals.com/health/healthy-eating/the-top-10-most-popular-starbucks-drinks-ranked/.
[9] "Starbucks Grande Caffe Latte - Caffeine Informer." Accessed January 12, 2022. https://www.caffeineinformer.com/caffeine-content/starbucks-grande-caffe-latte.

Having the blood pressure high for hours can cause these symptoms and cause other distress in the body, i.e., irregular bowel movements. This is a symptom I noticed as I experimented on myself.

4.2 Strengths

The chi-squared test can be used to see the accuracy of the readings, therefore, proving my experiment trustworthy. The preliminary experiments, such as the blood test and checking the blood pressure and the body's overall condition, determined that the data output should be valid. Furthermore, the scale I used has a precision of ±0.01 grams, with a low uncertainty proving the readings given by the scale to be precise and indicating a low chance of error.

4.3 Limitations

The accuracy of the data is something I concern myself with. Even though I performed a chi-squared test to prove the data accuracy, I read many articles that read the inaccuracy of the data provided by the fitness tracker. Apparently, the automatic monitoring isn't reliable, and there are records when the fitness tracker did not detect any pulse with the watch in hand. Sometimes it recorded heart rate data when the watch was lying on the table.[10] I have not faced any issue as such, but to avoid this circumstance, I would use an EKG machine for the complete accuracy of the data. Or to make things easier, I would use a more expensive fitness tracker which can provide more accurate data.

Moreover, the experiment wasn't as regulated as I would like it to be. I reduced my actions to the bare minimum to maintain the accuracy of the experiment. I watched videos to keep myself entertained during this period. I feel the videos may have impacted the readings as a visual stimulus can influence the blood flow. Plus, the environment I was in was filled with sound, which can influence blood flow and an auditory stimulus. To avoid inaccuracy, I would probably use a more controlled environment with low sound and minimise any activity for two hours. Repeating the experiments can also eliminate this weakness.

5. Conclusion

Overall, the experiment did support my hypothesis. The level of caffeine increased the peak time, but it did not affect the maximum heart rate. The blood pressure was at abnormal levels showing the correlation between the heart rate and the blood pressure. It has been said that 400mg consumed throughout the day is regular for the healthy average human being. I took a little over ½ of that and concentrated the timeframe to show the overall effect of the caffeine throughout the day. Performing this experiment, I have successfully outlined the effects of caffeine on the heart. The scatter plots showed how the heart tends to act under the influence of caffeine. The prolonged high blood pressure time threatens the individual's health as the caffeine silently deteriorates the body.

6. Bibliography

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10. "Starbucks Grande Caffe Latte - Caffeine Informer." Accessed January 12, 2022. https://www.caffeineinformer.com/caffeine-content/starbucks-grande-caffe-latte.