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EFFECT OF CAFFEINE ON THE ACCEPTABILITY OF NOVEL-FLAVOURED DRINKS

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ABSTRACT

Background: Research on the behavioural effects of caffeine is well documented and reviewed. One area rarely covered in the reviews is the effects of caffeine on the acceptability of novel drinks. Findings from such studies have been used to support the view that caffeine deprivation, and its reversal by the ingestion of caffeine, is a major mechanism underlying behavioural changes associated with caffeine. **Methods:** The present study continued this research on the repeated pairing of novel flavours with caffeine or placebo in groups differing in level of regular caffeine consumption (non-consumers, low consumers, and high consumers). Three groups of volunteers were recruited: non-consumers of caffeine (N=23); low consumers (<200md/day; N=40) and high consumers (>300mg/day; N=33). After abstaining from caffeine overnight, the volunteers visited the laboratory at 09.00 and consumed a fruit juice with either caffeine (100 mg) or placebo. The caffeine manipulation was double-blind. Participants rated the pleasantness of the drink after their initial taste and after they had consumed it. Two hours later, they returned to the laboratory and repeated the procedure with a fruit tea being consumed, again with or without caffeine. The procedure was repeated for five consecutive days. **Results:** The analysis of the fruit juice data showed that drink acceptability increased over days and decreased when caffeine was added to the drink. There were no interactions with consumer status. Similar results were found for the ratings of the fruit tea. In addition, those who had caffeine in the fruit juice rated the fruit tea as more acceptable. Again, there were no interactions with consumer status. **Conclusion:** These

results do not confirm the previous finding that caffeine-deprived participants develop a dislike for novel drinks not paired with caffeine, nor that caffeine increases the liking of a novel drink consumed by caffeine-deprived individuals. Rather the results suggest that the taste of caffeine reduces the acceptability of the current drink and leads to an increased liking of a subsequent drink due to the contrast with the previous one.

KEYWORDS: Caffeine; caffeine withdrawal; drink acceptability.

INTRODUCTION

Effects of caffeine on behaviour have been well documented and frequently reviewed[1-7], and plausible underlying mechanisms have been identified.[8-10] One explanation of the effects of caffeine has been that caffeine withdrawal leads to adverse behavioural outcomes, which are reversed by subsequent ingestion of caffeine.[11] However, this view has not been supported by the results from studies conducted in other laboratories, which have investigated both performance and mood outcomes.[12-23]

Another line of research has been used to support the caffeine withdrawal explanation. Several studies have shown that repeated pairings of novel flavours with the post-ingestive effects of caffeine can increase liking for those flavours in deprived caffeine consumers. For example, Rogers et al.[24] found that liking increased over time for a novel fruit-flavoured drink paired with a caffeine capsule (100 mg), whereas liking for a drink paired with a placebo decreased. These effects were observed in regular caffeine consumers tested at breakfast (i.e. after overnight withdrawal) but were not seen in low caffeine consumers. These findings have subsequently been replicated and extended in a series of studies carried out by Yeomans and colleagues.[25-28]

Yeomans et al.[25] found that caffeine (100 mg) in a novel fruit tea led to an increased liking for the tea when consumed by caffeine-deprived subjects and that this effect was greatest for individuals who rated the drink as highly novel. However, caffeine did not influence liking for a novel drink when the volunteers were not in a caffeine-deprived state. Thus, the authors concluded that there is no evidence for a "positive" reinforcing effect of caffeine (i.e. a learned association between caffeine ingestion and a subsequent pleasurable shift in mood). Instead, the results support "negative" reinforcement due to the ability of caffeine to remove the aversive mood state associated with caffeine abstinence in regular consumers.

