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ORIGINAL INVESTIGATION

Effects of caffeine and alcohol on mood and performance changes following consumption of lager

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Abstract

Rationale The present study examined whether caffeine would modify the behavioural effects of alcohol.

Objectives The aim of the study was to determine whether caffeine modifies the effects of alcohol on mood and psychomotor performance and to identify possible dose–response and temporal relationships.

Methods A double-blind study examined the effects of three successive lager drinks (330 ml each) in the early afternoon on mood and psychomotor performance assessed at 30-min intervals over a 2-h period. Participants carried out a baseline session and were then randomly assigned to one of six conditions formed by combining three different doses of caffeine (0, 62.5 and 125 mg per drink) with either no alcohol or 4.3 % alcohol. One hundred and forty-six young adults (65 male, 81 female; age range 18–30 years) participated in the study. Mood (alertness, hedonic tone and anxiety) was assessed before and after performing simple reaction time and choice reaction time tasks.

Results Alcohol was associated with higher hedonic tone ($p<0.005$), reduced anxiety ($p<0.05$) and reduced alertness ($p<0.005$). Caffeine had no modifying effect on hedonic tone or anxiety. However, the highest dose of caffeine did remove the effect of alcohol on alertness ($p<0.05$). Effects of alcohol and caffeine were found on the performance tasks (all p values<0.05) but these were independent effects.

Conclusions The results from the present study confirm that caffeine does not remove the negative effects of alcohol on performance although high doses counteract the drop in subjective alertness produced by alcohol.

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Introduction

Research on caffeine has demonstrated that it can remove impairments seen in low arousal states such as sleep deprivation (Bonnet et al. 2005) or when the person has a minor illness such as the common cold (Smith et al. 1997). This has led to other research which has addressed the question of whether caffeine can remove impairments produced by consuming alcohol. The evidence is equivocal as to whether caffeine reduces alcohol-induced impairments in blinded experimental design studies. Some studies have shown that caffeine removes the slowing of reaction time found after alcohol but does not improve accuracy (Burns and Moskowitz 1990; Fillmore and Vogel-Sprott 1995; Franks et al. 1975: Hasenfratz et al. 1993). Other studies have found that caffeine does not remove the alcohol-induced impairment in psychomotor tasks (Ferreira et al. 2006; Fillmore and Vogel-Sprott 1994; Fillmore et al. 2002; Liguori and Robinson 1991; Howland et al. 2011). There are other studies that suggest that caffeine partially but not totally removes alcohol-induced impairments (Alford et al. 2012; Attwood et al. 2012; Mackay et al. 2002), and other research suggests that caffeine antagonises alcohol's effects on response execution but not inhibitory control (Marczinski and Fillmore 2003).

Consumption of energy drinks with alcohol has grown exponentially in the last 10 years (Simon and Mosher 2007). Caffeinated alcoholic beverages are promoted as a way of enhancing enjoyment while reducing performance impairments (Simon and Mosher 2007). Guaraná is often added to alcohol and this combination was examined in the present study. It is important to obtain correct information about the behavioural effects of these beverages so that balanced dissemination can occur (Attwood 2012). One important feature of research on this topic must be the collection of both subjective reports and objective measures of performance. Perception of intoxication and objective measures of behavioural control are important tools that can readily lead to extrapolation to real-world situations (Attwood 2012).

There are relatively few studies of effects of alcohol in real-life drinking situations (exceptions being Curran and Travill 1997; Lyvers and Tobias-Webb 2010; Scholey et al. 2012; and Tiplady et al. 2009). The aim of the present study was to maintain the control obtained in double-blind laboratory studies but also to examine a realistic drinking situation. The present study monitored mood and performance during consumption of lager in the early afternoon. This is a time when the effects of alcohol are more pronounced than in the evening (Horne and Baumber 1991) which meant that only a relatively small amount of alcohol needed to be consumed in order to demonstrate impaired performance. In addition, by examining effects of three successive drinks, one can monitor temporal changes (speed of development of effects and the extent to which they are sustained or change over time) in the effects of alcohol, caffeine and their possible interaction. Most studies suggest that peak caffeine and alcohol levels occur 20–30 min after ingestion. However, there are studies suggesting that behavioural effects may occur more rapidly (e.g. Durlach 1998) and this was investigated here. Measures were selected that are known to be sensitive to effects of alcohol (Finnigan and Hammersley 1992) and caffeine (Smith 2011). The predictions were that alcohol would lead to an increase in positive affect that would also be associated with a reduction in alertness. It was predicted that caffeine would increase the speed of encoding of new information (Smith et al. 2013) and that this effect would show a dose response and be independent of alertness levels (Smith 2009). Caffeine generally increases alertness and improves simple reaction time in fatigued individuals, and the present study examined whether this occurred when alertness was likely to be reduced by alcohol. Smith et al. (2013) have argued that studies of effects of caffeine must have appropriate statistical power (e.g. an N of at least 24 in each arm of a separate groups design) and use a small number of sensitive tests in order to reduce the probability of chance results. This was achieved in the present study. Adoption of this approach also meant that robust effects of alcohol could be detected.

