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Liquor & Gaming New South Wales
Alcohol sales evaluation team
Evaluation of Kings Cross Alcohol Sales Data Reporting Requirement

SUBMISSION ON THE EVALUATION OF THE KINGS CROSS ALCOHOL SALES DATA REPORTING REQUIREMENT

I write on behalf of the Australian Beverages Council (**"The Beverages Council").** I thank you for the opportunity to provide feedback on the discussion paper regarding alcohol sales data reporting requirements in Kings Cross. The Beverages Council is the peak industry voice representing the $7 billion non-alcoholic beverages industry, which includes energy drinks. Member companies represent over 95% of non-alcoholic beverages sold and consumed in Australia and together provide 99% of all energy drinks sold.

Energy drinks in Australia

Energy drinks are regulated products under the Australia New Zealand Food Code (**"the Code"**). According to the Code, energy drinks (known as formulated caffeinated beverages) may have **no more** than 32mg of caffeine per 100ml. This equates to 80mg per 250ml serve, which is the standard serving size in on premise venues. 80mg of caffeine is approximately the same amount of caffeine as that found in one cup of instant coffee (1 tea spoon), and is considerably less than that found in a store brought flat white or latte coffee drink.

In addition, all cans must carry advisory statements regarding caffeine content, and must also carry maximum daily recommended consumption limits, based off the maximum recommended daily intake of vitamins that each can contains.

Energy drinks in the on premise environment

Energy drinks sold in on premise venues as a mixer, however they represent a very small proportion of total sales. Within the on premise environment non-alcoholic drinks make up approximately 8% of total revenue. Of that 8% only 8% again are energy drinks. Therefore, taking total revenue into account, energy drinks only constitute 0.64% of total revenue in the on premise environment, a very small number that includes both

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mixed and unmixed (non-alcoholic) sales.[1]

Energy drinks in Kings Cross

Like other suppliers to Kings Cross licensed venues, our members have reported significant reductions in trade volumes following the imposition of more restrictive conditions on the Kings Cross area since 2014. With respect to energy drinks, members report volume declines of:[2]

- 2014/15 — 85.7%
- 2015/16 — 45.3%

These annual declines were compounding, resulting in an overall percentage decrease of 92.05% between 2014 and 2016. As described above, the proportion of energy drinks sold in licensed venues is already miniscule, so this number represents a further and substantial decline on an already low base.

SPECIFIC FEEDBACK

The ABC wishes to provide feedback on the discussion paper, on the following points.

Necessity of sales data information

The Beverages Council queries the usefulness of the reporting data, especially given the recent reduction in licensed venues in the Kings Cross area. The Beverages Council also queries the inclusion of energy drinks as a specific category of beverage to be reported against, as energy drinks are non-alcoholic and contain no more caffeine than a cup of instant coffee. As discussed above, the necessity of this data is further questioned in light of the significant and steep reduction in sales.

Reason for inclusion of "energy drinks" as a reporting requirement

The Beverages Council submits that there is no valid reason for singling our energy drinks to be reported against. Energy drinks are no different to any other common mixer containing caffeine, such as coffee or tea. Moreover, energy drinks contain only slightly high caffeine content then commonly purchased mixers such as colas or lemonades, which are currently not required to be reported against. The Beverages Council is of the view that the inclusion of only energy drinks – as category of caffeinated products in the on premise environment – is arbitrary and unfair.

In addition, the requirement to report energy drink sales data creates an indirect cost to energy drink suppliers. As there are more onerous reporting requirements associated with this particular product, there is a direct cost to licensees who chose to range energy drinks in their venues. Furthermore, as noted above volumes of energy drinks in Kings Cross has dropped significantly since 2014. Therefore, the cost of the

1 *Over the Bar Scan Report*, 2010.
2 *Sales data from till receipts*, provided by Beverage Council Members.

reporting far outweighs the volume of reporting, meaning that the "cost per item reported" for venues is very high for energy drinks.

This direct cost also acts as a disincentive to stock energy drinks, which unfairly and arbitrarily impinges on the ability of energy drink suppliers to have their products sold. This cost is made all the more acute as energy drinks are not alcoholic products in their own right. As a consequence, consumers who may wish to choose a non-alcoholic product in a licensed premise are unfairly hampered from selecting this choice.

Evolution of scientific consensus on caffeine and alcohol

The Beverages Council understands that when the current alcohol sales data reporting requirement was formulated in 2013 and introduced in 2014 there was a public debate regarding the interaction of caffeine and alcohol. Then, as now, the Beverages Council queried the concern about caffeine and alcohol, and the appropriateness of isolating the debate specifically to one category of caffeinated products, namely energy drinks.

However, the Beverages Council is pleased to make the Department aware than since 2013 the debate on the interaction between alcohol and caffeine has significantly evolved. There is now a scientific consensus that there is no effect, either positive or negative, between alcohol and caffeine.

This has recently been confirmed by the European Food Safety Authority (**"EFSA"**) in its 2015 Scientific Opinion on the Safety of Caffeine.[3] EFSA's opinion was commissioned by the European Commission, and as part of its safety assessment into caffeine generally it was also asked to look into the interaction between caffeine and alcohol. Its conclusions in its lay summary were:

> Alcohol consumption at doses of up to about 0.65g/kg bw [body weight], leading to a blood alcohol content of about 0.08% - the level at which you are considered unfit to drive in many countries – would not affect the safety of single doses of caffeine up to 200mg. Up to these levels of intake, caffeine is unlikely to mask the subjective perception of alcohol intoxication.[4]

This supports earlier conclusions by the United Kingdom Committee on Toxicity:

> Overall, the COT concludes that the current balance of evidence does not support a harmful toxicological or behavioural interaction between caffeine and alcohol.[5]

Finally, this conclusion on alcohol and caffeine was supported by recent published and peer reviewed meta-analysis, which looked at varying levels of caffeine and alcohol consumption, in both controlled and real world scenarios:[6]

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3 European Food Safety Athority, ESFA NDA Panel (EFSA Panel on Dietetic Products, Nutrition and Allergies), 2015. *Scientific Opinion on the Safety of Caffeine*, EFSA Journal 2015;13(5): 4102, 120 pp.