Further studies have indicated a tendency for caffeine-deprived individuals to develop a dislike for novel drinks that are not paired with caffeine[26,28], and also support the view that such acquired preferences are acutely sensitive to the person's current caffeine deprivation state.[27,28] However, Richardson et al.[29] reported caffeine-mediated drinks preferences in non-deprived individuals tested after consuming lunch. This result was interpreted as an acquired association between drink flavour and the ability of caffeine to counteract the deterioration in mood known as "the post-lunch dip". Again, this result can be seen as an example of "negative" reinforcement in the form of the removal of an aversive mood state by caffeine ingestion.[26]

The purpose of the present study was to replicate and extend previous findings on the reinforcing properties of caffeine in novel-flavoured drinks.

METHODS

The research reported here was carried out with the ethics committee's approval, School of Psychology, Cardiff University, and carried out with the informed consent of the participants.

Design

Each consumer group was split into those who received caffeine in Drink 1 and those who received placebo. Half of the participants who received caffeine in Drink 1 received it again in Drink 2, whereas the other half received a placebo. The same was true for those who received a placebo in Drink 1.

Participants

Participants were selected if they were (1) high caffeine consumers (>300mg caffeine/day, N = 33), (2) low caffeine consumers (<200mg caffeine/day, N = 40), or (3) non-consumers (0mg caffeine/day, N=23). All participants were members of the Centre for Occupational and Health Psychology's volunteer panel (N=96; male=33; female=66; mean age=25 years, range 18 to 53 years).

Drinks

Fruit juice

The fruit juices used were Cranberry and Raspberry, Orange, Apple and Passion Fruit, and Mango and Apple. Either 100mg of caffeine in solution or the placebo solution (water) were added.

Fruit tea

The herbal infusions used were Lemon and Ginger, Camomile and Spiced Apple, and Strawberry and Raspberry Swirl. These were prepared by infusing for 3 minutes in boiling water. On serving, drinks were cooled down to a temperature of 60-65°C. To this was added either 100mg of caffeine or the placebo solution.

Procedure

Familiarisation session

Each volunteer was asked to rate the three fruit juices and the three fruit teas on a visual analogue scale measuring pleasantness. The middle choice of the juices and teas were selected as the person's test drinks.

Test days 1-5

Visit 1 (09:00)

Fruit juice was the test drink (containing either 100mg of caffeine or placebo), which participants were required to rate on the scales provided (with a scale of 1-100, with higher scores indicating greater pleasantness). They were instructed to rate the drink twice: once on initial taste, then again after finishing it.

Visit 2 (11:00)

The fruit teas were given, containing either 100 mg of caffeine or placebo. Participants were required to rate pleasantness using the scales provided (with a scale of 1-100, with higher scores indicating greater pleasantness). In addition, they were instructed to rate the drink twice: once on initial taste, then again after finishing the whole drink.

RESULTS

Ratings at familiarisation

There were no differences between both consumer groups and the non-consumers in terms of ratings of the drinks at familiarisation.

DRINK 1 (FRUIT JUICE)

An analysis of variance was carried out. The within-subject factors were days and initial rating/after drink rating and the between subject factors were drink (caffeine v placebo) and regular caffeine consumption. There was a significant effect of days ($F_{4, 348} = 3.63$ $p <$

0.01), with pleasantness ratings increasing over the week (see Table 1). There were no significant interactions between days and the other variables.

Table 1: Mean ratings of the pleasantness of fruit juices on the five test days (s.e.s in parentheses).

Days	Mean pleasantness rating
1	48.3 (2.5)
2	53.5 (2.5)
3	53.6 (2.6)
4	55.1 (2.6)
5	54.8 (2.7)

There was no significant difference between the initial rating of the drink and the rating after consumption. Neither did this variable interact with any of the other variables.

There was a significant main effect of caffeine v placebo ($F_{1,87} = 16.09$ $p < 0.001$), with the caffeinated drink being rated as less pleasant (see Table 2). This variable did not interact with any of the other variables.

Table 2: Mean ratings of caffeinated and placebo drinks (s.e.s in parentheses).