The source of caffeine in the present study was guaraná extract (*Paullinia cupana*). Research on the behavioural effects of guaraná (Kennedy et al. 2004; Haskell et al. 2007) has largely focused on doses which yield small amounts of caffeine (<50 mg) and suggests that effects do not solely reflect caffeine (see Scholey and Haskell 2008 for a review). As well as containing caffeine, guaraná also contains other xanthine alkaloids (e.g. theophylline and theobromine) and polyphenols (e.g. catechin and epicatechin) which could have direct behavioural effects or interact with alcohol. The present study used larger doses of caffeine than those used in previous studies of guarana, and it was of interest to see if the usual behavioural effects of caffeine were observed when it was in a very different vehicle and from a different source than that used in most caffeine research.

Methods

This study was carried out with the informed consent of the participants and was approved by the Ethics Committee, School of Psychology, Cardiff University.

Participants

One hundred forty-six volunteers (65 male, 81 female; age range 18–30 years) were recruited from the volunteer panel in the Centre for Occupational and Health Psychology at Cardiff University.

Exclusion criteria

Several exclusion criteria were applied for recruitment of participants in this study. Participants were not taking any medication that is affected by alcohol and were in good general health (i.e. not experienced an illness for a week prior to the familiarisation and test day). Volunteers were also required to be students aged between 18 and 30 years who were regular consumers of caffeine (daily) and alcohol (at least weekly).

Informed consent

All included participants were required to sign a consent form outlining the experiment, explaining that they were free to withdraw at any time and confirmed the anonymity of all information.

Payment

Participants were paid £15.00 on completion of the study.

Experimental beverages

The experimental drinks consisted of a 330-ml bottle of lager containing one of the following combinations of caffeine and/or alcohol, outlined below. Each experimental condition was coded A through F to allow double-blind administration of the drinks. All bottles were chilled in a refrigerator prior to consumption. Guaraná extract was used as the source of caffeine.

A. No caffeine/4.3 % alcohol
B. No caffeine/no alcohol
C. 62.5 mg caffeine/4.3 % alcohol
D. 62.5 mg caffeine/no alcohol
E. 125 mg caffeine/4.3 % alcohol
F. 125 mg caffeine/no alcohol

Experimental design

A between subjects design was used for the alcohol and caffeine conditions. The participants were randomly assigned to one of the six experimental conditions formed by combining alcohol conditions (0 or 4.3 %) and caffeine dose (0, 62.5 or 125 mg caffeine). The design also included approximately equal numbers of males and females in each drink condition. A baseline session was carried out prior to the drinks. Data from this session were used as covariates to adjust for unwanted individual differences. Volunteers then consumed three drinks with a repeat of the test session after each drink. In total, those in the alcohol condition ingested about 34 g of alcohol (4.25 units). Those in the caffeine conditions ingested a total of 187.5 or 375 mg caffeine. Over the course of the experiment, about 1 unit of alcohol and 30 mg caffeine may have been metabolised.

Schedule of testing

On recruitment, participants were required to read the information sheet outlining the study and sign the consent form. Prior to the test day, participants were familiarised with the experimental procedure and practised at the tasks. They also completed the following personality questionnaires: the Spielberger Trait Anxiety Scale (Spielbeger et al. 1970); the Eysenck Personality Inventory (Eysenck and Eysenck 1964); and the Obsessional Personality Questionnaire. Research has shown that these measures provide a good profile of personality (Smith et al. 1995). The main aim of administering the questionnaires was to determine whether participants in the different drinks conditions had similar personality profiles.

On the evenings prior to testing sessions, participants were required to limit their alcohol consumption to a maximum of four units and abstain from alcohol on the test days. Smoking and consumption of caffeinated products were prohibited 2 h prior to the test sessions. Participation in vigorous exercise was also prohibited on the test days. No direct measures of compliance were taken. In addition, all participants were required to be healthy for a minimum period of 1 week prior to the test session.

Table 1 Test day schedule

Time	Activity
12.00	Complete sleeping and eating questionnaire
12.15	Test session 1, Baseline (15 min)
12.30	Drink 1 (15 min to consume); Complete drink acceptability questionnaire 1
12.45	Test session 2 (15 min)
13.00	Drink 2 (15 min to consume); Complete drink acceptability questionnaire 2
13.15	Test session 3 (15 min)
13.30	Drink 3 (15 min to consume); Complete drink acceptability questionnaire 3
13.45	Test session 4 (15 min)
14.00	Payment

The study started at 1200 hours. On arrival at the testing facility, participants completed a sleeping and eating log recording sleep duration and quality, food consumption and intake of alcoholic drinks over the previous 24-h period. During the test session, participants were required to consume three 330-ml bottles of lager, one every 30 min. Participants were instructed to consume all of the contents of the bottle within 15 min of receiving it. Mood and performance were assessed prior to and after consumption of each drink. Ratings of acceptability and discrimination of caffeine and alcohol were also obtained post drink. The test session schedule is outlined below in Table 1.