4 European Food Safety Authority, *EFSA Explains Caffeine Risk Assessment*, p. 6.

5 United Kingdom Committee on Toxicity, *Lay Summary to the COT statement 2012/04*, December 2012.

> This review and meta-analysis suggests that consuming alcohol with caffeinated beverages does not impair judgement of subjective intoxication. This finding was found to be consistent at various levels of alcohol and caffeine.

Moreover, a recent study by Vic Health concluded that:

> After controlling for demographic and other environmental factors, AmED [alcohol mixed with energy drinks] consumption no longer predicted intoxication. This is consistent with street interview findings from the POINTED study (Pennay et al. 2015) and the in-depth interviews. What this suggests is that AmED use is strongly associated with intoxication, but is not the driver of this intoxication.[7]

And;

> Overall levels of consumption of AmED are relatively low compared to other alcoholic beverages such as bottled wine and beer.[8]

And;

> This research found that most Australians are not consuming AmEDs at risky levels.[9]

Copies of published scientific articles, with respect to the safety of alcohol and energy drinks, are appended to this submission.

Based on the above, The Beverages Council is of the firm view that there is a clear scientific conclusion that the combination of alcohol and caffeine poses no special or unique risk in the on premise environment. As such, the policy rationale for including energy drinks within the alcohol sales data reporting requirement is no longer relevant.

Industry measures to promote the responsible sale and promotion of energy drinks

Finally, the Beverages Council would like to reconfirm that its energy drink members are signatories to the Beverages Council's Energy Drinks Industry Commitment (**"the Commitment"**) and therefore are committed to the responsible sale and promotion of energy drinks, especially in the on premise environment. The Commitment includes, inter alia:

- No promotional activities are undertaken that encourage excessive consumption of energy drinks; and

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6 Benson, S., et al., *Effects of mixing alcohol with caffeinated beverages on subjective intoxication: A systemic review and meta-analysis,* Neurosci. Biobehav. Rev. (2014).

7 Vic Health, *Alcohol Mixed with energy drinks: exploring patterns of consumption and associated harms – Research Summary*, October 2016, p. 8.

8 Ibid, p. 10.

9 Ibid, p. 9.

- Labels of energy drinks do not promote the mixing of energy drinks with any other beverage.

And also:

- Energy drinks be promoted as an alternative to alcohol (like water, soft drinks, juice, tea and coffee) and included as part of a venue's responsible service of alcohol strategy;
- Venue staff continuing to use a range of indicators in assessing a person's level of intoxication which includes the number of standard alcoholic drinks consumed;
- Energy drinks should not feature in a practice or promotion that encourages rapid and excessive consumption of alcohol or energy drinks;
- Encouraging a consumer message of "responsible consumption of energy drinks" by reference to the recommended daily usage statement on product labelling; and
- Refraining from making any unsubstantiated scientific claims with regard to energy drinks and alcohol e.g. that the consumption of energy drinks counteracts the effects of alcohol

RECOMMENDATIONS

In light of the above, the Beverages Council recommends that:

1. Given the environmental changes in the Kings Cross area, the current requirement to report any sales data – including energy drinks – is no longer necessary and should be removed;
2. In the alternative, energy drinks should be removed from the list of products required to be reported in the alcohol sales data reporting requirement.

The Beverages Council thanks you again for the opportunity to submit on the Kings Cross Alcohol Sales Data Reporting Requirement, and is available to answer any further questions you might have.

The Beverages Council thanks you again for the opportunity to submit on the Kings Cross Alcohol Sales Data Reporting Requirement, and is available to answer any further questions you might have. Please don't hesitate to contact this office via the listed numbers or via info@ausbev.org.

Kind regards,

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REVIEW

Energy drinks mixed with alcohol: misconceptions, myths, and facts

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Background: Whilst energy drinks improve performance and feelings of alertness, recent articles suggest that energy drink consumption combined with alcohol may reduce perception of alcohol intoxication, or lead to increased alcohol or drug use. This review discusses the available scientific evidence on the effects of mixing energy drinks with alcohol.

Methods: A literature search was performed using the keywords "energy drink and Red Bull®" and consulting Medline/Pubmed, PsycINFO, and Embase.

Results: There is little evidence that energy drinks antagonize the behavioral effects of alcohol, and there is no consistent evidence that energy drinks alter the perceived level of intoxication of people who mix energy drinks with alcohol. No clinically relevant cardiovascular or other adverse effects have been reported for healthy subjects combining energy drinks with alcohol, although there are no long-term investigations currently available. Finally, whilst several surveys have shown associations, there is no direct evidence that coadministration of energy drinks increases alcohol consumption, or initiates drug and alcohol dependence or abuse.

Conclusion: Although some reports suggest that energy drinks lead to reduced awareness of intoxication and increased alcohol consumption, a review of the available literature shows that these views are not supported by direct or reliable scientific evidence. A personality with higher levels of risk-taking behavior may be the primary reason for increased alcohol and drug abuse per se. The coconsumption of energy drinks being one of the many expressions of that type of lifestyle and personality.