Drink	Mean pleasantness rating (s.e.)
Placebo	62.1 (3.2)
Caffeine	44.0 (3.1)

There was no significant interaction ($F < 1$) between drink (caffeine v placebo) and regular caffeine consumption (see Table 3).

Table 3: Mean ratings of caffeinated and placebo drinks (s.e.s in parentheses) by the different consumer groups.

Consumer group	Drink	Pleasantness rating
Non-consumer	Placebo	67.2 (6.7)
Non-consumer	Caffeine	47.8 (6.1)
Low consumer	Placebo	53.3 (4.7)
Low consumer	Caffeine	42.6 (4.9)
High consumer	Placebo	65.6 (5.2)
High consumer	Caffeine	41.7 (5.1)

In summary, this analysis showed that pleasantness ratings were lower in the caffeine group and that this effect did not change over days or as a function of consumer group.

DRINK 2 (FRUIT TEA)

A similar analysis was conducted on these data, and the ANOVA also included the nature of the previous drink (caffeine v placebo). The fruit teas were rated as less pleasant than the fruit juices. Again, there was a significant effect of days (F4, 348 = 3.98 p <0.005), with pleasantness rating increasing over days (see Table 4). There were no significant interactions between days and the other variables.

Table 4: Mean ratings of pleasantness for the fruit teas on the five test days (s.e.s in parentheses).

Days	Mean pleasantness rating
1	28.9 (2.5)
2	29.6 (2.3)
3	27.2 (2.3)
4	32.7 (2.4)
5	33.6 (2.7)

There was a significant difference between the initial rating of the drink and the rating after consumption (F 1, 82 = 4.64 p < 0.05), with the initial rating being higher than the final one (see Table 5). The timing of the rating did not interact with any of the other variables.

Table 5: Mean ratings of pleasantness at the start and end of the drinks (s.e.s in parentheses).

Time of rating	Mean pleasantness rating (s.e.)
Start of drink	31.5 (2.2)
End of drink	29.3 (2.3)

There was a significant effect of drink type (F 1, 82 = 3.47 p = 0.05), with the caffeinated drink being rated as less pleasant (see Table 6). However, drink type did not interact with any of the other variables.

Table 6: Mean ratings of caffeinated and placebo fruit tea drinks (s.e.s in parentheses).

Drink	Mean pleasantness rating (s.e.)
Placebo	34.4 (3.0)
Caffeine	26.4 (3.1)

There was also a significant effect of the type of previous drink (the fruit juice), with those who had caffeine in the previous drink rating the fruit tea as more pleasant (F 1, 82 = 10.27 P < 0.005; see Table 7). This variable did not interact with any of the other variables.

Table 7: Mean ratings for previous caffeinated and placebo drinks (s.e.s in parentheses).

Drink	Mean pleasantness rating (s.e.)
Placebo	23.5 (3.1)
Caffeine	37.3 (2.98)

None of the effects for the consumer groups were significant (all F's < 1), and the ratings for these groups are shown below for the current (Table 8) and previous drink types (Table 9).

Table 8: Mean ratings of caffeinated and placebo fruit tea drinks (s.e.s in parentheses) by the different consumer groups.

Consumer group	Drink	Pleasantness rating
Non-consumer	Placebo	31.0 (6.1)
Non-consumer	Caffeine	26.6 (6.1)
Low consumer	Placebo	36.0 (4.3)
Low consumer	Caffeine	23.1 (4.9)
High consumer	Placebo	36.2 (5.3)
High consumer	Caffeine	29.4 (4.9)

Table 9: Mean ratings of fruit tea drinks (s.e.s in parentheses) for those given caffeinated or placebo fruit juice by the different consumer groups.