Measures

Visual analogue mood scales

Mood was assessed both pre- and post-performance using 18 computerised visual analogue mood rating scales (Smith et al. 1999). Each of the 18 bipolar scales comprised of a pair of adjectives for instance, drowsy–alert or happy–sad. Participants were instructed to move the cursor from a central position anywhere along the horizontal rule, towards either extreme of the scale, until the cursor was at a position representative of their mood state at that exact time. These 18 scales were presented successively. Three main factors were derived from these scales; alertness, hedonic tone and anxiety.

Performance tasks

All of the performance tasks described below were completed at each test session.

Variable fore-period simple reaction time task

In this task (Smith et al. 1999), a box was displayed in the centre of the screen and at varying intervals (from 1 to 8 s) a target square would appear 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. This task lasted for 3 min. Mean reaction time was calculated from the total number of trials completed during the test.

Focused attention choice reaction time task

This choice reaction time task, developed by (Broadbent et al. 1986, 1989), measures various aspects of selective attention. In this task, target letters appeared as upper case A's and B's in the centre of the screen. Participants were required to respond as quickly and as accurately as possible to the target letter presented in the centre of the screen ignoring any distracters presented in the periphery. The correct response to A was to press a key with the forefinger of the left hand, while the correct response to B was to press a different key, with the forefinger of the right hand. Prior to each target presentation, three warning crosses were presented on the screen; the outside crosses were separated from the middle one by either 1.02° or 2.60°. The crosses were on the screen for 500 ms and were then replaced by the target letter. The central letter was either accompanied by (1) nothing, (2) asterisks, (3) letters which were the same as the target or (4) letters which differed from the target. The two distracters presented were always identical, and the targets and accompanying letters were always A or B.

Participants were given ten practise trials followed by three 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 distracter conditions. The nature of the previous trial was controlled. This task lasted approximately 4 min. Several aspects of choice responses to a target were measured. The global measures of choice reaction time that were assessed were mean reaction time and accuracy of response (percent correct). A more specific aspect of choice response was measured recording choice reaction time and accuracy with which new information was encoded i.e. the difference in reaction time and accuracy of response between conditions when the target is alternated from the previous trial and when the target is repeated from the previous trial.

Categoric search

This task was also developed by (Broadbent et al. 1986, 1989) and is similar to the focused attention task previously outlined. Each trial started with the appearance of two crosses either in the central positions occupied by the non-targets in the focused attention task i.e. 2.04° or 5.20° apart or further apart, located towards either left and right extremes of the screen. The target letter would then appear in place of one of these crosses. However, in this task, participants did not know where the target would appear. On half the trials, the target letter A or B was presented alone and on the other half it was accompanied by a distracter, in this task a digit (1–7). 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 letter B on the right) whereas the others were incompatible. The nature of the preceding trial was also controlled. In other respects (practise, number of trials, etc.) the task was identical to the focused attention task. This task also lasted approximately 4 min. As in the focused attention task, several aspects of choice responses to a target were measured. The global measures were mean reaction time and accuracy of response. The speed with which new information was encoded was also recorded.

Results

Participant profile

No significant differences were found between each of the six groups on all measures shown in Table 2.

Acceptability and perceptions of the drinks

The alcohol content of the drinks influenced perceptions of whether the lager contained alcohol or not, with 64 % of the participants in the alcohol conditions believing they were consuming an alcoholic drink and 39 % in the no alcohol conditions. Perception of caffeine was essentially at chance level although those given alcoholic drinks were less likely to believe they contained caffeine (32 %) than those given non-alcoholic drinks (54 %). Enjoyment of the drink was not influenced by caffeine content but it was by alcohol, with participants enjoying the alcoholic drinks more (mean enjoyment scores on a scale of 0–100: Alcohol, 43; No alcohol, 25). Similarly, the non-alcoholic drinks were rated as being more different from the usual lagers consumed (mean difference from normal scores on a scale of 0–100: Alcohol, 49; No alcohol, 70).

Mood and performance

In the following analyses, baseline scores were used as covariates to adjust for individual differences.

Table 2 Demographics, health-related behaviours and personality of the different drink groups (caffeine doses are per drink)

