

CAFFEINE AND RATINGS OF ALERTNESS IN THE LATE MORNING

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ABSTRACT

Background: Subjective alertness reaches a peak in the late morning. Previous research demonstrates that caffeine increases alertness when given in the early morning. This supports the view that caffeine is beneficial in low alertness situations. If caffeine mainly restores function when it is below optimum, one would expect less effect when circadian alertness is high in the late morning. This study examined this issue and whether any effects could be attributed to the reversal of caffeine withdrawal. **Methods:** Three groups of participants were recruited: non-consumers of caffeine (N=23); low consumers (<200mg/day; N=40) and high consumers (>300mg/day; N=33). After overnight caffeine abstinence, participants visited the laboratory and rated their alertness at 09.00. They then consumed a fruit juice which

had either caffeine (100 mg) or placebo added. Two hours later, they returned to the laboratory and drank a fruit tea which again contained either 100 mg caffeine or the placebo. They then returned to the laboratory at 13.00 and rated their alertness. They repeated this procedure for five consecutive days. **Results:** Caffeine was associated with higher alertness, but this effect was not significant. This effect did not change over days, and the absence of a significant effect of caffeine was observed in consumers and non-consumers. **Conclusion:** These results demonstrate that caffeine had no significant effect on alertness ratings in the late morning. This was reliable in that it did not change across days or with consumer status. These results support the view that caffeine has its clearest effects when alertness is below optimum. Alertness is below optimum for a large part of the day and can also be reduced by changes to the sleep-wake cycle and exogenous factors which increase fatigue. Previous results have important implications for real-life situations involving low arousal states and

show that caffeine is an effective countermeasure when circadian alertness is low, whereas the present findings confirm that it has less effect when alertness is near its peak.

KEYWORDS: Caffeine; Caffeine Withdrawal; Circadian Arousal; Ratings of Alertness.

INTRODUCTION

It is well established that alertness changes over the course of the day. Initial research^[1,2] focussed on the temperature rhythm, but it is now apparent that subjective ratings of alertness show a diurnal trend. This is shown in Figure 1, and alertness rises in the early morning reaches a peak in the late morning and then decreases over the rest of the day.

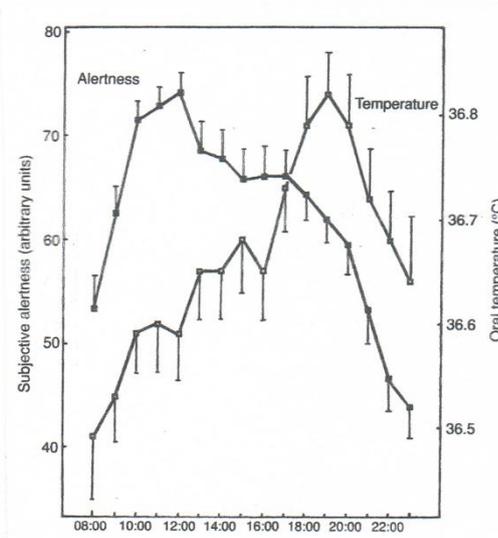


Figure 1: Diurnal rhythm of alertness ratings.

Recent research,^[3] has shown that caffeine increases alertness in the early morning. This is consistent with literature showing that caffeine is beneficial in low alertness states. The alerting effects of caffeine are well-documented.^[4-10] Beneficial effects of caffeine are often observed when arousal is low (e.g. after lunch,^[11] at night,^[12] when sleep-deprived,^[13] after working for many hours,^[14] and when the person is fatigued due to illness.^[15]). The present paper describes a study that examined the effects of caffeine on ratings of alertness in the late morning when circadian arousal was at its peak. It was predicted that caffeine would not increase alertness at this time.

Caffeine can increase alertness by the blockade of adenosine receptors.^[16] Adenosine inhibits metabolism, and the blockade by caffeine leads to alerting effects.^[17] Adenosine also inhibits the release of neurotransmitters, and the blockade of adenosine by caffeine increases the synthesis and turnover of these neurotransmitters. Caffeine increases the release of

noradrenaline,^[18] and it has been shown,^[19] that caffeine counteracts the effects of clonidine, which pre-synaptically binds to auto-receptors that reduce the turnover of central noradrenaline and leads to a low arousal state resembling sleep deprivation. The present study examined ratings of alertness ratings alone, whereas the majority of our research^[20-30] has included alertness rating in a battery of performance tasks. Performing these tasks increases fatigue, and measuring alertness at the end of the performance battery is very sensitive to the effects of caffeine.^[31,32]

It has been argued that caffeine has no direct effects on behaviour but that it only removes the negative effects of caffeine withdrawal.^[33] Research contradicts this view,^[4,10] and caffeine influences the behaviour of non-consumers and animals.^[34,35] who are not experiencing withdrawal. Effects of caffeine have also been found after prior consumption when the person is no longer deprived.^[36] Similarly, caffeine produces behavioural effects after a seven-day washout period,^[31] when negative effects of withdrawal are no longer present. Research on the effects of caffeine on drink acceptability provides evidence for the caffeine withdrawal hypothesis.^[37-43] These studies also included ratings of alertness without cognitive testing, and it was found that caffeine only increased alertness by removing the negative effects of caffeine withdrawal. The present study examined the effects of caffeine in non-consumers and withdrawn high and low caffeine consumers. It should also be noted that the present study is examining ratings of alertness with no accompanying performance tasks. This is quite rare but is important in terms of alertness. Performing a battery of tasks will reduce alertness, and this is why post-performance alertness is a sensitive indicator of the effects of caffeine.

