WORLD JOURNAL OF PHARMACY AND PHARMACEUTICAL SCIENCES
SJIF Impact Factor 7.632
Volume 13, Issue 2, 1203-1215 Research Article ISSN 2278 – 4357

EFFECTS OF CAFFEINE IN THE AFTERNOON UPON THE ENCODING OF NEW INFORMATION AND LAPSES OF ATTENTION

Andrew P. Smith*, PhD

School of Psychology, Cardiff University, Park Place, Cardiff CF10 3AT, UK.

Article Received on
06 December 2023,

Revised on 26 Dec. 2023,
Accepted on 16 Jan. 2024

DOI: 10.20959/wjpps20242-26606

***Corresponding Author**
Dr. Andrew P. Smith, PhD
School of Psychology, Cardiff University, Park Place, Cardiff CF10 3AT, UK.

ABSTRACT

Background: The behavioural effects of caffeine have been widely studied, and most studies have administered caffeine in the morning. The present study examined the effects of caffeine given in the post-lunch period. Caffeine increases the speed of encoding new information even when the person is alert, whereas it reduces lapses of attention when the person is fatigued. This was examined in the present study. **Methods:** Ninety-six university students took part in the study. There were twenty-four in each of the groups formed by combining lunch/no lunch conditions and caffeine/placebo. The caffeine manipulation was double-blind, and 100mg of caffeine was added to decaffeinated coffee in the caffeine conditions. Participants carried out a baseline test session in the morning, followed by the lunch and drinks conditions. There was then a post-drink test session one hour later. The test battery included measures of cardiovascular function, the speed of encoding new information, lapses of attention and indices of selective attention. **Results:** Consumption of lunch led to a higher pulse rate than when no lunch was consumed, but caffeine had no significant effect on cardiovascular parameters. Caffeine consumption led to faster encoding of new information at the start of the test session and reduced lapses of attention at the end of the session. There were no significant effects of caffeine on measures of selective attention. **Conclusion:** Administration of caffeine after lunch showed the predicted profile of behavioural change, and this was observed whether lunch was consumed or not. Lunch led to a higher pulse rate, whereas caffeine had no significant effect on cardiovascular outcomes.

KEYWORDS: Caffeine, Afternoon, Post-lunch, Encoding, Lapses of attention, Categoric Search, Selective attention, Blood pressure, Heart rate.

INTRODUCTION

Much of the research on the effects of caffeine on performance has administered caffeine in the early morning to have a period of withdrawal during sleep. However, there are some studies which have examined the effects of caffeine when circadian alertness is low (e.g., after lunch and at night). This approach was adopted in our early research on the effects of caffeine[1-10] and has continued in our more recent studies.[11-23] The results from studies on the behavioral effects of caffeine have been regularly reviewed,[24-30] and sensitive measures have been developed. It has been suggested that some tasks are sensitive to the effects of caffeine even when the person is alert. These often involve the speed of encoding new information. For example, in a choice reaction time task, the person may have to respond to either the same target as the previous trial (A repetition) or a different one (An alternation). Alternations are slower than repetitions, and caffeine reduces this difference, leading to faster encoding of new information. This effect reflects the cholinergic system. Other tasks are only sensitive to the effects of caffeine when the person is fatigued. For example, occasional long responses and errors increase with fatigue and are reduced in number by ingestion of caffeine. Such effects reflect the noradrenergic system. In the present study, these two profiles of the effects of caffeine were examined following ingestion of caffeine in the early afternoon. Fatigue was manipulated by the performance of a long battery of tests, and it was predicted that caffeine would influence the speed of encoding in a task carried out at the start of the battery and reduce lapses of attention in a task carried out at the end of the battery.

The performance tasks also measured many different aspects of selective attention.[31,32] It was predicted that caffeine would have little effect on selective attention in either a focused attention or a search task. Two of the tasks also examined stages of processing in more detail. It has been argued that by changing task parameters in a choice reaction time task, one can examine whether effects occur at the encoding, central or output stages of processing. Input-related encoding can be manipulated by degrading the quality of visual stimuli. Central processing or response selection can be changed by varying stimulus-response compatibility, and the output side of the processing system can be examined by varying the time uncertainty (The inter-stimulus interval). This approach was included in the present study, and the inclusion of these tasks was a method of inducing fatigue between the initial categoric search task and the last test in the battery.