Keywords: energy drink and Red Bull®, Red Bull®, alcohol, intoxication, caffeine, masking

Introduction

Although energy drinks comprise only 1% of the total soft drink market, these products are becoming increasingly popular.[1] The market leader, Red Bull® Energy Drink is available in over 160 countries and, although some local sales restrictions may apply, energy drinks are not banned in any country. The most important functional ingredient of energy drinks is caffeine. Table 1 lists some of the well known energy drink brands, and their caffeine content.

It is evident from Table 1 that popular energy drinks such as Red Bull (250 mL, 8.4 oz) contain a similar amount of caffeine (ie, 80 mg) to that present in one regular cup of coffee (240 mL, 8 oz).[2,3] However, less popular brands may have a higher caffeine content. Caffeine does not have adverse effects for the general population of healthy adults if they limit caffeine intake to 400 mg per day.[4] Various experimental studies have examined the behavioral effects of energy drinks when consumed alone. Most studies have shown that energy drink consumption can significantly improve cognitive

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Table 1 Caffeine content of some well known energy drinks[2,3]

	Bottle/can mL (oz)	Caffeine mg/100 mL (mg/oz)	Total caffeine mg (range)
Red bull	250 (8.4)	32 (9.6)	80
Monster	473 (16)	34 (10)	160
Rockstar	473 (16)	34 (10)	160
Full throttle	473 (16)	30 (9)	144
No fear	473 (16)	37 (10.9)	174
Amp	250 (8.4)	30 (8.9)	75
SoBe	250 (8.4)	32 (9.5)	79
Tab energy	311 (10.5)	31 (9.1)	95
Cola	355 (12)	11 (3.3)	40 (30–60)
Coffee	237 (8)	36 (10.6)	85 (65–120)
Tea	237 (8)	17 (5)	40 (20–90)

and psychomotor functioning[5–10] and driving ability,[10–12] pre-exercise consumption can significantly improve endurance and physical performance,[7,13–15] and whilst some studies have reported small changes in heart rate or blood pressure, no clinically relevant adverse cardiovascular effects have been reported after normal use of energy drinks in healthy volunteers,[7,16–21] although there is currently a lack of long-term data.

Health regulatory authorities across the world have concluded that energy drinks are safe to consume, although some authorities have expressed concerns about the potential health risks associated with mixing alcohol and caffeine. It should also be noted that there are anecdotal and case reports of acute adverse effects, including fatalities, in individuals consuming energy drinks combined with alcohol, but no confirmation of any causal relationship between the reported effects and the consumption of energy drinks.[22]

Research and media attention has recently been drawn to alcohol mixed with energy drinks (AmED). In this context, it has been suggested that AmED consumption may reduce the perception of alcohol intoxication or that coconsumption may lead to increased alcohol consumption. This paper aims to review and put into perspective the current scientific evidence on the combined use of energy drinks and alcohol.

Methods

A literature search was performed (updated December 1, 2011) using the keywords "energy drink" and "Red Bull", consulting Medline/Pubmed, PsycINFO, and Embase for clinical trials and surveys examining the effects of energy drinks consumed together with alcohol. Cross-references were checked for additional research papers. This literature search yielded 23 research articles that were included in this review.

Results

Most people consume energy drinks only occasionally (eg, less than 6% of college students consume energy drinks daily).[23] Surveys among students reveal that they consume energy drinks to counteract sleepiness, to enhance energy and concentration,[24] or because they simply like it.[25] Reasons given for consuming energy drinks combined with alcohol include "during partying",[24] to celebrate,[26] because they like the taste,[26] to hide the flavor of alcohol,[27] or to get drunk.[26] However, only 2% of all students (and 15% of those who combined alcohol with energy drinks) indicated they did so in an attempt to be able to drink more and not feel as drunk.[27]

Surveys among students have found that 6%–44% report consumption of AmED.[24–32] Price et al interviewed 72 regular consumers of energy drinks about their past week and lifetime energy drink and alcohol intake, applying the time-line follow-back approach.[33] Thirteen percent of past-week alcohol consumption sessions involved the co-use of energy drinks. Analysis of survey data revealed that students who consume AmED were significantly more often young white males.[27,31,34] Taken together, these surveys suggest that a relative minority of students occasionally consume AmED.

Do energy drinks antagonize alcohol-induced performance impairment?

Seven studies examined the possible antagonizing effects of energy drinks on alcohol-induced performance impairment, including both recovery from physical exercise and cognitive testing.[16,35–40] The results of these studies are summarized in Table 2.

A significant limitation of two of these studies[36,37] is that alcohol was not tested alone, so it cannot be determined if the effects caused by AmED are actually the same as when administering alcohol alone. Ferreira et al failed to find significant differences on a variety of physical performance and recovery parameters.[16] The statistical analysis reported by Marczinski et al, based on significant changes from baseline, found that some aspects of cognitive performance were poorer for alcohol alone compared with the energy drink, placebo, or AmED groups, but not for all tests.[38] In a second study, Marczinski et al did not find any significant difference between impairment on information processing and motor coordination tasks between AmED and alcohol only.[39] Ferreira et al also failed to show differences between alcohol and AmED,[35] whilst Alford et al showed improvement with AmED in one test, but not others, compared with alcohol.[40] Therefore, there is mixed evidence that energy drink consumption antagonizes some performance effects

Table 2 Studies examining potential antagonizing effects of energy drinks on alcohol-induced performance impairment

