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EXPECTATION OF HAVING CONSUMED CAFFEINE CAN IMPROVE PERFORMANCE AND MOOD

Lynne Dawkins, Fatima-Zahra Shahzad, Suada S. Ahmed, Caroline J. Edmonds

School of Psychology

University of East London

Stratford Campus

Water Lane

Stratford

LONDON E15 4NO

Corresponding author: Lynne Dawkins

E-mail: l.e.dawkins@uel.ac.uk

Tel: +44 (0)20 8223 4421

Fax: +44 (0)20 223 4937

Abstract

We explored whether caffeine, and expectation of having consumed caffeine, affects attention, reward responsivity and mood using double-blinded methodology. 88 participants were randomly allocated to 'drink-type' (caffeinated/decaffeinated coffee) and 'expectancy' (told caffeinated/told decaffeinated coffee) manipulations. Both caffeine and expectation of having consumed caffeine improved attention and psychomotor speed. Expectation enhanced self-reported vigour and reward responsivity, the latter restricted to those who received decaffeinated coffee. Self-reported depression increased at post-drink for all participants, but less in those receiving or expecting caffeine. These results suggest caffeine expectation can affect mood and performance but do not support a synergistic effect.

Keywords: caffeine, expectancy, placebo, performance, mood, attention, reward-responsivity

Introduction

Caffeine, an adenosine receptor antagonist, is widely consumed throughout the world in beverages such as coffee, tea and energy drinks. It has mild psychomotor stimulant properties via its blockade of adenosine's inhibitory mechanisms. Caffeine consumption has been associated with self-reported increases in: wakefulness, alertness, ability to concentrate and energy (e.g. Peeling & Dawson, 2007). Placebo-controlled trials using objective measures can corroborate these reports; consumption of caffeine can produce significant improvements in: reaction time, short-term memory, vigilance, reasoning, response accuracy, attention, and general alertness (see Glade, 2010)

Paralleling its effects on cognition, caffeine consumption is also accompanied by improved mood including increased 'happiness' (Amendola, Gabrieli & Lieberman, 1998), a reduction in depressive symptoms (Childs & de Wit, 2008), and decreased anxiety (Quinlan, Lane & Aspinall, 1997), although there are conflicting results with respect to anxiety (Broderick & Benjamin, 2004).

That coffee produces stimulant effects is the prevailing societal view; such expectations about its effects on performance and mood are likely to impact on the magnitude of its effect – the well known placebo effect. Indeed, expectancy concerning the effects of an ingested substance have been repeatedly demonstrated to exert an influence on behaviour in the alcohol (Leigh & Stacy, 1991) and nicotine literature (Kelemen, 2008). Expectations about the effects of caffeine have also been shown to affect performance in studies in which participants have been led to believe that a decaffeinated coffee contained caffeine and given contrasting information about expected effects (Fillmore & Vogel-Sprott, 1992; Lotshaw, Bradley & Brooks, 1996).

However, two double-blind studies which manipulated expectancy through accurate, deceptive or ambiguous information, failed to replicate caffeine expectancy effects for physiological, psychological and cognitive variables (Walach, Schmidt, Bihr & Wiesch, 2001; Walach, Schmidt, Dirhold & Nosch, 2002). Other studies partially support caffeine expectancy effects; for instance,

Schneider et al., (2006) reported an expectancy effect for subjective alertness, but not for well-being or reaction time. Oei and Hartley (2005) took a slightly different approach and compared *pre-existing beliefs* about caffeine's effects as well as manipulating the message concerning whether caffeine had been consumed using the balanced placebo design. Those who had pre-existing beliefs that caffeine would stimulate them showed better signal detection performance under caffeine, but there was no overall effect of message, and no effects of pre-existing beliefs or message on reaction time or delayed recall. Elliman, Ash and Green (2010), again using the balanced placebo design found an effect of expectancy (told caffeine) on sustained attention, but only when caffeine had actually been consumed (there was no effect of caffeine expectancy when decaffeinated coffee had been consumed) and no effect of expectancy on mood. Overall then, caffeine has well-documented psychomotor stimulant effects and there is evidence, at least in some individuals on some aspects of performance, that expectations about the caffeine's effects can also impact on mood and performance.