Cardiovascular parameters were also examined to determine whether these were influenced by lunch and caffeine. Consumption of lunch usually increases heart rate, whereas caffeine may increase blood pressure. Half of the participants were given lunch, and the rest abstained from eating until the end of the study. Early studies contrasting afternoon performance in lunch and no-lunch conditions failed to show a strong effect of consuming a meal on post-lunch performance, suggesting that any change in performance observed in the afternoon is due to endogenous circadian rhythms.[33] However, later experimental evidence provided support for the behavioural effects of meal consumption on performance.[34,35] Thus, change in performance in the afternoon seems to be influenced by both endogenous and exogenous factors. Several additional factors have been found to play a significant role in the post-lunch effects on cognitive performance: personality, sex differences, nutritional composition and size of the meal, and stimulants such as noise and caffeine following the meal. In addition, the effects of meals are largely restricted to sustained attention tasks, and they do not influence selective attention.[35] The aim of the present analyses was to determine whether the effects of caffeine were observed in both lunch and no lunch conditions.

METHOD

Ethics approval: The present study was approved by the psychology ethics committee.

Participants

Sample

A sample of 96 participants were recruited from a university student population.

Exclusion criteria

Participants were not selected for the study if they

- Had suffered serious physical or mental illness that would influence physical or mental performance
- Smoked more than five cigarettes during the daytime
- Consumed more than 20 units of alcohol during the week (Monday - Friday)
- Drank less than 1 cup of coffee or tea during the daytime or were unwilling to drink coffee.
- The above criteria were imposed to eliminate possible effects of alcohol or nicotine withdrawal and to ensure that only habitual caffeine consumers were included.

Informed consent

Participants signed an informed consent form before being entered into the study. They received a written explanation of the experiment explaining the aims of the research and that they were free to withdraw at any time. They were assured that all data collected would remain anonymous.

Payment

Participants were paid £20 for completing the study and were provided with lunch.

Design

This study employed both a between and within-subjects design. Participants were randomly assigned to one of two conditions: lunch or no lunch. Within each condition, participants were assigned to caffeine condition A or B, receiving coffee containing either caffeine solution A or B (Double-blind manipulation). Equal numbers of male and female participants were assigned to each condition.

The test day involved a single test session lasting approximately 4 hours (11 am - 3 pm/12 pm - 4 pm). The scores from the morning test session were used to control for individual differences present before the caffeine challenge.

Lunch

Each participant was provided with a sandwich-based lunch, with a choice of additional crisps, biscuits and fruit. This lunch was consumed at either lunchtime (Lunch condition) or given at the end of the test day upon departure (No lunch condition). Those who abstained from lunch were told that they would receive the lunch of their choice at the end of the afternoon test session, thus minimising induction of negative mood because of being asked to miss lunch.

Nature of the drink

Each cup of coffee was made with one rounded teaspoon of decaffeinated coffee in a 150ml mug of boiling water. Placebo or caffeine solution (Coded solution A or B) was added. The drink condition remained double-blind, with participants being randomly assigned to coffee conditions A or B. The placebo solution consisted of preserved water, while the caffeine solution contained 10mg of caffeine per ml. A fixed quantity (10mls) of the appropriate solution was added to the mug of coffee to ensure that those in the caffeine condition

received a 100mg dose of caffeine. Milk and sugar were added in accordance with the usual preference.

Schedule of testing

Familiarisation

Having satisfied the inclusion criteria, all participants attended the research unit for a 45-minute familiarisation session. During this preliminary session, they were measured and weighed and had their blood pressure and pulse recorded. Participants were thoroughly familiarised with the performance tests.

Testing Pre-requisites

The evening before each test day, participants were asked to limit their alcohol consumption to a maximum of four units, with none to be consumed after midnight. Two hours prior to each test session, participants were required not to smoke, eat, drink any alcoholic drinks or participate in vigorous exercise. In addition, they had to refrain from consuming any caffeinated products or drinks such as over-the-counter cold medication, cola, tea, coffee and hot chocolate.

Test day

Participants were permitted to select a suitable start time for their test day: 11 am or 12 pm. Upon arrival at the unit, they were asked a series of questions to ensure they were in good health and had adhered to the test pre-requisites. The test day schedule is shown in Table 1.