Reference	Subjects and design	Dosing	Findings highlighted by authors	Comment
Ferreira et al[16]	Double-blind crossover trial in 14 healthy volunteers	Alcohol (1.0 g/kg), energy drink (3.57 mL/kg body weight), and their combination	No significant difference on maximal effort test (cycle ergometer) or recovery for a number of physiological and biochemical parameters between alcohol alone, and alcohol administered in combination with energy drink	No evidence of energy drink antagonizing effects of alcohol
Ferreira et al[35]	12 healthy volunteers received lower dose, 14 higher alcohol dose, both also receiving energy drink or water control, or alcohol + energy drink in a mixed, blind design with random allocation	Alcohol (0.6 and 1.0 g/kg); energy drink, or same volume water (3.57 mL/kg body weight)	Breath alcohol concentration, visual reaction time, and grooved peg-board reported as not showing differences between alcohol alone and AmED	No evidence of energy drink antagonizing effects of alcohol
Wiklund et al[37]	Double-blind, crossover trial to examine heart rate variability and ECG changes in 10 healthy volunteers	3 cans (750 mL) of energy drink alone or in combination with alcohol (vodka, 0.4 g/kg body weight) or no drink at all	Subjects performed a maximal bicycle ergometer exercise for 30 minutes. Postexercise recovery in heart rate and heart rate variability was slower after energy drink and alcohol than after exercise alone. No clinically significant arrhythmias or ECG changes were observed	Alcohol alone not tested, therefore no comparison can be made between alcohol and AmED
Curry and Stasio[36]	Double-blind, placebo-controlled trial in 27 healthy females	AmED (6% alcohol by volume), energy drink alone, and a noncaffeinated placebo drink	AmED significantly impaired neuropsychological function (in particular visuospatial and language skills), whereas the energy drink alone nonsignificantly improved performance (in particular attention scores)	Alcohol alone not tested, therefore no comparison can be made between alcohol and AmED
Alford et al[40]	Double-blind, placebo-controlled study in two groups of 10 healthy volunteers	Alcohol or AmED in a rising dose (0.046% and 0.087% BrAC)	Reaction time and memory were impaired by both alcohol and AmED, although Stroop performance was improved for AmED compared with alcohol suggesting partial antagonism. No significant difference in breath alcohol concentration between alcohol and AmED	Possible antagonism of alcohol seen in one out of three tests for AmED compared with alcohol alone
Marczinski et al[38]	Double-blind, placebo-controlled, between subjects comparison in 56 healthy volunteers, divided into four groups	Placebo, energy drink, alcohol (0.072%–0.089% BrAC), AmED (0.07%–0.08% BrAC)	Compared with alcohol, coadministration of energy drink counteracted some but not all performance impairment. No significant difference in breath alcohol concentration between alcohol and AmED	Possible antagonism of alcohol seen in three out of four performance tests for AmED compared with alcohol alone
Marczinski et al[39]	Double-blind, placebo-controlled study in18 healthy volunteers	Placebo, energy drink (3.57 g/kg), alcohol (0.65 g/kg), AmED	Compared with alcohol, AmED did not significantly alter performance on tests of information processing and motor coordination	No evidence of energy drink antagonizing effects of alcohol

Abbreviations: BrAC, breath alcohol concentration; AmED, alcohol mixed with energy drink; ECG, electrocardiogram.

caused by alcohol intoxication but not others. This suggests no consistent antagonism of alcohol-induced impairment by coconsumption of energy drinks. A recent double-blind, placebo-controlled study by Howland et al did not observe any significant differences on simulated driving, sustained attention, or reaction time between caffeinated and non-caffeinated beer (383 mg caffeine, peak breath alcohol concentration [BrAC] of 0.12%), suggesting no consistent antagonism of alcohol-induced impairment by coconsumption of caffeine.[41]

Do energy drinks change the drinker's perception of intoxication?

It has been claimed that people consume energy drinks because they presume it will counteract the impairing effects of alcohol. For example, O'Brien et al reported this for 15% of students who consumed AmED.[27] Few experimental studies actually examined the perception of intoxication after consuming AmED. One of the most cited studies in this context was performed by Ferreira et al, who evaluated breath alcohol concentration (0.04%–0.1% BrAC), psychomotor functioning, and subjective intoxication after administration of an energy drink, alcohol (vodka, 0.6 or 1.0 g/kg), or AmED.[35] Twenty-six subjects participated in this randomized, controlled trial. Coadministration of energy drink did not affect breath alcohol concentration. Symptoms during intoxication were scored using the Bond and Lader 13-item somatic symptoms scale,[42,43] extended with five additional items, giving 18 items in all. The paper revealed that alcohol and AmED similarly impaired psychomotor performance. The results section reports that AmED reduced the perception of headache, dry mouth, and impairment of motor coordination compared with alcohol alone. However, the appropriateness of using these symptoms as a measure of intoxication should be questioned, especially because most other symptoms, of which several are related to feelings of intoxication (eg, dizziness, speech, tiredness, vision, walking, wellbeing), did not show a significant reduction for AmED compared with alcohol alone. Consequently, the interpretation of these results as showing a reduction in perceived intoxication after AmED compared with alcohol alone cannot be taken as consistent and reliable on the basis of this single study.