In addition to its arousing effects, evidence indicates that caffeine interacts with neural systems involved in motivation and reward by antagonising the effect of adenosine on the mesocorticolimbic dopamine system (Ferré, 2010; Salamone et al., 2009; although see Nehlig, Armspach & Namer, 2010). The effect of caffeine on reward motivation in humans has received very little attention, but the Card Arranging Reward Responsivity Objective Test (CARROT; Al-Adawi & Powell, 1997) has recently been used to explore this. The CARROT measures the extent to which participants' psychomotor performance is enhanced by financial incentive. Participants sort cards across four trials according to a simple rule. The average speed of card sorting across two non-rewarded trials is subtracted from card sorting speed on a rewarded trial (10p for every five cards sorted up to a maximum of £2) to provide an index of reward responsivity. Using this task, McFie (2005; doctoral thesis) found an enhancing effect of caffeine on reward responsivity in abstinent smokers. Augmented reward responsivity has also been reported with nicotine (Dawkins, Powell,

West, Powell & Pickering, 2006) and alcohol (Kambouropoulos & Staiger, 2001). Nevertheless, the extent to which expectations about effects of ingested substances impact on reward motivation has not been explored. The present study therefore aims to further elucidate the effects of caffeine and expectancy on subjective mood and attention/speed of processing using the balanced placebo design. It also aims to examine, for the first time in a double-blinded study, the effects of caffeine and expectancy on reward responsivity.

Method

Overview

Participants were randomly allocated to either caffeine or placebo condition and then completed two experimental tasks and a mood scale. Within these conditions, participants were either accurately informed or misinformed as to the caffeine content of the drink. Thus there were four between-participants conditions: given caffeine/told caffeine [GC/TC]; given caffeine/told decaff [GC/TD]; given decaff/told caffeine [GD/TC]; given decaff/told decaff [GD/TD].

Participants

88 non-smoking participants (44 female) aged 18 to 47 years (mean: 26) were undergraduate students and habitual coffee drinkers (consumed two or more cups of coffee per day for at least 6 months). Participants responded to posters advertising a study about 'the effects of caffeine on mood and cognitive performance.' They were asked to abstain from consuming caffeinated beverages for 2 hours prior to testing (not confirmed) in order to maintain consistency at baseline but to ensure that they were not in an obvious state of withdrawal. The study was granted ethical approval from UEL's School of Psychology ethics committee.

Procedure

Within this double-blinded, between-subjects design, participants were randomly allocated to both a drink (caffeinated coffee vs. decaffeinated coffee) and an expectancy (told caffeine vs. told decaffeinated) condition. Groups were matched for gender (11 females and 11 males in each group) and age (group means: GC/TC 26.45 [7.73]; GC/TD 24.95 [6.40]; GD/TC 26.14 [6.83]; GD/TD 25.82 [6.92]).

Expectancy was manipulated by telling participants at the start of the session (either accurately or falsely) that they would receive an 'ordinary cup of caffeinated coffee' or an 'ordinary cup of decaffeinated coffee' (according to group allocation). After providing written informed consent, participants completed the short form of the Profile of Mood States including the four most relevant subtests (fatigue-inertia, depression-dejection, tension-anxiety, vigour-activity; POMS; MacNair, Lorr & Droppleman, 1971) before being presented with the drink in a disposable foam cup. Participants were given 5 minutes to drink it and 55 minutes to wait (during which time they sat quietly and read) before commencement of testing.

Drinks were prepared by a research assistant in an adjacent room. One heaped teaspoon (approx. 2g) of either caffeinated (Maxwell House; approx. 75mg caffeine) or decaffeinated (Fair Trade Classic Coffee) coffee was used, with 250ml of warm water and 28ml milk (2 x 14ml of UHT semi-skimmed milk pots), no sugar added. This dose (75mg caffeine) was chosen to reflect what participants would ordinarily consume in a cup of coffee in their everyday lives.