Table 1: Test day schedule.

First test group

11.00 - 12.15 Go straight to computer booths,

Measure (Pre-baseline) BP and Pulse, complete hunger and thirst rating scales.

Start Performance Tests

Measure (Post-baseline) BP and Pulse

Complete hunger and thirst rating scales

12.15 - 12.45 If in lunch condition, they went to an allocated room and received the menu they requested. Everything chosen had to be consumed.

If not in lunch condition, they remained in the main testing area.

12.45 - 13.00 All participants given coffee

Having finished lunch, participants must complete the assessment of lunch acceptability.

13.00 - 13.45 Participants completed psychosocial questionnaires.

13.45 - 15.00 Go to computer booths.

Measure (Pre-test) BP and Pulse, complete hunger and thirst rating scales.

Start Performance Tests

Measure (Post-test) BP and Pulse

Complete hunger and thirst rating scales

End of test session

The second test group started one hour after the first group and then followed an identical schedule.

Computerised performance tests

All of the tests were presented on IBM-compatible PCs. Completion of the whole battery of performance tests took approximately one hour. The following performance tasks were completed during each test session.

a) Focused attention task

This selective attention task was developed by Broadbent.[31,32] Target letters appeared as upper case A's and B's. In each trial, three warning crosses were presented on the screen, and the outside crosses were separated from the middle one by either 1.02 or 2.60 degrees. Participants were told to respond to the letter presented in the centre of the screen and ignore any distractors presented in the periphery. The crosses were on the screen for 500 msecs and were then replaced by the target letter. The central letter was either accompanied by 1) nothing, 2) asterisks, 3) letters that were the same as the target, or 4) letters that differed. The two distractors were identical, and the targets and accompanying letters were always A or B. The correct response to A was to press a key marked A on the left-hand side of the response box, while the correct response to B was to press the key marked B on the right-hand side of the response box. Participants were given ten practice trials followed by ten blocks of 64 trials. In each block, there were equal numbers of near/far conditions, A or B responses and equal numbers of the four distractor conditions. The nature of the previous trial was controlled.

b) Categoric Search test 1 (basic form)

This task was also developed by Broadbent[31,32] to measure aspects of selective attention. Each trial started with the appearance of two crosses in the positions occupied by the non-

targets in the focused attention task (i.e. 2.04 or 5.20 degrees apart). Participants did not know which of the crosses would be followed by the target. The letter A or B was presented alone on half the trials and was accompanied by a digit (1-7) on the other half. Again, the number of near/far stimuli, A versus B responses and digit/blank conditions were controlled. Half of the trials led to compatible responses (i.e. the letter A on the left side of the screen or the letter B on the right), whereas the others were incompatible. Participants were given ten practice trials followed by five blocks of 64 trials. In each block, there were equal numbers of near/far conditions, A or B responses and equal numbers of the four distractor conditions. The nature of the previous trial was controlled.

c) Categoric Search Test 2 (with delay)

This test was similar to the categoric search task described above. However, this form of the test included a variable length delay after the warning crosses disappeared and the target letter appeared on the screen. Manipulating the task in this way permits closer examination of motor preparation in organising an appropriate response to the target. Participants were given ten practice trials followed by five blocks of 64 trials. In each block, there were equal numbers of near/far conditions, A or B responses and equal numbers of the four distractor conditions. The nature of the previous trial was controlled.

d) Categoric Search Test 3 (With Delay and Masked target)

This test was similar to the two categoric search tasks described above, but this form of the test included a variable length delay after the warning crosses disappeared and the target letter appeared on the screen. In addition, the target letter was ‘masked’. The stimulus quality was degraded to examine the encoding stage. Participants were given ten practice trials followed by five blocks of 64 trials. In each block, there were equal numbers of near/far conditions, A or B responses and equal numbers of the four distractor conditions. The nature of the previous trial was controlled.

The order of task presentation was manipulated to ensure any effects identified were not the result of the task order. The two task orders are described below.