Variable	0 mg caffeine & alcohol	0 mg caffeine & no alcohol	62.5 mg caffeine & alcohol	62.5 mg caffeine & no alcohol	125 mg caffeine & alcohol	125 mg caffeine & no alcohol
Age (years)	20.36 (0.32)	19.92 (0.29)	20.96 (0.47)	21.13 (0.48)	20.83 (0.58)	20.91 (0.52)
Weight (kg)	66.49 (2.09)	65.27 (2.15)	65.55 (1.89)	64.58 (2.32)	66.15 (2.19)	67.24 (3.13)
Mean daily caffeine intake (mg)	169.0 (24.52)	182.71 (37.59)	125.77 (21.52)	135.00 (26.17)	133.96 (19.75)	220.83 (33.80)
Alcohol intake per week (units)	21.32 (2.17)	19.0 (2.92)	17.12 (2.88)	15.65 (1.99)	16.22 (2.50)	24.25 (3.06)
Units of beer per week	9.68 (1.97)	9.96 (1.86)	10.04 (2.10)	7.39 (1.49)	8.96 (1.91)	12.44 (11.64)
Percentage of smokers	40 %	29 %	31 %	35 %	35 %	54 %
Spielberger Trait Anxiety	40.72 (1.78)	39.71 (1.50)	39.0 (1.27)	38.17 (1.54)	39.17 (1.75)	38.91 (1.86)
Obsessional Personality	2.36 (0.23)	2.5 (0.28)	2.73 (0.20)	2.09 (0.21)	2.21 (0.30)	2.33 (0.25)
Neuroticism (EPI)	9.67 (0.92)	11.38 (1.08)	9.52 (1.00)	11.61 (1.08)	8.96 (1.07)	11.33 (1.05)
Impulsivity (EPI)	4.36 (0.42)	5.29 (0.36)	5.00 (0.38)	5.26 (0.41)	4.64 (0.37)	5.04 (0.33)

Scores are the means (standard error in parentheses)

Table 3 Mood scores for the different drink conditions before performance testing

	No caffeine/no alcohol	No caffeine/ alcohol	62.5 mg caffeine/no alcohol	62.5 mg caffeine/ alcohol	125 mg caffeine/no alcohol	125 mg caffeine/ alcohol
Alertness						
Baseline	255.3 (63.0)	248.4 (45.3)	240.9 (55.0)	248.5 (60.5)	253.1 (58.0)	251.2 (69.0)
After 1st drink	246.5 (46.0)	238.5 (44.0)	249.4 (47.1)	232.4 (42.9)	240.1 (43.6)	241.0 (45.7)
After 2nd drink	228.2 (40.2)	218.8 (53.1)	236.0 (48.5)	202.9 (55.5)	232.0 (37.3)	231.9 (43.4)
After 3rd drink	225.6 (38.9)	209.4 (56.6)	241.1 (55.6)	200.0 (62.5)	228.5 (36.7)	219.3 (48.4)
Hedonic						
Baseline	203.3 (36.7)	205.6 (32.1)	204.6 (39.3)	200.7 (34.5)	205.6 (37.6)	199.0 (39.6)
After 1st drink	199.4 (33.1)	201.4 (31.7)	203.1 (37.4)	202.6 (26.7)	194.6 (43.1)	198.8 (40.7)
After 2nd drink	192.8 (31.2)	205.6 (36.2)	203.0 (33.9)	203.6 (25.4)	192.9 (31.4)	198.5 (36.8)
After 3rd drink	190.0 (36.3)	204.3 (40.7)	197.4 (29.7)	203.0 (28.9)	185.1 (33.0)	194.3 (38.5)
Anxiety						
Baseline	91.6 (18.5)	91.4 (18.0)	92.5 (24.7)	89.1 (20.3)	97.8 (19.0)	88.2 (19.9)
After 1st drink	83.3 (11.8)	84.8 (12.7)	88.8 (23.4)	89.2 (12.6)	90.3 (16.2)	87.3 (19.5)
After 2nd drink	86.3 (15.7)	87.3 (15.0)	90.9 (20.1)	91.2 (14.3)	88.7 (14.1)	89.7 (19.0)
After 3rd drink	86.9 (12.6)	87.8 (11.5)	91.7 (21.6)	89.7 (13.7)	90.8 (15.2)	90.0 (16.9)

High scores=a more positive mood; scores are the means with standard deviations in parentheses; caffeine doses are per drink. After first drink, there were no significant effects of alcohol or caffeine. After second drink, alertness (main effect of alcohol: $F_{1,\ 137}$=4.35 p<0.05; Caffeine×Alcohol interaction: $F_{2,\ 137}$=3.61 p<0.05) and hedonic tone (main effect of alcohol: $F_{1,\ 137}$=5.07 p<0.05) were affected. After third drink, alertness (main effect of alcohol: $F_{1,\ 138}$=8.12 p<0.01; Caffeine×Alcohol interaction: $F_{2,\ 138}$=3.81 p<0.05) and hedonic tone (main effect of alcohol: $F_{1,\ 138}$ =9.22 p<0.005) were affected

Effects on mood

Effects after the first drink

There were no significant effects following consumption of the first drink (see Tables 3 and 4). This is not surprising given the short time period between consumption and testing.

Effects after the second drink

There were significant main effects of alcohol on both pre- and post-performance mood (see Tables 3 and 4). Alcohol reduced alertness (pre-performance: $F_{1,\ 139}$=4.35, p<0.05; post-performance: $F_{1,\ 139}$=5.07, p<0.05), increased hedonic tone (pre-performance: $F_{1,\ 139}$=5.07, p<0.05; post-performance: $F_{1,\ 139}$ =9.99, p<0.005) and reduced anxiety (post-performance: $F_{1,\ 139}$=5.37, p<0.05). The effect of alcohol on alertness was removed by the higher dose of caffeine which resulted in significant alcohol×caffeine interactions (pre-performance: $F_{2,\ 139}$=3.61, p<0.05; post-performance: $F_{1,\ 139}$=4.64, p<0.05).

