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Investigation into the Effects of Caffeine on Reaction Time

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Abstract

How reaction time changed depending on dose of caffeine consumed was investigated by conducting an experiment where participants drank different quantities of coffee each day and measured their reaction time using a website that asked the user to tap the screen when it turned green. This was measured every 30 minutes for 7 hours after the caffeine had been fully consumed. Graphs were plotted for the results obtained and regression fits were added to analyse the data. The observed trends were that reaction time decreased when caffeine consumption was increased, which correlated with expected results. The highest administered dose deviated from this trend, however, was put down to a 'caffeine crash' that was experienced by the participants. Important factors that were considered when discussing the results were pre-established caffeine tolerances as well as the diversity within the sample of participants.

1 Introduction

Caffeine is a natural stimulant found in many products that millions of people consume daily such as coffee, tea, energy drinks, and is known for its cognitive effects in reducing tiredness and reaction times. It is very similar in structure to adenosine, a neurotransmitter that is responsible for an individuals sleep drive[1]. When ATP is broken down to release energy within the body, adenosine is released as a secondary byproduct. As the brain is the highest consumer of ATP within the body, a large excess of adenosine builds up here after a period of time. When this excess amount accumulates, it binds to specific receptors that restrict neuron activity within the brain, therefore promoting sleep. Caffeine behaves in a similar way when consumed, however causes the opposite effect. Due to the similar structure of both molecules, caffeine binds to 2 receptor subtypes, A1R and A2aR [1], causing the build-up of adenosine to go unnoticed by the brain, thereby promoting wakefulness and preventing tiredness. Consumers tend to experience its peak 30-45 minutes after consumption; however, its metabolic half-life is 3-5 hours [2] and it takes around 10 hours for it to be cleared from the bloodstream. Many external factors can change how it affects one's body, food intake being a key factor as caffeine absorption is directly dependant on pH [2].

Many studies have been performed to demonstrate the vast effects of caffeine on cognitive abilities, with these effects being one of the primary reasons as to why many consume caffeine in the first place. Around 63% of the UK population regularly drink coffee [3], with over 30% of those consumers drinking coffee several times a day. There are many additional effects associated with a moderated increase in caffeine consumption that are not related to cognitive abilities, such as health benefits [4] or decreased sensitivity to caffeine.

The purpose of this experiment is to investigate the effect caffeine has on reaction time by varying the quantity of caffeine consumed and recording how reaction time changes by measuring the time to tap a screen once it turns green. These results can be compared to others that are obtained from similar experiments to evaluate what the expected conclusions should be and highlight potential errors and external factors that cause discrepancies within the results.

2 Experimental

The experiment involved 5 different quantities of caffeine, ranging from 80-400mg per day, which is equivalent to 1-5 cups. 400mg was chosen as the limit as this is the maximum recommended daily dose of caffeine for adults. Each day, a set quantity of caffeine was ingested, and reaction time was measured as soon as the amount was fully consumed using a website that timed how quickly the user taps the screen once it turns green. Reaction times were measured every 30 minutes for 7 hours. Decaffeinated coffee was used as a control and the average of each data set was plotted onto a graph with a linear regression fit.

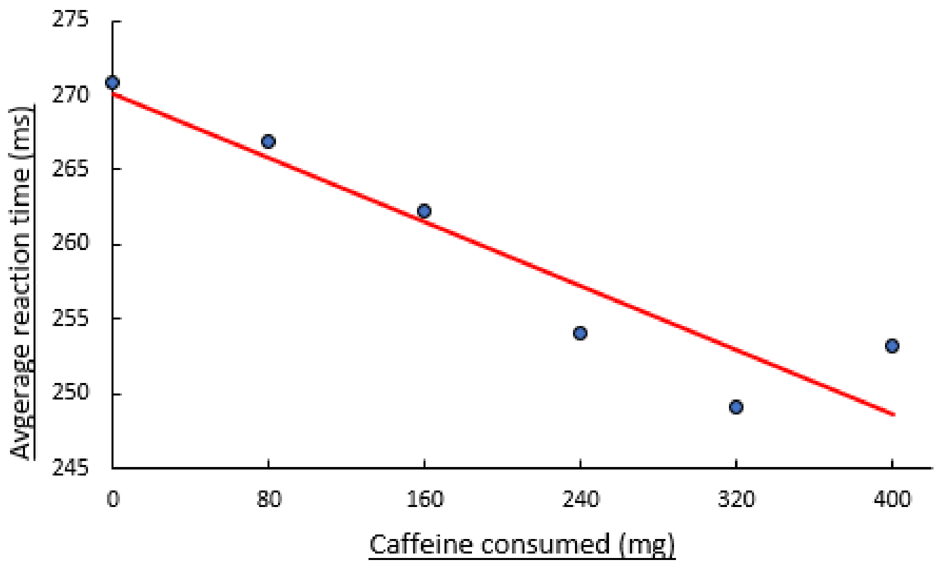

Figure 1: A graph showing the relationship between mg of caffeine consumed and the average reaction time experienced over 7 hours. A linear regression fit using all data, but not forced through the origin, is shown.