Alford et al found participants felt significantly impaired after alcohol (0.05%–0.09% BrAC) and significantly impaired by the higher compared with lower alcohol dose (4/5 scales), but no overall difference between alcohol alone and energy drink combined with alcohol.[40]

Marczinski et al reported that alcohol alone (0.07–0.09 BrAC) significantly increased ratings of feeling the drink, liking the drink, impairment, and level of intoxication, whereas it reduced the rating of ability to drive.[38] AmED showed no significant difference for these ratings. The abstract of this article implies that self-reported stimulation was increased for AmED compared with alcohol alone, and that this might contribute to a higher risk scenario. However, their data showed that subjective stimulation was significantly increased from baseline for both the alcohol and AmED groups. Unfortunately, in this paper, no direct statistical comparisons were made between the AmED and alcohol group. In a second study, Marczinski et al reported that consumption of AmED reduced mental fatigue and increased feelings of stimulation, when compared with consuming alcohol alone.[39] No significant difference between AmED and alcohol alone was reported on subjective intoxication or ability to drive. Taken together, the results from these studies do not show a change in perceived intoxication on the majority of subjective scales, including intoxication and ability to drive, when alcohol is mixed with energy drink. Higher levels of alcohol have been compared with alcohol and caffeine in combination, though not using energy drinks. Howland et al investigated higher doses of alcohol comparing the effects of caffeinated beer versus noncaffeinated beer, and nonalcoholic beer in 127 nondependent, heavy episodic drinkers, aged 21–30 years.[41] When a peak BrAC of 0.12% was achieved, there was no significant difference in estimated BrAC between caffeinated and noncaffeinated beer, indicating that caffeine (a total dose of 383 mg on average) did not mask the alcohol intoxication effects, and thereby supporting the majority of findings observed with energy drinks.

Do energy drinks enhance alcohol consumption?

Given the stimulant effects of caffeine-containing energy drinks, it has been suggested that when consumed together with alcohol, energy drinks would increase alcohol ingestion. Although no experimental data are available, several surveys examined the coconsumption of energy drinks and alcohol.[27–34,44–48] The design and results of these studies, which are nearly all from the US, are summarized in Table 3. In addition to the conclusions drawn by the respective authors, Table 3 also includes our interpretation of the data in the comment column.

Arria et al conducted a 3-year longitudinal study aiming to examine illicit drug use patterns among college students (the 2003 College Life Study).[49] Annually, they interviewed

Table 3 Surveys and on-premise studies that examined the relationship between alcohol and energy drink consumption

Reference	Subjects and design	Findings highlighted by authors	Authors' conclusion	Comment
Miller[34] US	602 undergraduate students	Frequency of energy drink consumption was positively associated with marijuana use, sexual risk-taking, fighting, not wearing a seat belt, risk-taking, smoking, drinking, alcohol problems, and illicit prescription drug use	Energy drink consumption is closely associated with a problem behavior syndrome	• No information on quantity of energy drink consumption was provided • No information was provided on whether alcohol and drugs were consumed together with energy drink or alone • No information was provided on whether alcohol-related consequences were experienced when alcohol was consumed together with energy drinks or alone • Energy drink consumption explains only a small part of the variance of ten domains of problem behavior that were examined ($R^2 = 0.23$ or less) • The presented associations prove no causal relationship
Miller[44] US	795 undergraduate students	Jock identity (mediated by masculine norms and risk-taking behavior) was positively related to energy drink consumption (without alcohol)	Risk-taking behavior partly mediates the relationship between jock identity and AmED consumption	• No evidence of a causal relationship is provided
O'Brien et al[27] US	4271 college students; 697 AmED (16%); 2189 alcohol alone (52%); 1351 nondrinkers (32%); between-subject comparison	AmED consumption was associated with significantly increased heavy episodic drinking, episodes of weekly drunkenness, and alcohol-related consequences	With AmED consumption students are at increased risk for alcohol-related consequences (also after adjustment for the amount of alcohol consumed)	• The authors show that those who consume more alcohol experience more alcohol-related consequences • The authors do not provide evidence that during the days of heavy episodic drinking or reported drunkenness alcohol was mixed with energy drinks • No evidence of a causal relationship between energy drink and alcohol consumption is provided • Only a relative minority (16%) mixed alcohol with energy drinks
Arria et al[28] US	1060 college students; 264 energy drink users; 796 nonusers; between-subject comparison	Compared with nonusers of energy drinks, energy drink users had a heavier alcohol consumption pattern, and were more likely to have used other drugs. Year 2 energy drink consumption correlated significantly with year 3 nonmedical use of prescription stimulants and analgesics, but not other drugs	Energy drink users tend to have greater involvement in alcohol and other drug use	• The study was designed for another purpose, and those with past experience of illicit and/or prescription drugs were oversampled • The difference between alcohol consumption of energy drink users and nonusers is statistically significant but of no clinical relevance (6.0 versus 4.7 drinks per drinking day); similarly for the past year count of drug use (1.5 versus 1.0 occasions) • It is not determined whether energy drinks and alcohol were consumed together or alone • Prescription and illicit drug use was measured using a binary (yes or no) scale • No evidence of a causal relationship between energy drink and alcohol consumption is provided
Attila and Cakir[30] Turkey	439 Turkish students; between-subject comparison	Those who consume energy drinks are more likely to smoke and drink alcoholic beverages. 40% of current users report mixing energy drinks with alcohol	Consumption of energy drinks is quite common among students. Their knowledge of ingredients and potential health hazards is low	• Only 15.2% of current users reported that the main reason to consume energy drinks is to mix with alcohol. Most students consumed energy drinks to feel energetic (24.2%), boost performance during exercise (21.4%), or because of its taste (17.0%)

(*Continued*)

Table 3 (*Continued*)