Participants then completed the following measures in fixed order: the standard computerised Stroop task with 40 congruent stimulus presentations (printed colour and

written word the same) and 40 incongruent stimulus presentations (printed colour and written word differ); the Card Arranging Reward Responsiveness Objective Test (CARROT, described in detail in Al-Adawi & Powell, 1997); and the POMS (short-form, as above).

Finally, participants were debriefed and if they had been misinformed, were told which drink they had actually been given. No participants suspected that they had been misinformed.

Results

All variables were analysed using ANOVA with two between-subjects factors: DRINKTYPE (caffeinated vs. decaffeinated coffee) and EXPECTANCY (told caffeine vs. told decaff). Within-subject factors differed according to variable as outlined below.

Stroop Task

CONGRUENCY (congruent vs. incongruent) was a within-subjects variable in ANOVA for both Stroop accuracy (number correct) and reaction time (RT). As can be seen from Figure 1, in the case of accuracy, there was a significant main effect of CONGRUENCY ($F(1,84) = 30.04$, $p < 0.0001$) reflecting greater accuracy in the congruent condition. There were also highly significant main effects of DRINKTYPE ($F(1,84) = 9.63$, $p < 0.005$) reflecting better performance in the caffeine group, and EXPECTANCY ($F(1,84) = 48.57$, $p < 0.0001$), with superior performance in the told caffeine (TC) condition. The CONGRUENCY X DRINKTYPE interaction was also statistically significant ($F(1,84) = 5.09$, $p < 0.05$). This interaction should be interpreted in light of the significant main effect of trial type. Paired t-tests examining the

congruent minus incongruent difference score (interference score) showed that the interference score was lower in the caffeine group; i.e. caffeine had a larger impact on incongruent accuracy; t (86) = 2.27, $p < 0.05$). The DRINKTYPE X EXPECTANCY interaction did not reach statistical significance ($F (1,84) = 2.95$, $p = 0.09$) and all other interactions were non-significant ($F (1,84) < 1$, ns in each case).

For Stroop RT, performance was faster in the congruent condition (main effect of CONGRUENCY: $F (1,84) = 19.88$, $p < 0.0001$), and when caffeine was expected (main effect of EXPECTANCY $F (1,84) = 67.67$, $p < 0.0001$). Group means (not presented) showed a similar pattern to those for accuracy but the faster performance with caffeine did not reach statistical significance (main effect of DRINKTYPE: $F (1,84) = 1.86$, $p = 0.18$). All interactions were non-significant ($F (1,84) < 1$, ns).

- FIGURE 1 HERE -

Card Arranging Reward Responsivity Objective Test (CARROT)

Rate of card sorting (number of cards sorted per second) for the (averaged) non-rewarded trials versus the reward trial (TRIALTYPE) was a within-subjects variable in ANOVA . Card sorting was significantly faster: on the rewarded trial (TRIALTYPE: $F (1,84) = 207.32$, $p < 0.0001$); when caffeine had been consumed (DRINKTYPE: $F (1,84) = 24.70$, $p < 0.0001$); and when caffeine was expected (EXPECTANCY: $F (1,84) = 100.25$, $p < 0.0001$; see Figure 2). The main effect of TRIALTYPE was qualified by an interaction with EXPECTANCY ($F (1,84) = 7.45$,

p < 0.01), but not with DRINKTYPE (F (1,84) < 1, ns).

Breakdown of the TRIALTYPE X EXPECTANCY interaction using an independent samples t-test on the derived reward responsivity index (mean card sorting speed on non-rewarded trials subtracted from mean card sorting speed on reward trial) confirmed that reward responsivity was significantly higher in the TC than TD condition (t (86) = -2.70, p < 0.01)

There was also a marginally significant 3-way TRIALTYPE X EXPECTANCY X DRINKTYPE interaction (F (1,84)= 3.76, p = 0.056). To unpack this, a one-way ANOVA on the derived reward responsivity index across the four groups was conducted, with post-hoc t-tests to follow this up. An overall significant effect of group (F (3,84) = 3.84, p = 0.01) was driven by higher reward responsivity in those expecting caffeine than those expecting decaff in the given decaff (GD) (p = 0.001) but not in the given caffeine (GC) (ns) condition.