Order of computerised performance tests

Test Order 1

Categoric Search Task (Basic form)

Focused Attention Task

Categoric Search Task - with delay and masked target

Categoric Search Task - with delay only

Categoric Search Task (Basic form)

Test Order 2

Categoric Search Task (Basic form)

Categoric Search Task - with delay only

Categoric Search Task - with delay and masked target

Focused Attention Task

Categoric Search Task (Basic form)

RESULTS

Analysis strategy

The difference between the post-lunch/drink scores and the baseline scores were used in the analyses. The between-subject factors in the ANOVA were lunch conditions, caffeine conditions, order of tests and early versus late testing times.

Cardiovascular outcomes

Those who consumed lunch showed a smaller drop in pulse rate than those who abstained from eating. There was a main effect of lunch consumption upon pulse rate prior to the final test session: $F(1, 79)$ 6.65, $p < 0.05$. Lunch group = -0.83 No lunch group = -7.04. Similarly, there was a main effect of lunch consumption upon pulse rate following the final test session, $F(1, 79)$ 9.36, $p < 0.01$. Lunch group = 3.03 No lunch group = -3.10. There were no significant effects of caffeine on cardiovascular outcomes, and caffeine did not modify the effects of lunch.

Ratings of Hunger and Thirst

There was a main effect of lunch consumption upon hunger ratings prior to the final test session, with the no-lunch group feeling more hungry compared to the pre-lunch time; $F(1, 79)$ 98.15, $p < 0.001$. Lunch group = -36.28 No lunch group = 18.48. There was also a main effect of lunch consumption upon thirst ratings prior to the final test session: $F(1, 79)$ 16.88, $p < 0.001$. Lunch group = -20.77 No lunch group = 0.17. There was a main effect of lunch consumption upon hunger ratings following the final test session: $F(1, 79)$ 184.87, $p < 0.001$. Lunch group = -50.66 No lunch group = 10.58. Again, there was also a main effect of lunch consumption upon thirst ratings following the final test session: $F(1, 79)$ 16.13, $p < 0.001$.

Lunch group = -19.04 No lunch group = -3.17. There were no significant effects of caffeine on the ratings of hunger and thirst, and caffeine did not modify the effects of lunch.

Selective attention

The focused attention allowed measurement of the effects of distraction and funnel vision.[31,32] None of these measures were significantly changed by lunch, caffeine or the different combinations of these conditions. The categoric search task provides a measure of distraction from irrelevant stimuli, spatial uncertainty, stimulus-response compatibility and place repetition. None of these measures were significantly changed by caffeine, lunch or the combination of these conditions.

Encoding of new information

The difference in msec between alternations and repetitions was calculated. Previous research has shown that these scores are smaller after caffeine. There was a main effect of caffeine condition upon the mean time taken to encode a new stimulus in the first (basic) categoric search task, F (1, 80) 5.97, $p<0.05$. Caffeine group = -5.92 msec Placebo group = 2.07 msec. There were no effects of lunch or lunch x caffeine interactions for this measure.

Lapses of attention

The accuracy of performing the categoric search tasks was generally very high, so errors represented a good example of a lapse of attention. Similarly, very long reaction times (> 750 msec) were also rare and were considered as another indicator of lapses of attention. There was a significant main effect of caffeine upon mean accuracy in the second (basic) categoric search task presented at the end of the test session, F (1, 80) 6.67, $p < 0.01$; Negative scores = less accurate than baseline: Caffeine group = 0.02 Placebo group = -0.18. This effect of caffeine on accuracy was observed when no distracting stimuli were present in the second (basic) categoric search task presented at the end of the test session, F (1, 80) 6.11, $p < 0.5$: Caffeine group = 0.06 Placebo group = -0.16. There was a significant main effect of caffeine condition upon the number of long response times in the second (basic) categoric search task presented at the end of the test session, F (1, 80) 9.44, $p < 0.01$. The caffeine group had fewer long responses than at baseline, whereas the placebo group had more (Caffeine group = -2.75, Placebo group 2 = 2.33). There were no significant effects of lunch on the measures of lapses of attention, nor were there any significant lunch x caffeine interactions.

DISCUSSION

The present study has shown that a relatively small dose of caffeine, given following a short period of abstinence, has a positive effect on performance. Two types of performance change were identified. The first occurred at the start of the test battery when the participants were alert and involved faster encoding of new information. This finding replicates earlier results obtained in different contexts (e.g., in the morning, with higher doses of caffeine and non-consumers of caffeine). The second effect of caffeine occurred when the participants were more fatigued by performing several tasks, and caffeine reduced lapses of attention, as measured by occasional errors and long reaction times.