Research often uses coffee as a vehicle for caffeine. Coffee contains many different ingredients,^[44] some of which might lead to behavioural effects. Possible effects of these other ingredients was ruled out by giving the caffeine in fruit juice and fruit tea. Pre-experimental acceptability ratings ensured that the volunteers consumed drinks of mid-range acceptability.

In summary, the study reported here describes the second phase of a project that examined the effects of caffeine in fruit juice and fruit tea on subjective alertness in the late morning. The study examined the effects of caffeine withdrawal by comparing non-consumers and withdrawn consumers. The reliability of the effects of caffeine was investigated by testing over five days. The dose of caffeine was also manipulated, with one group having the placebo

in both drinks, another 100 mg at 9.00 and placebo at 11.00, another placebo at 09.00 and 100mg at 11.00, and the last group having caffeine at both 9.00 and 11.00.

MATERIALS AND METHODS

The present study was approved by the ethics committee, School of Psychology, Cardiff University, and carried out with the informed consent of the participants.

Participants

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

Design

The level of caffeine consumption was a between-subject factor. The dose of caffeine was the second between-subject factor: one group had the placebo at both 09.00 and 11.00, another 100 mg caffeine at 9.00, another 100mg caffeine at 11.00, and the last group had 100mg caffeine at both 9.00 and 11.00. The caffeine manipulation was double-blind. The repeated measure variable was days, with participants following the same procedure for five consecutive days.

Fruit juice

The caffeine (100mg of caffeine in solution) and placebo (water) were added to fruit juices at 09.00. The fruit juices used were mango and apple, orange, apple and passion fruit, and cranberry and raspberry.

Fruit Tea

The caffeine (100mg of caffeine in solution) and placebo (water) were added to fruit teas at 11.00. The fruit teas were lemon and ginger, camomile and spiced apple, and strawberry and raspberry swirl. These were prepared by infusing for 3 minutes in boiling water and then serving at a temperature of 60-65 degrees C.

Procedure

Choice of fruit juice and fruit tea: Each volunteer attended a session before the test week, which familiarised them with the procedure and involved the selection of test drinks. The participants were asked to rate the three fruit juices and teas for pleasantness. The middle choice was then used as the test drink.

Test days 1-5

Visit 1 (09:00): Participants abstained from caffeine overnight, and at 09.00 saliva samples were taken to assess compliance. Alertness was then rated using visual analogue scales.^[3] The fruit juice containing either 100mg of caffeine or the placebo was then consumed.

Visit 2 (11:00): The volunteers were given the fruit tea with either 100 mg caffeine or the placebo.

Visit 3 (13.00): The post-drinks alertness ratings were then made.

RESULTS

The alertness scores from visit 3 were converted to percentage change from baseline. Numerically, the caffeine conditions were associated with a greater increase in alertness than the placebo condition (placebo mean = 18.9%; caffeine mean = 26.1%). Those given caffeine at 09.00 showed a greater increase (mean = 32.2%) than those given it at 11.00 (mean = 22.7%) or both times (mean = 23.5%). A repeated-measures analysis of variance was carried out with the alertness data. Consumer group and amount of caffeine were the between-subject factors. Days were the repeated-measures. The results of the analysis showed:

- No significant effects of caffeine condition ($F < 1$).
- No significant caffeine x consumer group interaction ($F < 1$).
- No significant interactions between caffeine and days ($F_{12, 328} = 1.65$ $p > 0.05$).

The mean ratings for the different conditions (averaged across days) are shown in Table 1.

Table 1: Ratings of alertness at 13.00: Percentage change from baseline (0.900) [scores are the means, s.e.s in parentheses; higher scores = greater alertness change}

Non-consumers	Placebo both drinks	9.1 (16.3)
	Caffeine drink 1	40.0 (14.9)
	Caffeine drink 2	29.3 (16.3)
	Caffeine both drinks	27.1 (14.9)
Low consumers	Placebo both drinks	14.9 (9.7)
	Caffeine drink 1	25.2 (12.1)
	Caffeine drink 2	23.3 (13.8)
	Caffeine both drinks	25.1 (12.1)
High consumers	Placebo both drinks	32.9 (13.8)
	Caffeine drink 1	31.5 (12.1)
	Caffeine drink 2	15.6 (12.1)
	Caffeine both drinks	18.4 (12.9)

DISCUSSION

This study has demonstrated that there are no significant effects of prior caffeine consumption on ratings of alertness at a time when alertness is at its peak. This effect did not vary with consumer status, amount of caffeine or days of the week. The present study shows very different results to ratings of alertness given after consumption in the early morning when alertness is much lower. The results support the view that caffeine restores function when below optimum but does not increase peak levels.

One must now ask whether the absence of an effect of caffeine when alertness is high is specific to ratings of alertness. Some performance tasks, such as simple reaction time, only show a benefit from caffeine when alertness is low. These effects may reflect noradrenergic functioning.^[32] Other tasks show effects of caffeine in alert volunteers and may be due to faster encoding of new information due to changes in the cholinergic system.^[45,46]

CONCLUSION

There is a large literature showing that caffeine increases alertness. Most of these studies have measured subjective alertness in the context of a battery of cognitive tasks, the performance of which can induce fatigue. Previous research shows that the clearest effects of caffeine on ratings of alertness can be observed when the ratings are carried out after the task battery. A recent study showed that another low alertness context, namely the early morning, led to caffeine increasing alertness when there were no other tasks carried out. The present analyses showed that there was no significant effect of caffeine when alertness was at its peak. These effects were reliable over a five day test period and were observed in both regular consumers of caffeine and non-consumers.

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