- FIGURE 2 HERE -

Profile of Mood States (POMS)

The POMS was administered before and after drink consumption, thus TIME (pre- vs post-drink) was a within-subjects variable in ANOVA.

The four sub-scales were analysed separately (see Table 1). For fatigue-inertia, participants reported higher fatigue post-drink, (main effect of TIME: F (1,84) = 204.4, p < 0.001), and a higher score if they were told decaffeinated coffee (trend for EXPECTANCY: F (1,84) = 3.9, p = 0.052).

In the case of depression-dejection, all pre-drink scores were 0, and there was a significant effect of TIME ($F(1,84) = 229.75$, $p < 0.001$). Participants were more depressed if they received decaffeinated versus caffeinated coffee, (main effect of DRINKTYPE: $F(1,84) = 4.86$, $p < 0.05$), and there was an EXPECTANCY effect with greater self-reported depression in the TD group ($F(1,84) = 115.52$, $p < 0.001$). The TIME X DRINKTYPE ($F(1,84) = 4.86$, $p < 0.03$) and TIME X EXPECTANCY ($F(1,84) = 115.52$, $p < 0.001$) interactions were also significant, but these should be considered in the light of the scores at 0 at pre-test.

For tension-anxiety, participants were less anxious at pre-test (main effect of TIME: $F(1,84) = 32.0$, $p < 0.001$), but there were no interactions with either DRINKTYPE or EXPECTANCY ($F(1,84) < 1$, ns in both cases). In the case of vigour-activity, participants reported greater vigour pre-drink (main effect of TIME: $F(1,84) = 5.76$, $p < 0.05$), and if they thought they were receiving caffeine (main effect of EXPECTANCY: $F(1,84) = 14.54$, $p < 0.001$). There was also a significant TIME X EXPECTANCY interaction ($F(1,84) = 14.54$. $p < 0.001$); whilst self-reported vigour did not change over time in the TC group ($t(43) < 1$, ns), the TD group rated themselves as less vigorous post-drink compared to pre-drink ($t(43) = 4.75$, $p < 0.0001$).

- Table 1 HERE -

Discussion

This study explored the effects of caffeine, and expectation of having consumed caffeine, on attention, reward responsivity and mood using a double-blinded design. On the Stroop task,

caffeine enhanced accuracy, particularly when there was mis-match between printed colour and semantic colour (incongruent trials), but did not influence RT. Expectation of having consumed caffeine by contrast, enhanced both overall accuracy and RT, regardless of the nature of the trial (congruent vs incongruent). These findings are in contrast to those reported by Schneider et al. (2006) and Oei and Hartley (2005) who both found no effect of caffeine expectancy (i.e. whether participants had been told that they had been given caffeine or placebo) on RT. Walach and colleagues (2001; 2002) have also reported a lack of expectancy effect using a double-blinded design. Older studies, however, have found improved performance with the belief that caffeine has been consumed (Fillmore & Vogel-Sprott, 1992; Lotshaw et al., 1996) although these have focused on psychomotor performance rather than attention/RT.

The exact relationship between caffeine consumption and expectancy is not simple; two recent studies, for example have found expectancy effects on sustained attention only when caffeine had actually been consumed (Oei & Hartley, 2005; Elliman et al., 2010) suggesting that caffeine and expectation work synergistically. The present findings did not support this view; we found performance enhancement by expectation of caffeine regardless of whether caffeinated or decaffeinated coffee had been consumed. Procedural differences might account for the discrepant findings; whereas participants in the Elliman et al. study were 12 hour abstinent, participants in the present study were only minimally (2 hours) deprived. Thus it is possible that synergistic effects of caffeine and expectancy might be restricted to caffeine withdrawal. Alternatively, it is possible that expectations about caffeine's effects might at least partly depend on a consumer's ability to detect physiological effects of caffeine which is less likely in the present study given the low dose used. Overall, the

findings from the Stroop task suggest that expectation of having consumed caffeine confers an enhancement on sustained attention that is at least comparable, and perhaps superior to, pharmacological effects of caffeine.