Reference	Subjects and design	Findings highlighted by authors	Authors' conclusion	Comment
Price et al[33] Canada	72 subjects, of which 10 consumed AmED and alcohol alone during the past week; within-subject comparison	Subjects (10) consumed significantly more alcohol when mixed with energy drinks (8.6 drinks) when compared with consuming alcohol alone (4.7 drinks)	AmED consumption seems associated with increased alcohol ingestion	• Low sample size does not have sufficient power to draw any conclusion • Short time-frame (one week)
Woolsey et al[48] US	401 student athletes: 165 alcohol only; 150 AmED; 194 energy drinks alone. Both within-group and between-subject comparison	Combined users consumed significantly more alcohol and had riskier drinking habits than those who consume alcohol only, and experience more negative alcohol-related consequences	Combined users consumed significantly more alcohol and had riskier drinking habits than those who consume alcohol only. The combined use of alcohol and energy drinks may increase alcohol consumption, risk-taking behavior, and the chance of experiencing negative alcohol-related consequences	• Within-subject comparisons show that combined users (AmED, n = 150) report drinking significantly less (27%) alcohol when mixing alcohol with energy drinks (and 41% less on the heaviest drinking day) • Within-subject comparison provides much more reliable evidence than between-subject comparison. Nevertheless, authors do not discuss their within subject findings • No significant within-subject differences were found on the major risk-taking items
Thombs et al[29] US	802 bar patrons (people who visit a bar and consume alcohol): 602 alcohol only, 45 AmED; onpremise study	Patrons who consumed AmED were at three-fold increased risk of leaving the bar highly intoxicated (BrAC > 0.08%), and a four-fold increased risk of intending to drive upon leaving the bar district	Energy drink consumption by young adults at bars is a marker for elevated involvement in night-time risk-taking behavior	• It was not verified if they indeed drove a car (no actual risk-taking was determined, only the intention to do so) • The quantity of energy drink consumption was not determined • No significant difference in AUDIT-C (alcoholic drink consumption) score between AmED and alcohol alone • BrAC difference between AmED (0.1%) and alcohol alone (0.08%) was equivalent to just one alcoholic drink
Thombs et al[45] US	328 bar patrons: 180 alcohol only, n = 64 cola-caffeinated alcohol only, n = 10 AmED only; onpremise study	Cola-caffeinated alcoholic beverages consumers and AmED consumers leave the bar significantly more intoxicated than those who consume alcohol alone	Mixing alcohol with cola poses a similar level of risk for bar patrons to those associated with AmED consumption	• AmED group (n = 10) has insufficient power to draw reliable conclusions
Rossheim and Thombs[32] US	413 bar patrons For secondary analyses, see data references 29 and 45	Comparing n = 69 alcohol mixed with regular cola, n = 24 alcohol mixed with diet cola, n = 19 AmED, and n = 147 alcohol only, n = 129 noncaffeinated mixers and alcohol. Those who mix alcohol with diet-cola have a significantly higher BrAC when leaving the bar. No significant difference between alcohol only and AmED was found	Reported risks associated with on premise AmED drinking may be reduced by greater attention given to other types of mixers, particularly diet cola	• Mixing alcohol with caffeinated cola (22.5%) was more popular than mixing with energy drinks (6%) • No significant difference was found between alcohol only and AmED • Relatively low power (AmED group, n = 19) limits conclusions
Arria et al[46] US	1097 fourth-year college students, 975 entered analyses (338 nonusers, 518 low-frequent users 1–51 times/year),	Energy drink consumers consumed more alcohol (both quantity and frequency) and a significant association was reported between high-frequency energy drink users	Weekly or daily energy drink consumption is strongly associated with alcohol dependence	• The survey fails to indicate whether or not energy drinks were consumed with alcohol, or separately. Hence, the authors do not rule out the possibility that energy drinks were consumed during the day. For example, to compensate for alcohol-related hangover effects

	119 high-frequent users (52+ times/year); between-subject comparison	and having a DSM-IV diagnosis of alcohol dependence		• The authors show that those who consume more alcohol (quantity and frequency) also consume more energy drinks. The correlation reported does not imply a cause-and-effect relationship • Those who consume more alcohol are more likely to meet the criteria of alcohol dependence • Only a minority of college students (10.1%) was classified as high-frequency energy drink consumers (52+ times/year)
Berger et al[31] US	946 adults aged 18–92 years; between-subject comparison	Compared with nonconsumers, ED drinkers were predominantly male, non-Black, and young (18–29 years old), AmED drinkers white and young. Hazardous drinkers (AUDIT-C 4 or more) were four times more likely to consume energy drinks	There are population differences between those who mixed alcohol with energy drinks and those who consume alcohol alone	• No information on amount of alcohol consumed or AUDIT-C scores was provided • 6% mixed energy drinks with alcohol during the past year
Penning et al[47] The Netherlands	549 Dutch students, who reported on their latest hangover; between-subject comparison	No significant difference was found in the number of alcoholic drinks consumed on the night before their latest hangover between those who consumed AmED and those who consumed alcohol alone	Mixing with caffeinated beverages does not change overall alcohol consumption, nor does it affect next-day hangover severity	• The number of subjects who consumed energy drinks was low (n = 24) and this limits conclusions • The data did not allow a within-subject comparison • A heavy drinking night that caused a hangover may not reflect a regular night of alcohol consumption

Abbreviations: AmED, alcohol mixed with energy drink; US, United States; BrAC, breath alcohol concentration; AUDIT-C, Alcohol Use Disorders Identification Test, version C; DSM-IV, Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition.