Effects after the third drink

These were very similar to those seen after the second drink, and in most cases, the effects were bigger (see Tables 3 and 4; Alertness: pre-performance: $F_{1,\ 139}$ =8.12, p<0.01; post-performance: $F_{1,\ 139}$=12.63, p<0.001. Hedonic tone: pre-performance: $F_{1,\ 139}$=9.22, p<0.005; post-performance: $F_{1,\ 139}$=5.83, p<0.05. Anxiety: post-performance: $F_{1,\ 139}$ =5.86, p<0.05).

The effects of alcohol (combined second and third drink data) on mood, and the alcohol×caffeine interaction for alertness, are shown in Figs. 1, 2 and 3. These analyses also included pre- and post-performance measures in the same analyses. There were significant main effects of alcohol on alertness ($F_{1,\ 139}$=9.40, p<0.005), hedonic tone ($F_{1,\ 139}$= 10.8, p<0.005) and anxiety ($F_{1,\ 139}$=4.89, p<0.05). The alcohol×caffeine interaction was also significant in the alertness analysis ($F_{1,\ 139}$=3.85, p<0.05) and this reflected no difference between alcohol/no alcohol conditions in the groups that received the highest dose of caffeine whereas the alcohol groups reported significantly lower alertness when given no caffeine or the smaller dose of caffeine.

Table 4 Mood scores for the different drink conditions after performance testing

	No caffeine/ no alcohol	No caffeine/ alcohol	62.5 mg caffeine/ no alcohol	62.5 mg caffeine/ alcohol	125 mg caffeine/ no alcohol	125 mg caffeine/ alcohol
Alertness						
Baseline	234.5 (60.1)	231.4 (39.1)	211.9 (55.8)	228.0 (56.2)	223.7 (57.2)	223.7 (55.8)
After 1st drink	224.0 (49.2)	214.8 (43.0)	217.2 (49.3)	209.2 (47.8)	225.0 (54.7)	230.6 (41.8)
After 2nd drink	214.7 (54.5)	200.2 (52.9)	221.6 (57.3)	191.9 (58.5)	211.8 (42.5)	222.8 (46.0)
After 3rd drink	222.8 (45.1)	195.4 (50.3)	221.9 (54.5)	185.0 (74.9)	217.0 (89.0)	207.9 (50.3)
Hedonic						
Baseline	191.0 (34.2)	192.9 (33.7)	194.5 (33.0)	195.0 (31.3)	181.2 (41.8)	188.7 (37.6)
After 1st drink	191.1 (33.2)	200.2 (34.8)	196.3 (33.0)	199.4 (24.7)	185.3 (38.1)	196.0 (36.8)
After 2nd drink	187.2 (36.4)	203.6 (36.1)	195.6 (33.6)	201.3 (27.6)	179.8 (34.7)	197.5 (36.4)
After 3rd drink	190.1 (34.3)	200.5 (37.8)	200.0 (30.6)	207.6 (28.6)	176.4 (33.3)	193.5 (38.0)
Anxiety						
Baseline	85.8 (17.9)	86.8 (15.2)	93.8 (24.2)	86.1 (15.8)	91.1 (22.6)	89.0 (16.0)
After 1st drink	87.5 (16.2)	86.0 (13.9)	90.2 (14.5)	90.8 (14.5)	92.5 (18.7)	88.5 (19.3)
After 2nd drink	86.1 (12.9)	90.1 (15.3)	92.9 (19.7)	94.0 (15.6)	88.5 (16.6)	93.7 (17.9)
After 3rd drink	87.5 (15.2)	91.8 (16.8)	91.5 (22.0)	92.1 (18.8)	85.2 (20.3)	93.9 (16.8)

High scores=a more positive mood; scores are the means with standard deviations in parentheses; caffeine doses are per drink. After first drink, there were no significant effects of alcohol or caffeine. After second drink, alertness (main effect of alcohol: $F_{1,\ 139}$=4.30 p<0.05. alcohol×caffeine interaction: $F_{2,\ 139}$=4.64 p<0.05), hedonic tone (main effect of alcohol: $F_{1,\ 139}$=9.99 p<0.005) and anxiety (main effect of alcohol: $F_{1,\ 139}$=5.37 p <0.05) were affected. After third drink, alertness (main effect of alcohol: $F_{1,\ 139}$=12.63 p<0.0005), hedonic tone (main effect of alcohol: $F_{1,\ 139}$= 5.83 p<0.05) and anxiety (main effect of alcohol: $F_{1,\ 139}$=5.86 p<0.05) were affected