In addition to the above effects, some of the outcomes showed no effect of caffeine. Caffeine had no significant effects on the selective attention and response organisation measures derived from the focused attention and categoric search tasks. Caffeine also had no significant effect on blood pressure or pulse. In contrast, lunch consumption increased pulse rate compared to the no lunch condition. Lunch also did not affect the selective attention and response organisation variables. The absence of an effect of lunch on lapses of attention is inconsistent with some research findings. However, this may reflect the nature of the task, the size and constituents of the lunch, or the characteristics of the sample.

In conclusion, the present study has confirmed that caffeine leads to well-established performance changes when administered in the early afternoon, a finding which plausibly accounts for caffeinated beverages being chosen at this time of day.

REFERENCES

1. Smith AP, Rusted JM, Eaton-Williams P, Savory M, Leathwood P. Effects of caffeine given before and after lunch on sustained attention. Neuropsychobiology, 1990; 23: 160-163.
2. Smith AP, Rusted JM, Savory M, Eaton-Williams P, Hall SR. The effects of caffeine, impulsivity and time of day on performance, mood and cardiovascular function. Journal of Psychopharmacology, 1991; 5: 120 - 128.
3. Smith AP, Brockman P, Flynn R, Maben AL, Thomas M. Investigation of the effects of coffee on alertness and performance and mood during the day and night. Neuropsychobiology, 1993; 27: 217-223.
4. Smith AP, Kendrick, AM, Maben, AL. Effects of breakfast and caffeine on performance and mood late in the morning and after lunch. Neuropsychobiology, 1992; 26: 198-204.

5. Smith AP, Kendrick AM, Maben AL, Salmon, J. Effects of breakfast and caffeine on cognitive performance, mood and cardiovascular functioning. Appetite 1994; 22(1): 39-55.
6. Smith AP, Maben A, Brockman P. 1993. The effects of caffeine and evening meals on sleep and performance, mood and cardiovascular functioning the following day. Journal of Psychopharmacology, 1993; 7: 203-206.
7. Smith AP, Maben A, Brockman P. 1994. Effects of evening meals and caffeine on cognitive performance, mood and cardiovascular functioning. Appetite, 1994; 22: 39-55.
8. Smith AP, Whitney H, Thomas M, Perry K, Brockman P. Effects of caffeine on mood, performance and cardiovascular functioning. Human Psychopharmacology-Clinical and Experimental, 1997; 12(1): 27-33.
9. Smith AP. Caffeine, performance, mood and states of reduced alertness. Pharmacopsychoecologia, 1994; 3: 75-86.
10. Smith AP, Whitney H, Thomas M, Perry K, Brockman P. Effects of caffeine and noise on mood, performance and cardiovascular functioning. Human Psychopharmacology, 1997; 12: 27-34.
11. Smith, A.P. Caffeine, breakfast cereal and time of day: effects on alertness, encoding and recall. European Journal of Pharmaceutical and Medical Research, 2020; 7(11): 51-56. https://storage.googleapis.com/journal-uploads/ejpmr/article_issue/1604058787.pdf
12. Smith AP. 2020. Fasting, breakfast, caffeine and caffeine withdrawal: effects on alertness, recall and encoding. European Journal of Pharmaceutical and Medical Research, 2020; 7(12): 41-46. https://storage.googleapis.com/journal-uploads/ejpmr/article_issue/1606471517.pdf
13. Smith AP. Caffeine and long hours of work: Effects on alertness and simple reaction time. World Journal of Pharmaceutical Research, 2021; 10(2): 79-89. DOI: 10.20959/wjpr20212-19694
14. Smith AP. Caffeine and ratings of alertness in the early morning. World Journal of Pharmaceutical and Medical Research, 2021; 7(3): 53-57. https://www.wjpmr.com/home/article_abstract/3334
15. Smith AP. Ratings of alertness after caffeine in the late morning. World Journal of Pharmaceutical Research, 2021; 10(4): 112-121. DOI: 10.20959/wjpr20214-20130.
16. Nguyen-Van-Tam DP, Smith, AP. Caffeine and iconic memory. World Journal of Pharmacy and Pharmaceutical Studies, 2023; 12(3): 38-52. DOI: 10.20959/wjpr20233-24328