1063 college students. To ensure a sufficient number of eligible subjects, those with past experience of illicit and/or prescription drugs were oversampled. An exploratory analysis of the data was performed comparing those who consume energy drinks and those who do not.[28] Since the study was not set up for this purpose, only two questions about energy drink consumption were asked. These questions were "What types of caffeinated products do you consume?" and "Estimate the typical, minimum, and maximum number of caffeinated drinks you consume during a typical week". Based on the first question, subjects were classified as energy drink users (n = 264) and those who do not consume energy drinks (n = 796). Energy drink consumers reported significantly more alcohol intake (both quantity and frequency). Illicit drug use was not significantly higher in energy drink consumers, nor was the use of medicinal drugs, except for prescription stimulants and analgesics. Subjects also completed the short form of the Zuckerman–Kuhlman Personality Questionnaire. Energy drink consumers scored significantly higher on the subscale of impulsive, sensation-seeking behavior.

Unfortunately, the authors did not gather any specific data on whether energy drinks were mixed with alcohol or not. Also, prescription and illicit drug use was only measured using a binary (yes or no) scale. Recently, Arria et al published data from the fourth yearly interview of students participating in the 2003 College Life Study.[46] In this interview, students estimated the types of energy drinks and the number of days and usual quantity of energy drinks they consumed during the previous 12 months. The statistical analysis showed an association between energy drink and alcohol consumption, and reported that those who "frequently" consume energy drinks ($\geq$52 days per year, ie, $\geq$1 per week; representing 10.1% of the sample) significantly more often met the Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition (DSM-IV) criteria for alcohol dependence. However, the survey also failed to indicate whether or not energy drinks were consumed together with alcohol, or separately. In fact, in both studies, the authors do not rule out the possibility that energy drinks were consumed separately during the day, or the day after to compensate for alcohol-related hangover effects.[28,46]

A survey among 4271 college students by O'Brien et al showed that consumption of AmED was associated with increased heavy episodic drinking (6.4 days versus 3.4 days in the past 30 days) and weekly drunkenness (1.4 days/week versus 0.73 days/week), and experiencing negative alcohol-related consequences significantly more often.[27] Again, this study also does not provide any evidence for a causal

relationship, but does support the association that when people drink more alcohol they may also mix some of their alcohol with energy drinks.

Price et al interviewed 10 regular energy drink users about their past week and lifetime energy drink and alcohol use.[33] These 10 subjects consumed significantly more alcohol on the occasion that they also consumed energy drinks (8.4 versus 4.7 alcoholic consumptions, respectively). The authors acknowledge the small sample size and recommend additional research, but nevertheless conclude that using energy drinks is associated with increased alcohol consumption.

Thombs et al examined energy drink and alcohol use in a naturalistic setting, ie, college bars, between 10.00 pm and 03.00 am.[29] In a bar district, 802 subjects were interviewed about their alcohol use and energy drink consumption and performed a breath analysis test to estimate BrAC. Subjects also completed the shortened Alcohol Use Disorders Identification Test (AUDIT-C), a measure of quantity/frequency of consumption, and were asked how likely it was that they would drive home by car at the end of their night out. Significant differences were observed between those who consumed alcohol only (n = 602) and those who mixed energy drinks with alcohol (n = 46); the differences included mean BrAC (0.08% versus 0.11%), alcohol consumed (95.3 g versus 152.2 g), and total hours of drinking (2.9 hours versus 3.9 hours) for these two groups, respectively. AUDIT-C scores did not significantly differ between the groups.

Logistic regression analysis revealed that those who mixed alcohol and energy drinks were 3.32 times more likely to leave the bar intoxicated (BrAC $\geq$ 0.08%) and had a 4.26 times increased risk of intending to drive a car after leaving. The authors concluded that the latter suggests perception of alcohol-induced impairment is reduced when coconsumed with energy drinks. An alternative explanation may be that the groups already differed at baseline in alcohol consumption and risk perception. In a second study by Thombs et al, only 10 people reported consuming AmED.[45] Therefore, the conclusions drawn based on the data from this small study should be interpreted with caution. Rossheim and Thombs then combined the data from both onpremise studies.[32] Based on the combined data, they concluded that energy drink consumption was not associated with an increased risk of being intoxicated.

Miller conducted a survey among 602 undergraduate students that indicated energy drink consumption was associated with problem behaviors, particularly among white students.[34] Frequency of energy drink consumption was positively associated with marijuana use, smoking, drinking, alcohol problems, illicit drug use, and risk-taking behavior. In a second survey among 795 undergraduate students, Miller confirmed that levels of conformity to masculine norms, risk-taking behavior, and sport-related ("jock") identity significantly predicted the frequency of energy drink consumption.[44]

Berger et al reported ethnic and other differences between those who consume alcohol alone compared with energy drink users, or those who consume AmED.[31] These differences were noted by the authors, who then suggest subgroup targeting for health information. However, they fail to point out that the observed increase in "hazardous drinking" for the AmED group may be accounted for by intergroup differences alone (eg, age, ethnicity), rather than to AmED consumption.

A finding from several surveys has been that AmED consumption was associated with increased alcohol consumption.[27,28,46] These surveys show that research comparing different groups (eg, those who combine alcohol with energy drinks and those who do not) is always difficult to interpret, and can yield potentially biased results because baseline and other characteristics of the groups have not been controlled for and may differ significantly. This potential bias can be prevented by conducting research using a within-subject design, ie, comparing drinking occasions in the same subjects with and without energy drink consumption and using an appropriate sample size. This design was applied in a recent survey by Woolsey et al among athletes.[48] When comparing drinking habits of those who drink alcohol only (n = 165) and those who mixed alcohol with energy drinks (n = 150) these researchers showed that those who consumed AmED drank alcohol significantly more often, drank more alcohol on single occasions, reported more heavy drinking episodes, and had consumed twice the amount of alcohol during the past year when compared with the group that never mixed alcohol with energy drinks.