In parallel with previous reports of enhanced psychomotor performance with both caffeine (see Glade, 2010) and expectancy (Fillmore & Vogel-Sprott, 1992; Lotshaw et al., 1996), overall speed of card sorting on the CARROT was faster with both caffeine and expectation of having consumed caffeine. In relation to reward responsivity (increase in speed of card sorting with reward), no overall effect of caffeine was found, however expectation of having consumed caffeine was associated with augmented responsiveness to reward, particularly in those receiving decaffeinated coffee. The lack of a caffeine effect is in contrast to McFie (2005; doctoral thesis) who found augmented reward responsivity with 100mg of caffeine in abstinent smokers. It is possible that the slightly higher dose and/or nature of the participant sample in the McFie study favoured an enhancing effect of caffeine on responsiveness to reward. Indeed, smokers might possess sensitized dopaminergic reward systems (Robinson & Berridge, 2000) thus fostering greater potential for caffeine enhancement via a cross-priming effect of caffeine on the reward system. Nevertheless, whether caffeine, at this dose, can trigger dopamine release in the reward pathways is debateable (Hsu et al., 2009; Nehlig, Armspach & Namer, 2010).

Regardless of the pharmacological effects of caffeine, expectation of having received caffeine in this study promoted responsiveness to reward using the CARROT. This is an intriguing finding since coffee is not commonly perceived to enhance reward responsivity, although it may do so via associative learning mechanisms – for example, via its pairing with other rewarding activities such as taking a break, eating a biscuit and so on. However this

novel finding clearly requires replication.

In relation to mood state, caffeine had no effect on the fatigue-inertia, tension-anxiety or vigour-activity sub-scales of the POMS, indicating no self-reported stimulant or anxiogenic effect at this dose. There was, however, a significant caffeine effect on the depression-dejection subscale; whilst depression scores increased over the course of the testing session across the four groups, the magnitude of the increase was significantly lower in those receiving caffeine. This finding is consistent with previous studies suggesting that caffeine can alleviate depressed mood (Childs and de Wit, 2008). Consistent with other studies (Lotshaw et al., 1996; Schneider al al., 2006), expectancy effects were found for two of the four POMS sub-scales: depression-dejection and vigour-activity. Others, however, have found no consistent effects on self-reported mood (Elliman et al., 2010), which might reflect procedural differences. In particular, it is noteworthy that the present study is one of the first to use double-blinded methodology with pre-post assessment of mood state.

To conclude, the present study has found evidence of caffeine expectancy effects on a diverse range of indices: attention, reward responsivity, and mood. Unlike some other studies (Oei & Hartley, 2005; Elliman et al., 2010) these findings do not support a synergistic effect of caffeine and expectation; indeed, the effect of caffeine expectation on reward responsivity was greater in the decaffeinated condition. The present findings thus add to the growing body of evidence that highlights the importance of psychological variables over pharmacology.

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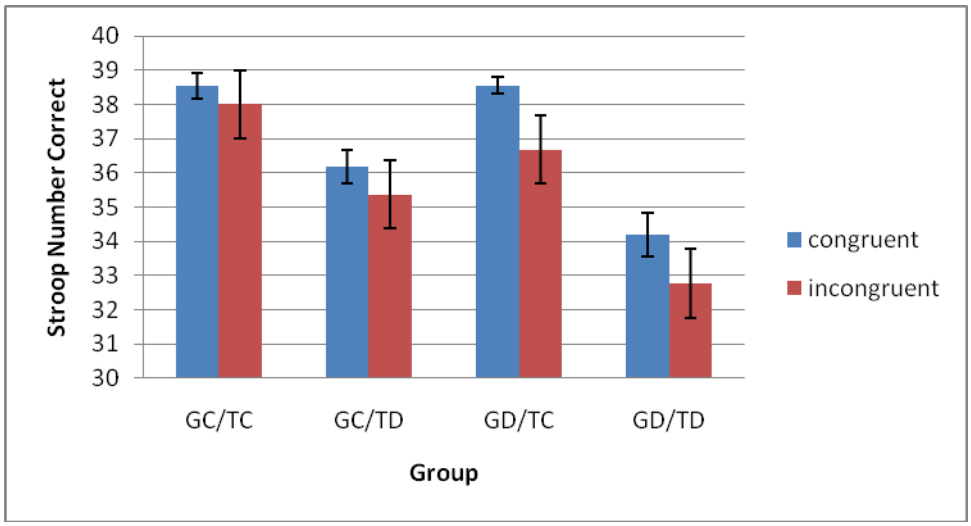
Table 1