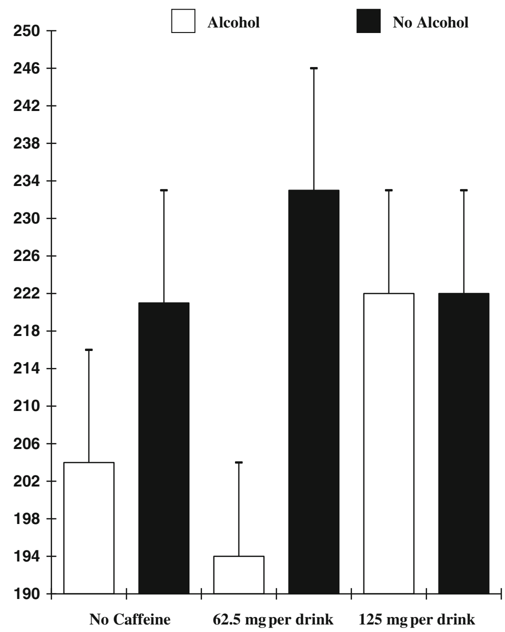

Fig. 1 Effects of alcohol and caffeine on alertness. (Scores are the adjusted means. Standard errors are shown as *bars*. High scores=more alert)

Effects on performance tasks

Effects after the first drink

There were no significant effects following consumption of the first drink (see Table 5).

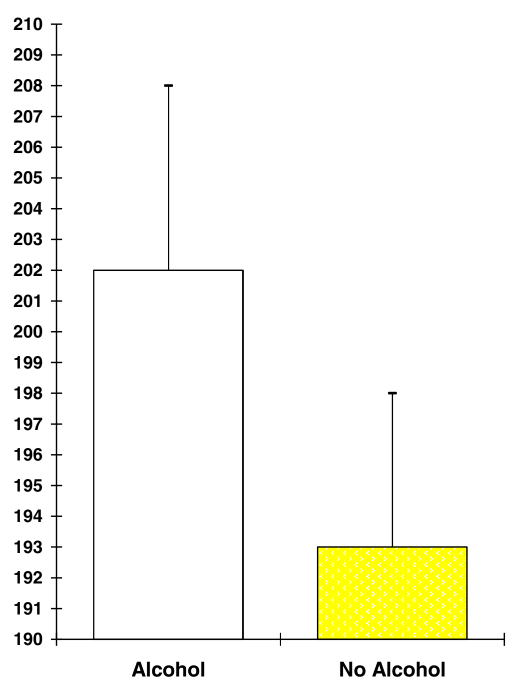

Fig. 2 Effects of alcohol on hedonic tone. (Scores are the adjusted means. Standard errors shown as *bars*. High scores=more positive mood)

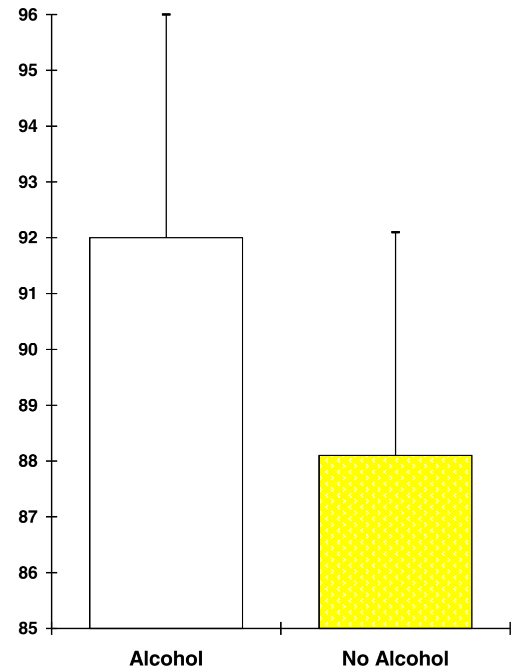

Fig. 3 Effects of alcohol on anxiety. (Scores are the adjusted means. Standard errors shown as *bars*. High scores=greater calm)

Effects after the second and third drink

Alcohol was associated with slower reaction times in the simple reaction time task and categoric search task. These effects became more apparent over time (after second drink: simple RT: $F_{1,\ 139}=5.23$, $p<0.05$; after third drink: simple RT: $F_{1,\ 139}=4.97$, $p<0.05$; focused attention RT: $F_{1,\ 139}=4.18$, $p<0.05$; categoric search RT: $F_{1,\ 139}=11.63$, $p<0.001$). These effects (averaged over sessions) are shown in Figs. 4 and 5. In these analyses, there were significant main effects of alcohol on simple reaction time ($F_{1,\ 139}=6.22$, $p<0.05$) and categoric search RT ($F_{1,\ 139}=7.54$, $p<0.01$).

Caffeine had no significant effect (either as a main effect or interaction with alcohol) on the mean reaction times in the simple and choice reaction time tasks. Ingestion of caffeine did improve the encoding of new stimuli, a result that has been obtained before in many previous studies; this is shown, averaged across sessions, in Fig. 6 ($F_{2,\ 139}=5.21$, $p<0.05$). A clear dose response was observed for this outcome, and the highest dose of caffeine was significantly different from the placebo condition.

There were no significant effects of alcohol or caffeine on the accuracy of performing the tasks.

