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CAFFEINE AND LONG HOURS OF WORK: EFFECTS ON ALERTNESS AND SIMPLE REACTION TIME

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ABSTRACT

Background: The effects of caffeine on cognition and alertness are well-documented. One established effect of caffeine is that it restores function when the person has a low level of alertness. This topic was examined here, with alertness being reduced by prolonged work. The effects of caffeine were assessed by two measures known to be sensitive to fatigue, namely subjective alertness and simple reaction time. The study also examined whether effects could be attributed to the reversal of caffeine withdrawal and whether decaffeinated coffee also had beneficial effects. **Methods:** Each participant carried out three twelve-hour sessions (from 9.00 to 21.00). The first eight hours were constant and involved four test batteries and consumption of water at the breaks. On one of the days, participants were given caffeinated coffee (3mg/kg) after eight hours, followed by another test battery, another dose of caffeine at ten hours, followed by the final test session. On the other days, volunteers were given juice or decaffeinated coffee. Twenty-four students (12 male) took part in the study. **Results:** The results showed that caffeine was associated with higher alertness scores and faster simple reaction times. The effects of caffeine increased from the first dose to the second. There were no differences between the decaffeinated coffee and the juice conditions. **Conclusion:** These results demonstrate that caffeine is beneficial in low arousal situations. The results could not be attributed to the reversal of caffeine withdrawal as effects were still observed following a prior dose of caffeine. Decaffeinated coffee had no significant effects. These results have important implications for real-life situations involving prolonged work and show that caffeine is an effective countermeasure to fatigue.

KEYWORDS: Caffeine; Long hours of work; Alertness; Simple Reaction Time.

INTRODUCTION

The effects of caffeine on human behaviour are well-documented.[1-7] Most of the research has been conducted in the laboratory, and the findings can be briefly summarised as follows. Overall, the behavioural effects of caffeine appear to be largely positive except when one considers very large doses and sensitive individuals (e.g. children – James et al., 2011.[8] Temple, 2009).[9] Glade (2010)[2] concludes that moderate amounts of caffeine lead to the following benefits: increased alertness, wakefulness and feelings of energy; decreased mental fatigue; faster and more accurate reactions; enhanced motor performance; enhanced cognitive performance; increased ability to concentrate and focus attention; enhanced short term memory; and increased ability to solve problems requiring reasoning. Beneficial effects of caffeine are often most easily observed when alertness is already reduced (e.g., when working at night,[10] when sleep-deprived,[11] after lunch,[12] and when the person has a cold).[13] The present study continued this line of research by examining the effects of caffeine on fatigue due to long hours of work. Subjective alertness and the variable fore-period simple reaction time task have been shown to be sensitive indicators in studies examining effects of caffeine in low arousal states,[14] and they were the outcome measures in the present study.

One must now consider the mechanisms that could underlie the effects of caffeine in low arousal states. The most plausible mechanism of caffeine, at doses reflecting typical usage, is the blockade of adenosine receptors.[15] Adenosine generally inhibits physiological activity, and the blockade of adenosine receptors by caffeine leads to its stimulant effects[16] Research has also examined the effects of caffeine on neurotransmitters which could reflect adenosine inhibiting the release of various neurotransmitters through their presynaptic receptors. One might expect therefore, that adenosine antagonists, such as caffeine, would increase the release of neurotransmitters. Research has shown that caffeine increases the rates of synthesis and turnover of noradrenaline.[17] Smith et al.[18] have shown that caffeine counteracts the effects of clonidine, which at low doses leads to a state resembling sleep deprivation and acts pre-synaptically binding to autoreceptors that reduce the turnover of central noradrenaline.

As well as laboratory research, there have been studies that examined real-life performance in various settings. Lieberman et al.[19] reviewed the effects of caffeine in sustained military operations and concluded that “When cognitive performance is critical and must be

maintained during exposure to severe stress, administration of caffeine may provide a significant advantage". Smith[20] investigated habitual caffeine consumption and performance and safety at work. Higher consumers of caffeine (> 220mg/day) reported greater alertness and a smaller slowing of reaction time over the working day. Associations between caffeine consumption, cognitive failures (problems of memory, attention and action) and accidents at work were also investigated. Higher caffeine consumption was associated with less frequent cognitive failures, and also a lower risk for accidents at work. Other research[21] has examined the effects of caffeine on performance decrements associated with shift work. The authors concluded that "Based on the current evidence, there is no reason for healthy individuals who already use caffeine within recommended levels to improve their alertness to stop doing so."