Consumer group	Drink	Pleasantness rating
Non-consumer	Placebo	20.0 (6.4)
Non-consumer	Caffeine	37.6 (5.8)
Low consumer	Placebo	23.0 (4.4)
Low consumer	Caffeine	36.2 (4.7)
High consumer	Placebo	27.4 (5.3)
High consumer	Caffeine	38.2 (4.9)

In summary, the results from the ratings of the fruit teas confirm effects observed in the fruit juice data, namely, pleasantness of the drink increases over days and is lower if it contains caffeine. However, these effects did not interact with consumer status. In addition, prior consumption of caffeine in the fruit juice was associated with higher pleasantness ratings for the fruit tea drink. However, again, this effect did not interact with consumer status.

DISCUSSION

Previous research examining the effects of caffeine on performance and mood has found limited support for the reversal of caffeine withdrawal explanation. The present study investigated another area where reversal of caffeine withdrawal has been implicated as the underlying mechanism, namely the acceptability of novel flavoured drinks, with and without caffeine. In the present study, the liking of both beverages increased over the week. However,

caffeine in both drinks led to reduced liking, presumably due to the taste of the caffeine. In the case of the second drink, prior caffeine was associated with greater pleasantness which may reflect a contrast with the previous unpleasant drink containing caffeine. There were no significant interactions with regular consumption patterns, which contrasts with earlier results using this methodology. Another study[30] found that the post-ingestive effects of caffeine on pleasantness ratings varied with time of day. This study also demonstrated that caffeine drinks were rated as less pleasant because of the bitter flavour of the caffeine. The impact of the caffeine taste will depend on the drink used in the study, and only complex flavours may mask the caffeine. Other background conditions may also influence the conditioned flavour preference negatively reinforced by caffeine. The present study had a design similar to an earlier study[25] that found that liking for the first drink increased for those receiving caffeine but decreased for the no-caffeine group. The previous research[25] found that for the second drink, those with no caffeine in this drink or the first one showed a decrease in liking the second drink, whereas those given caffeine in the second drink, but not the first, rated the second drink as more pleasant. The present study obtained a very different profile of results to the earlier research. The current study suggests that, as in studies of cognitive performance and mood, reversal of effects of caffeine withdrawal by caffeine appears to be difficult to replicate across different laboratories.

CONCLUSION

The research described in this study examined the effects of pairing caffeine with novel flavoured drinks. Level of regular caffeine consumption was also investigated. The results showed that caffeine in a fruit juice or a fruit tea led to lower pleasantness ratings. Caffeine in the fruit juice led to higher pleasantness ratings of the fruit tea. There were no interactions between caffeine (either in the current or previous drink) and level of regular caffeine consumption. These results are another example of effects of caffeine which cannot be interpreted in terms of negative effects of caffeine withdrawal and their reversal by subsequent caffeine ingestion.

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REFERENCES

1. Lieberman HR. Caffeine. In: Handbook of Human Performance, Vol.2: Health and performance. (eds) A. P. Smith & D. M. Jones. London: Academic Press, 1992: 49-72.
2. Smith AP. Effects of caffeine on human behavior. Food Chem Toxicol, 2002; 40: 1243-55.
3. Smith AP. Caffeine. In: Nutritional Neuroscience. Edited by H. Lieberman, R. Kanarek and C Prasad, 2005; 335-359. London: Taylor & Francis.
4. Glade MJ. Caffeine – Not just a stimulant. Nutrition, 2010; 26: 932-938.
5. Smith AP. Caffeine: Practical implications. In: Diet, Brain, Behavior: Practical Implications. Eds: R.B. Kanarek & H.R. Lieberman. Taylor & Francis, 2011; 271-292.
6. 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.
7. 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.
8. Fredholm B. Adenosine, adenosine receptors and the actions of caffeine. Pharmacology and Toxicology, 1995; 7: 93-101.
9. Franchetti P, Messini L, Cappellacci L, Grifantini M, Lucacchini A, Martini C, Senatore G. 8- Azaxanthine derivatives as antagonists of adenosine receptors. Journal of Medical Chemistry, 1994; 37: 2970-5.
10. Nehlig A, Daval JL, Debry G. Caffeine and the central nervous system: mechanisms of action, biochemical, metabolic and psychostimulant effects. Brain Research Reviews, 1992; 17: 139-170.
11. James JE, Rogers PJ. Effects of caffeine on performance and mood: withdrawal reversal is the most plausible explanation. Psychopharmacology, 2005; 182: 1-8.
12. Grahan, TE. Caffeine and exercise: metabolism, endurance and performance. Sports Medicine, 2001; 31(11): 785-807.
13. Snel J, Lorrist MM. Effects of caffeine on sleep and cognition. Prog Brain Res, 2011; 190: 105-117.
14. Morava A, Fagan MJ, Effects of Caffeine and Acute Aerobic Exercise on Working Memory and Caffeine Withdrawal, Prapavessis H. Sci Rep, 2019; 9(1): 19644.