Discussion

The aim of the present study was to examine effects of caffeine and alcohol on mood and performance using a

Table 5 Performance scores for the different drink conditions with simple reaction time, choice reaction time and speed of encoding of new information

	No caffeine/no alcohol	No caffeine/ alcohol	62.5 mg caffeine/no alcohol	62.5 mg caffeine/ alcohol	125 mg caffeine/no alcohol	125 mg caffeine/ alcohol
Simple reaction time						
Baseline	296 (44)	281 (45)	278 (43)	288 (42)	295 (41)	305 (49)
After 1st drink	324 (52)	308 (48)	301 (57)	319 (52)	313 (47)	325 (45)
After 2nd drink	334 (58)	332 (57)	318 (61)	342 (57)	330 (55)	349 (51)
After 3rd drink	338 (56)	351 (55)	333 (65)	340 (60)	334 (48)	363 (53)
Speed of encoding						
Baseline	7.1 (15.5)	5.5 (22.2)	8.3 (24.8)	9.6 (24.8)	12.5 (24.8)	14.5 (21.3)
After 1st drink	16.9 (18.3)	11.9 (24.3)	14.9 (19.9)	13.7 (26.3)	15.7 (21.3)	15.7 (17.7)
After 2nd drink	20.7 (16.3)	17.8 (24.9)	21.1 (28.0)	9.7 (26.0)	12.8 (22.4)	15.6 (17.5)
After 3rd drink	11.4 (16.8)	13.7 (29.1)	10.5 (26.5)	9.0 (27.7)	10.2 (21.8)	7.8 (28.7)
Focused attention RT						
Baseline	380 (36)	378 (51)	379 (46)	375 (38)	387 (37)	374 (44)
After 1st drink	370 (36)	376 (54)	370 (33)	370 (38)	379 (42)	357 (39)
After 2nd drink	362 (27)	366 (46)	364 (28)	367 (42)	364 (27)	355 (43)
After 3rd drink	363 (32)	374 (40)	359 (38)	371 (41)	362 (30)	355 (37)
Categoric Search RT						
Baseline	498 (45)	503 (68)	502 (43)	500 (42)	512 (48)	496 (56)
After 1st drink	473 (37)	484 (68)	481 (44)	477 (47)	489 (49)	470 (48)
After 2nd drink	461 (36)	474 (57)	469 (40)	473 (51)	474 (37)	466 (49)
After 3rd drink	455 (38)	479 (62)	467 (47)	477 (45)	466 (35)	472 (56)

High scores=slower simple and choice reaction time and slower encoding of new information; scores are the means in millisecond with standard deviations in parentheses; caffeine doses are per drink. After first drink, there were no significant effects of alcohol or caffeine. After second drink, simple RT (main effect of alcohol: $F_{1,\ 139}$=5.23 p<0.05) and speed of encoding (main effect of caffeine: $F_{2,\ 139}$=4.23 p<0.05) were affected. After third drink, simple RT (main effect of alcohol: $F_{1,\ 139}$=4.97 p<0.05), focused attention RT (main effect of alcohol: $F_{1,\ 139}$=4.18 p<0.05), categoric search RT: (main effect of alcohol: $F_{1,\ 139}$ = 11.63 p<0.0001) and speed of encoding: (main effect of caffeine: $F_{2,\ 139}$=3.77 p<0.05) were affected

realistic drinking regime involving multiple drink administrations. The results confirmed recent results showing that effects of alcohol and caffeine on performance are independent (Howland et al. 2011). Alcohol was associated with slower simple and choice reaction time whereas caffeine led to faster encoding of new information. Both the effects of alcohol and caffeine confirm previous findings (Finnigan and Hammersley 1992; Smith 2009). The absence of moderating effects of caffeine does not reflect an absence of statistical power as the interaction effect sizes were very small and not of a meaningful size. These results are not surprising when one examines mechanisms underlying effects of alcohol and caffeine on performance (Smith 2011; Tzanbasis and Stough 2000). In terms of practical implications, the present results are counter to marketing claims and support the conclusion from other studies that caffeine has no beneficial effects on the performance of individuals who have consumed alcohol. In the present study, the dose of caffeine was higher than in many previous experiments and the dose of alcohol, lower. If no beneficial effects are seen with such doses, it is highly unlikely that effects will be observed with larger amounts of alcohol and less caffeine.

Alcohol had the expected effects on mood in that it increased hedonic tone and reduced anxiety. These effects were not modified by caffeine. Alcohol also reduced alertness and this effect was removed by the highest dose of caffeine. This result suggests that individuals who have consumed a high dose of caffeine and alcohol feel as alert as those who have consumed no alcohol even though their

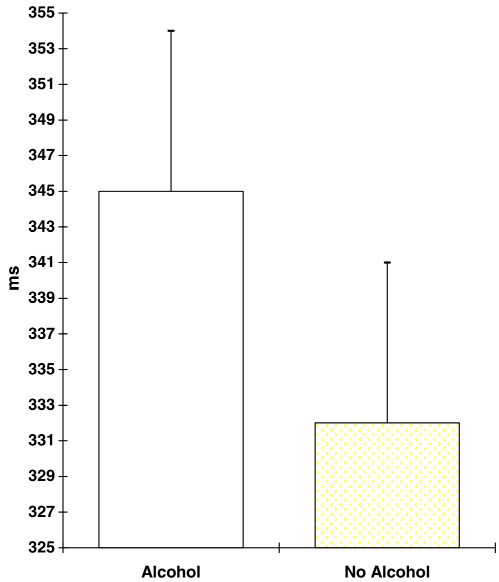

Fig. 4 Effects of alcohol on simple reaction time. (Scores are the adjusted means. Standard errors shown as bars)