Similar results have been obtained in analyses of human error and accidents in non-working adults.[22] Research has also shown that caffeine can improve driving performance. This has been demonstrated in studies using driving simulators and has also been found in epidemiological studies.[23]

It has been suggested that there are no direct benefits of caffeine on behaviour, but that caffeine withdrawal leads to impairments and ingestion of caffeine simply removes these negative effects of withdrawal.[24] However, this theory is unlikely to be correct[4,5] as caffeine influences the behaviour of animals and non-consumers[25] who are not experiencing withdrawal. The behavioural changes after caffeine have been observed after a seven-day washout period[14] when effects of withdrawal should have diminished. Behavioral effects of caffeine have also been observed after prior consumption (i.e., when the person is no longer deprived).[26] The present study examined the effects of caffeine in withdrawn volunteers and after a prior dose of caffeine. If the reversal of withdrawal explanation is correct, there should be no effects of the second dose of caffeine.

Many studies have used coffee as the vehicle for the caffeine. As well as caffeine, coffee contains many different compounds such as phenolics, diterpenes and melanoidins,[27] which have the potential to alter behavior. Indeed, a recent study[28] suggested that decaffeinated coffee produced more behavioural changes than a coffee flavoured water placebo. This issue was examined here by comparing caffeinated coffee with both decaffeinated coffee and fruit juice.

In summary, the present study examined the effects of caffeine in coffee on the alertness and simple reaction time of individuals fatigue by long work. Use of repeated doses of caffeine enabled one to determine whether the effects of caffeine reflected the removal of negative effects of withdrawal. Use of decaffeinated coffee and fruit juice comparison groups allowed the identification of other possible effects of coffee which were independent of caffeine.

MATERIALS AND METHODS

The studies described here were carried out with the approval of the ethics committee, School of Psychology, Cardiff University, and carried out with the informed consent of the volunteers.

Design- Each participant carried out three twelve-hour sessions (from 09.00- 21.00), with at least one rest day between each. Each session involved carrying out batteries of cognitive tasks every two hours for the first eight hours. During the first eight hours, participants were given water at the breaks. On one of the days, participants were given caffeinated coffee at the end of the fourth test session (after 8 hours), and they completed the fifth test session one hour after consuming the caffeinated coffee. Caffeinated coffee was given after the fifth test session (after 10 hours), and a final sixth test session completed one hour later. The other days followed a similar procedure, and on one day, they were given decaffeinated coffee, and on the other fruit juice. The order of the different drinks was counterbalanced across participants. Participants were given a sandwich-based lunch at 13.00, and a similar meal at 17.00

Caffeine- In the caffeine condition, 3 mg/kg body weight of caffeine tablets were added to the decaffeinated coffee. The caffeine manipulation was double-blind, although both experimenters and participants knew when fruit juice rather than coffee was given.

Participants- Twenty-four students (12 male, 12 female; age range 18-24 years) took part in the study. They were paid for participation. They were all regular caffeine consumers (mean daily consumption = 220 mg).

Exclusion criteria- Any current physical or mental illness; unable or unwilling to consume caffeinated coffee or fruit juice; unable to complete battery of tests; unwilling to consent following provision of information about the study.

Familiarisation with procedures- Prior to both studies, the volunteers were familiarised with the tasks and procedures.

Procedure– Participants carried out the performance batteries at 10.00, 12.00, 14.00, 16.00, 18.00, and 20.00. Each session lasted for approximately one hour. In between sessions, volunteers stayed in the laboratory and were allowed to read or use their laptops.

Performance battery– The following tasks were carried out in order to induce fatigue in the participants**:**

a. Five-choice serial response task[29] – 10 minutes duration
b. Focused attention choice reaction time task[29] – 10 minutes duration
c. Categoric search task[29] – 10 minutes duration
d. Verbal reasoning task[29] – 10 minutes duration
e. Semantic processing task[29] – 10 minutes duration

Primary outcome measures – The primary outcome measures were subjective alertness and speed of simple reaction time both measured after the fifth and sixth performance battery.

a. Variable fore-period simple reaction time task[29] In this task a box was displayed in the centre of the screen and at varying intervals (from 1-8 seconds) a target square appeared in the box. As soon as they detected the square, participants were required to press a response key using the forefinger of their dominant hand only. Reaction times were measured to the nearest millisecond using a timer card. This task lasted for 10 minutes. The measure of interest here was mean reaction time (test-re-test reliability = 0.65).

b. Subjective alertness:[29] This was assessed using bi-polar visual analogue scales (e.g. Drowsy-Alert; Lethargic-Energetic; Attentive-Dreamy, and Incompetent-Proficient). Some scales were reversed scored so that high scores reflected higher alertness. The mean score was used in the analyses.