15. Haskell CF, Kennedy DO, Wesnes KA, Scholey AB. Cognitive and mood improvements of caffeine in habitual consumers and habitual non-consumers of caffeine. Psychopharmacology, 2005; 179(4): 813-25.
16. Einother SJL, Giesbrecht T. Caffeine as an attention enhancer: reviewing existing assumptions. Psychopharmacology, 2013; 225(2): 251-274.
17. Hewlett P, Smith AP. Acute effects of caffeine in volunteers with different patterns of regular consumption. Human Psychopharmacology Clinical and Experimental, 2006; 21: 167-180.
18. Hewlett P, Smith AP. Effects of repeated doses of caffeine on performance and alertness: new data and secondary analyses. Human Psychopharmacology: Clinical and Experimental., 2007; 22: 339-350.
19. Christopher G, Sutherland D, Smith AP. Effects of caffeine in non-withdrawn volunteers. Human Psychopharmacology Clinical and Experimental, 2005; 20: 47-53.
20. Smith AP, Christopher G., Sutherland D. Effects of repeated doses of caffeine on mood and performance of alert and fatigued volunteers. Journal of Psychopharmacology, 2005; 19(5): 620-626.
21. Smith A, Christopher C, Sutherland D. Effects of caffeine in overnight-withdrawn consumers and non-consumers. Nutritional Neuroscience, 2006; 9: 63-71.
22. Smith AP, Christopher G, Sutherland D. Acute effects of caffeine on attention: A comparison of non-consumers and withdrawn consumers. Journal of Psychopharmacology, 2013; 27: 77-83.
23. Cooper RK, Lawson SC, Tonkin SS, Ziegler AM, Temple JL, Hawk LW. Caffeine enhances sustained attention among adolescents. Exp Clin Psychopharmacol, 2021; 29(1): 82-89.
24. Rogers PJ, Richardson NJ, Elliman NA. Overnight caffeine abstinence and negative reinforcement of preference for caffeine-containing drinks. Psychopharmacology, 1995; 120: 457-462.
25. Yeomans MR, Spetch H, Rogers PJ. Conditioned flavour preference negatively reinforced by caffeine in human volunteers. Psychopharmacology, 1998; 137: 401-409.
26. Yeomans MR, Jackson A, Lee MD, Steer B, Tinley E, Durlach P, Rogers PJ. Acquisition and extinction of flavour preferences conditioned by caffeine in humans. Appetite, 2000; 35: 131-141.
27. Yeomans MR, Ripley T, Lee MD, Durlach PJ. No evidence for latent learning for flavours conditioned by caffeine. Psychopharmacology, 2001; 157: 172-179.

28. Yeomans MR, Pryke R, Durlach PJ. Effect of caffeine deprivation on liking for a non-caffeinated drink. Appetite, 2002; 39: 35-42.
29. Richardson NJ, Rogers PJ, Elliman NA. Conditioned flavour preferences reinforced by caffeine consumed after lunch. Physiology & Behavior, 1996; 257-263.
30. Mobini S, Elliman T, Yeomans MR. Changes in the pleasantness of caffeine-associated flavours consumed at home. Food Quality and Preference, 2005; 16: 659-666.