17. Nguyen-Van-Tam DP, Smith AP. Caffeine, memory, impulsivity and time of day. European Journal of Pharmaceutical and Medical Research, 2022; 9(12): 99-105.
18. Nguyen-Van-Tam DP, Smith AP. Caffeine, mood, verbal reasoning, semantic processing and levels of processing: An investigation of state-dependent memory. World Journal of Pharmaceutical Research, 2022; 11(13): 2166-2190. doi: 10.20959/wjpr202213-25780
19. Nguyen-Van-Tam DP, Smith AP. Caffeine, semantic processing, logical reasoning, implicit memory, recognition memory, and allocation of memory resources. World Journal of Pharmaceutical Research, 2023; 12(2): 1-28. doi: 10.20959/wjpr20232-26897
20. Nguyen-Van-Tam DP, Smith AP. Further investigation of the effects of caffeine on implicit memory, allocation of memory resources, semantic memory and executive function. World Journal of Pharmacy and Pharmaceutical Studies, 2023; 12(2): 1564-1584. doi: 10.20959/wjpps20232-24227
21. Nguyen-Van-Tam DP, Smith AP. Caffeine and iconic memory. World Journal of Pharmacy and Pharmaceutical Studies, 2023; 12(3): 38-52. DOI: 10.20959/wjpr20233-24328
22. Nguyen-van-Tam, DP, Smith AP. Effects of regular caffeine consumption on semantic memory and executive function: A secondary analysis. World Journal of Pharmaceutical Research, 2023; 12(4): 1852-1873. DOI: 10.20959/wjpr20234-27409
23. Nguyen-Van-Tam DP, Smith AP. Effects of caffeine, beliefs about whether caffeine was consumed and beliefs about the behavioural effects of caffeine: A secondary analysis of semantic memory and central executive tasks. World Journal of Pharmaceutical Research, 2023; 12(5): 65-84. DOI: 10.20959/wjpr20235-27641
24. Lieberman HR. Caffeine. In: Handbook of Human Performance, Health and performance. (eds) A. P. Smith & D. M. Jones. London: Academic Press. 1992; 2: 49-72.
25. Smith AP. Effects of caffeine on human behavior. Food Chem Toxicol, 2002; 40: 1243-55.
26. Smith AP. Caffeine. In: Nutritional Neuroscience. Edited by H. Lieberman, R. Kanarek and C Prasad, 2005; 335-359. London: Taylor & Francis.
27. Glade MJ. Caffeine – Not just a stimulant. Nutrition, 2010; 26: 932-938.
28. Smith AP. Caffeine: Practical implications. In: Diet, Brain, Behavior: Practical Implications. Eds: R.B. Kanarek & H.R. Lieberman. Taylor & Francis, 2011; 271-292.
29. Doepker C, Lieberman H, Smith AP, Peck J, El-Sohemy A, Welsh B. Caffeine: Friend or Foe? Annual Review of Food Science and Technology, 2016; 7: 6.1 – 6.22. doi: 10.1146/annurev-food-041715-033243.

30. Smith AP. The psychobiological processes underpinning the behavioural effects of caffeine. In: P. Murphy (ed), Routledge International Handbook of Psychobiology. London, New York: Routledge. ISBN: 978-1-138-18800-6 (hbk) ISBN: 978-1-315-64276-5 (ebk), 2019; 239-250.
31. Broadbent DE, Broadbent MH, Jones JL. Performance correlates of self-reported cognitive failure and of obsessionality. Br J Clin Psychol, 1986; 25(Pt 4): 285-99. doi: 10.1111/j.2044-8260.
32. Broadbent DE, Broadbent MHP, Jones JL. Time of day as an instrument for the analysis of attention, European Journal of Cognitive Psychology, 1989; 1(1): 69-94, DOI: 10.1080/09541448908403072
33. Smith AP, Kendrick A. Meals and performance. In: Handbook of human performance, Health and Performance. (eds) A. P. Smith & D. M. Jones. London: Academic Press, 1992; 2: 1-23.
34. Smith AP, Miles C. Effects of lunch on cognitive vigilance tasks. Ergonomics, 1986; 29: 1251 - 1261.
35. Smith AP, Miles C. Effects of lunch on selective and sustained attention. Neuropsychobiology, 1987; 16: 117 - 120.