RESULTS

Separate analyses of variance (ANOVA) were carried out on the alertness and simple reaction time scores. The between-subject factor was the order of drink conditions. The within-subject factors were drinks and sessions (5 and 6). T-tests were then carried out to examine specific comparisons between the drink conditions. The descriptive statistics for the alertness ratings are shown in Table 1. The ANOVA showed a significant effect of drink

conditions (F (2,42) = 7.08 p < 0.005). There was no significant interaction between drinks and session. After session 5, the caffeine condition had higher alertness ratings than the decaffeinated coffee (t = 4.8 p < 0.001; effect size: large, d =0.98) and juice conditions (t= 5.3 p < 0.001; effect size: large, d = 1.09). There was no significant difference between the caffeine and juice conditions. Similarly, after session 6 the caffeinated condition had higher alertness ratings than the decaffeinated coffee (t = 5.2 p < 0.001; effect size: large, d = 1.07), and the juice condition (t=5.1 p < 0.001; effect size = large, d =1.04). There was no significant difference between the caffeine and juice conditions. The alertness rating in the caffeine condition after session 6 was significantly higher than that in the caffeine condition after session 5 (t = 2.1 p < 0.05; effect size = medium, d =0.42).

Table 1: Mean alertness ratings for the drinks conditions after sessions 5 and 6 (high ratings = greater alertness; s.e.s in parentheses).

After session 5	
Caffeine	30.7 (2.1)
Decaffeinated	21.8 (1.9)
Juice	20.8 (1.7)
After session 6	
Caffeine	34.5 (2.1)
Decaffeinated	23.5 (2.0))
Juice	23.8 (2.3)

The descriptive statistics for the simple reaction time task are shown in table 2. The ANOVA showed a significant effect of drinks (F (2,42) = 6.11 p < 0.005) but no interaction between drinks and session. After session 5 the mean reaction time in the caffeine condition was significantly shorter than in the decaffeinated coffee condition (t = 2.9 p < 0.01; effect size = medium, d = 0.6) and the juice condition (t = 2.8 p = 0.01; effect size = medium, d = 0.56). The decaffeinated coffee and juice conditions were not significantly different. Similarly, after session 6 the mean reaction time in the caffeine condition was significantly shorter than in the decaffeinated coffee condition (t = 6.8 p < 0.001; effect size = large, d = 1.39) and the juice condition (t = 4.6 p = 0.001; effect size = large, d = 0.94). The decaffeinated coffee and juice conditions were not significantly different. The reaction time for the caffeine condition after session 6 was significantly faster than the caffeine condition after session 5 (t = 3.9 p < 0.001; effect size = large, d = 0.8).

Table 2: Mean simple reaction time (msec) in the different drink conditions after session 5 and session 6 (high scores = worse performance; s.e.s in parentheses).

After session 5	
Caffeinated	430 (10)
Decaffeinated	463 (12)
Juice	461 (11)
After session 6	
Caffeinated	389 (8)
Decaffeinated	460 (12)
Juice	437 (11)

DISCUSSION

The results from the present study show that drinking caffeinated coffee reduced the effects of prolonged work. This finding supports other research which shows that caffeine reduces the negative effects seen in low alertness situations. Indeed, many laboratory studies of caffeine have used long test batteries which fatigue the participant, and the present study was a more extreme form of this. There are plausible CNS mechanisms underlying these effects of caffeine, such as increased turnover of central noradrenaline. The results also have implications for real-life activities. Twelve-hour shifts are becoming more common in the workplace, as is overtime. Consumption of caffeine may reduce the problems associated with these long working hours.

A second aim of the study was to demonstrate that there are sensitive tasks that can detect the effects of caffeine in low alertness situations, namely ratings of alertness after the task battery and the variable fore-period simple reaction time tasks. These are different from the tasks which are sensitive to the effects of caffeine when the person is alert, [30] where the underlying CNS mechanisms may be different. When caffeine is given to alert individuals, the major effect is to increase the speed of encoding of new information,[30, 31] which may be due to changes in the cholinergic system.[32]

Another aim of the study was to determine whether the benefits of caffeine reflected the removal of the negative effects of withdrawal. Repeated doses of caffeine were given, and the second dose led to higher alertness and faster reaction time than the first dose. This suggests that the present results are not due to the reversal of the effects of caffeine withdrawal.

The final aim of the study was to examine whether consumption of decaffeinated coffee led to greater alertness and faster reaction time than the consumption of fruit juice. No

differences between these conditions were observed, showing that the effects of the caffeinated coffee were due to the caffeine rather than another compound in the coffee.

CONCLUSION

A laboratory study of prolonged work showed that caffeine given after 8 and 10 hours led to higher alertness ratings and simple reaction time. Effects of caffeine were observed at both time points, which suggests that they were not due to the reversal of withdrawal. Decaffeinated coffee did not produce different effects to fruit juice, which suggests that the effects of the caffeinated coffee were due to the caffeine and not to other constituents. Overall, the results show that ratings of alertness after performing the task battery and simple reaction time are sensitive to the effects of caffeine seen after prolonged work. Caffeine is known to produce CNS effects that plausibly underlie the effects observed here. Long work is also a major real-life problem, and caffeine is a short-term countermeasure to reduce the negative effects seen in longer shifts and in working overtime.

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