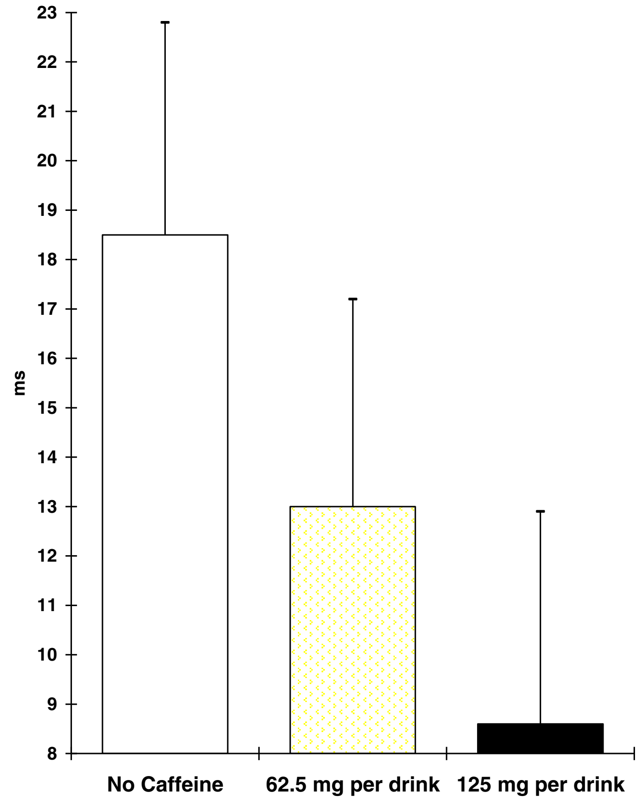

Fig. 6 Effects of caffeine ingestion on the encoding of new stimuli (the difference between response times to a stimulus which differed from the previous trial and one which was a repeat). Scores are the adjusted means. Standard errors shown as *bars*

speed of reactions are impaired. It was not observed with the lower dose of caffeine, a finding which confirms previous research (Alford et al. 2012). This effect requires communication to consumers especially as harmful effects may occur when individuals expect that caffeine will offset alcohol's negative effects (Fillmore et al. 1994; Fillmore and Vogel-Sprott 1996).

The limitations of the present study include the restricted age range, limited doses of alcohol, no measurement of alcohol or caffeine levels and failure to consider a wider range of cognitive functions. In addition, individual differences, such as personality, should ideally be considered. The effects of caffeine on the reaction time tasks were restricted to faster encoding of new information. This has been observed in other studies where relatively short reaction time tasks have been used. One could also suggest that this lack of effects of caffeine could reflect the short period of abstinence used here although other studies have demonstrated the sensitivity of longer tasks even when participants have recently received prior doses of caffeine (Christopher et al. 2005; Smith et al. 2005). Other alternative explanations may reflect the use of guarana as a source of caffeine or the relatively high percentage of smokers in the study (smoking may affect the pharmacokinetics of both caffeine and alcohol, and withdrawal from smoking may influence mood and performance). While further research on this topic is still required, results from the present study suggest that caffeine counteracts alcohol-induced reductions in alertness but does not reduce slowing of reaction time observed after ingestion of alcohol. These results can be accounted for by the different mechanisms underlying effects of alcohol and caffeine. They are also of practical importance in that they demonstrate that expectancies that caffeine will remove all the negative effects of consuming alcohol are incorrect.

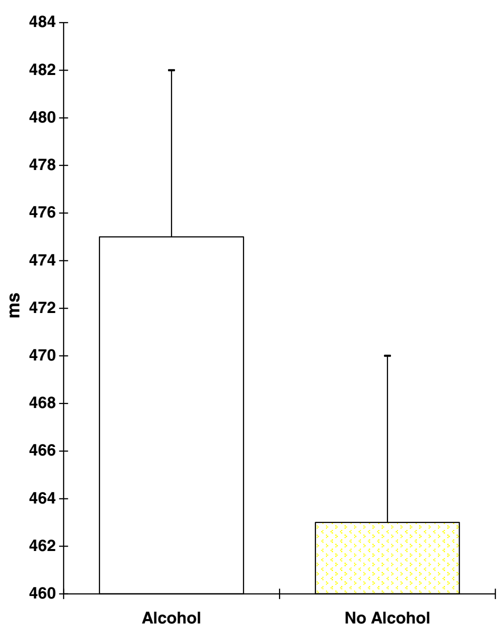

Fig. 5 Effects of alcohol on mean reaction time in the categoric search task. (Scores are the adjusted *means*. Standard errors shown as bars)

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