By evaluating Figure 1, there is an overall visible decrease in reaction time when caffeine quantity is increased, which follows what was expected. The only exception to this was when 400mg was consumed. This shows evidence that a 'caffeine crash' may have happened at this amount. When high doses of caffeine are consumed, a larger number of adenosine receptors become blocked, and so when the caffeine becomes metabolised, there is a larger number of adenosine molecules binding to these receptors at once, therefore causing a drastic drop of energy in a short period of time[5]. This sharp decrease in energy then causes a larger increase in tiredness, and consequently in reaction time.

Further analysis into each separate data set shows that the higher the dose of caffeine, the

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quicker the onset of the caffeine crash.

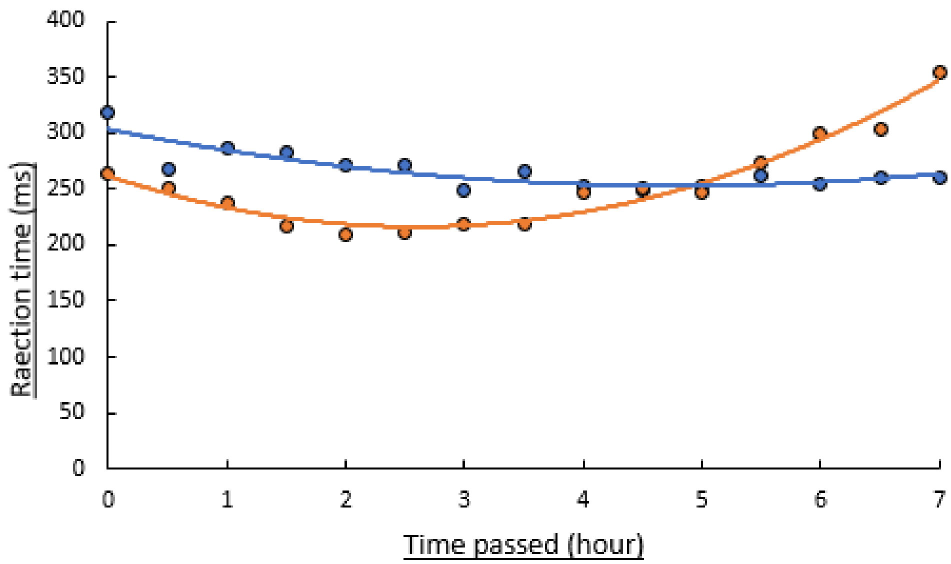

Figure 2: A graph comparing the progression of reaction time for 80mg of caffeine (blue) and 400mg of caffeine (orange) over a period of 7 hours. Polynomial regression fits using all data are shown.

Figure 2 compares the data collected for the lowest dose of caffeine consumed vs the highest. At 400mg of caffeine (orange data), there is a larger decrease in reaction time up until 3.5 hours, at which point the reaction times experience a sharp increase that gradually overtakes those for 80mg of caffeine (blue data). At 80mg, there is a steady decline in reaction time, even after the full 7 hour duration of the experiment, suggesting that less caffeine could be more beneficial for increasing reaction time and alertness over a long period of time.

Additionally, at higher quantities of caffeine, further symptoms included shaking and jitteriness along with an increase in exhaustion after the 7 hours had elapsed, all of which can be considered unwanted effects. These were not experienced at lower doses, therefore solidifying the idea that moderate quantities of caffeine are more beneficial than higher doses.

Many studies have been performed to evaluate the effects of caffeine on reaction time, both positive, such as experiments done by Childs and De Wit (2006) or Mclellan et al. (2016), and negative, such as experiments done by Gendle (2009) and Greganti (2023). From the results obtained within this experiment, it can be inferred that a moderate caffeine intake can have significant positive effects in reducing reaction time, hence coinciding with the findings of positive investigations.

Nonetheless, there are factors to consider when interpreting the validity of these results, one of these being the sample size. This experiment was conducted on one participant who is a habitual coffee drinker, and therefore it is worth considering whether caffeine tolerance had any effect. When caffeine is regularly consumed, the brain adapts to this by increasing its number of adenosine receptors [7], and so more caffeine is required to experience the expected effects. Similarly, dopamine receptors downregulate to control the constant excitation from caffeine [7] and the liver develops an accelerated metabolism due to a greater simulation of CYP1A2 enzymes [7]. Therefore, the results may not accurately depict what the effects of changing caffeine doses are on a population of people, or for individuals who do not regularly consume caffeine in any form.

Another element to consider is external factors that can also affect reaction time, such as glucose consumption, age, sex or even whether a participant is left or right handed[6]. All these categories have their own effects on reaction time, and due to the small sample size, these could've caused large discrepancies within the results obtained. A way to minimise the error from this would be to increase the participants of the experiment to represent a diverse population.

3 Conclusion

The experiment involved getting a participant to drink 5 different doses of caffeine where decaffeinated coffee was used as a placebo. The observed trend was that higher caffeine doses decreased the average reaction time over a period of 7 hours, which was the expected result. The highest administered quantity of 400mg was the only value to deviate from this trend, therefore suggesting that a 'caffeine crash' was experienced due to the sudden binding of adenosine to specific receptors at the same time. Furthermore, unwanted effects were observed at these doses, such as jitteriness and shaking as well as an increased levels of tiredness after the caffeine has been metabolised to a half-life of 3-5 hours. There are many important factors to consider when analysing the results, including a pre-established tolerance to caffeine, number of participants and diversity within the participants.

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4 Copyright Notice

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