	fatigue-inertia		depression-dejection		tension-anxiety		vigour-activity	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
GC/TC	0.41 (0.67)	3.59 (1.97)	0.0 (0.0)	0.14 (0.35)	3.77 (2.11)	2.05 (1.91)	5.32 (0.95)	5.23 (2.99)
GC/TD	0.45 (0.60)	4.14 (1.46)	0.0 (0.0)	2.0 (0.93)	1.09 (1.69)	2.18 (1.97)	5.59 (1.59)	3.73 (1.55)
GD/TC	0.55 (0.60)	3.18 (2.22)	0.0 (0.0)	0.59 (0.91)	3.91 (1.41)	1.27 (1.16)	5.27 (1.08)	6.05 (1.36)
GD/TD	0.50 (0.80)	4.05 (1.43)	0.0 (0.0)	2.27 (0.76)	3.86 (1.64)	2.09 (2.43)	5.55 (1.47)	4.41 (1.74)
Caffeine effect?	No		Yes		No		No	
Expectancy effect?	No		yes		No		Yes	

Figure 1


Stroop Number Correct
40
39
38
37
36
35
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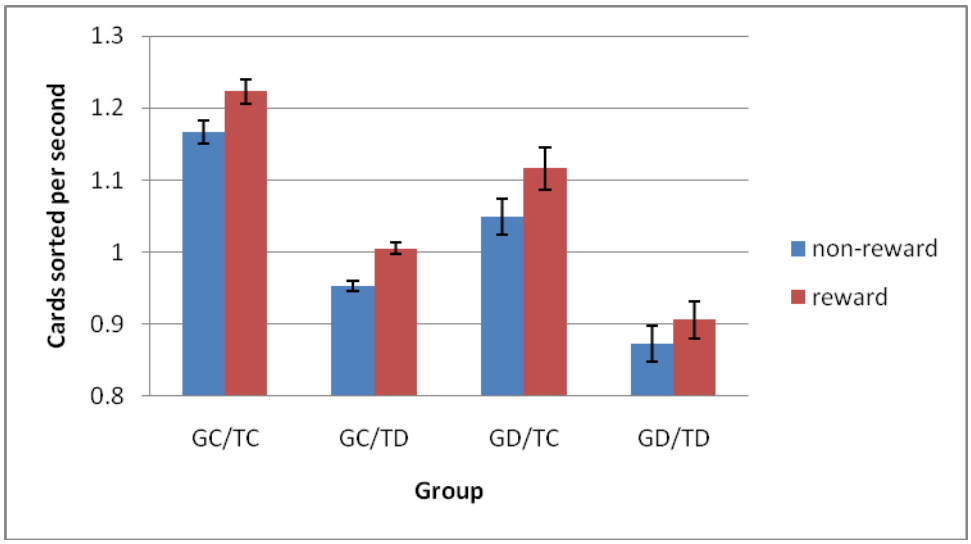
33
32
31
30
GC/TC
GC/TD
GD/TC
GD/TD
Group
congruent
incongruent

Figure 2


1.3
1.2
1.1
1
0.9
0.8
Cards sorted per second
GC/TC
GC/TD
GD/TC
GD/TD
Group
non-reward
reward

Legend for Table and Figures:

Table 1: Mean (SD) scores on Profile of Mood States subtests by caffeine and expectancy groups

Figure 1: Mean Stroop accuracy for congruent and incongruent words by caffeine and expectancy groups. Error bars are 1SE

Figure 2: Mean rate of card sorting on the CARROT for non-rewarded and rewarded trials for caffeine and expectancy groups. Error bars are 1SE