However, when looking at the group that combined energy drinks with alcohol, it was shown that on occasions when they did mix alcohol and energy drinks they consumed significantly less alcohol (6.28 drinks) when compared with occasions when they consumed alcohol without energy drinks (8.60 drinks) a reduction of 27%. Also, when reporting on the greatest number of alcoholic drinks consumed on a single occasion during the past year, the combined group reported significantly less alcohol consumption (10.83 drinks) when combining alcohol with energy drinks compared with a session of alcohol without energy drinks (18.23 drinks), ie, a reduction of 41%. Also, no significant within subject

differences were found on the major risk-taking items "taking risks", "being brave and daring", and "being likely to fight", whereas the statistically significant differences found for "acting aggressively" (2.46 versus 2.76) and "driving a motor vehicle" (1.57 versus 1.75) for alcohol versus AmED, respectively, reflect only small numerical differences and therefore have no clinical relevance.

Unfortunately, the authors concluded their article with a discussion of the potential dangers of energy drinks and a call for action to protect the public, and disregarded their own findings showing that alcohol consumption within subjects was substantially reduced when mixing alcohol with energy drinks.

Interestingly, recent onpremise studies reveal that the single focus on energy drinks as a mixer for alcohol may be unjustified and misplaced, because other caffeinated mixers such as cola beverages are more popular than energy drinks.[29,32,45] They showed that mixing alcohol with caffeinated cola (22.5%) was much more popular than mixing with energy drinks (6%). Breathalyzer assessment on leaving the bar revealed that BrAC levels were similar in those who consumed alcohol mixed with cola (BrAC 0.108%) or consumed AmED (BrAC 0.106%), and somewhat higher than found in those who consumed alcohol only (BrAC 0.091%). A recent survey confirmed these findings among Dutch students, when reporting on their latest night out that caused a hangover.[47] No difference in total alcohol consumption was found between those who consumed alcohol alone or AmED, whereas those who mixed alcohol with cola beverages consumed significantly more alcohol.

In conclusion, the specific nature of the relationship between energy drink consumption and alcohol consumption, if any, cannot be established from these surveys. The fact that two things occur together (ie, the presented correlations in the surveys between energy drink and alcohol consumption) does not imply that one causes the other.[50] More direct and reliable within-subject comparisons comparing occasions of alcohol intake both with and without energy drink consumption, such as performed by Woolsey et al,[48] are necessary to establish if there is an actual difference, and to what extent energy drinks influence alcohol consumption, or not.[50]

Discussion

Excessive and irresponsible consumption of alcoholic drinks has adverse effects on human health and behavior, but it should be clear that this is due to the alcohol, and not the mixer. When presenting their data, several authors fail to acknowledge that correlations between energy drink and alcohol consumption do not provide any cause-and-effect relationship.[50,51] Instead, they describe the "high" risk of combined use of energy drinks and alcohol[52] as "a growing problem"[3] or "a new hazard for adolescents",[53] without providing supportive scientific evidence, or they simply copy the conclusions of other authors without having a closer look at the methodology of the surveys and the way the data were analyzed and presented.[54] This way of presenting and interpreting scientific data may raise unsubstantiated concerns among consumers and parents about the use of energy drinks (alone or in combination with alcohol) and may actually trigger unjustified regulations in the absence of appropriate data. Some recent reviews have copied the conclusions of these authors, summarizing the data and its interpretation as offered by the authors that conducted these studies, draw unjustified conclusions, or present recommendations for legislation that are not supported by the available scientific data.[53–55]

However, other authors have commented on the current energy drink debate and disputed the conclusions drawn in these reviews.[50,51,56] Other criticism focuses on the methodology and setup of previous studies, some of which were underpowered or were not specifically designed to examine the association between energy drink consumption and alcohol consumption.[49] Given the limitations of these studies (summarized in Tables 2 and 3), Skeen and Glenn[56] concluded that there is an "imaginary link between alcoholism and energy drinks", and Verster and Alford[50] concluded that the concerns about energy drinks are not justified by the currently available scientific data. But most importantly, when judging articles on energy drinks mixed with alcohol, it should be kept in mind that correlation does not mean causation.[51]

In fact, there are many alternative explanations. Several surveys compared groups of subjects who do and do not combine alcohol with energy drinks. As some surveys on energy drink consumption suggested, it is possible that the groups of subjects that were compared already differed at baseline regarding the level of risk-taking behavior and other personality traits.[28,34,44,46,48] This may explain the observed differences in alcohol and drug use between the groups. People who are high risk-takers are more likely to exhibit life-style behaviors characterized by disinhibition and loss of moderation. These behaviors include increased frequency and amount of alcohol consumption, caffeine consumption, smoking, and recreational drug use, as well as gambling and engagement in risk-taking behavior.[57,58] Being a high risk-taker may then be the cause of increased alcohol consumption.

A significant association between levels of risk-taking behavior (measured as sensation-seeking, impulsivity, and related traits) has been reported for alcohol and drug use,[59,60] as well as energy drinks.[28,34,44,46,48] These surveys link the consumption of energy drinks with a risk-taking lifestyle that is already characterized by higher levels of alcohol consumption. In other words, a personality with higher levels of risk-taking behavior may be the primary reason for increased alcohol and drug abuse. The coconsumption of energy drinks is just one of the many expressions of such a lifestyle and personality.

Given that energy drink companies often market their products by relating them to extreme sports and adventurous activities, it is understandable that individuals who are attracted to energy drinks more often have a higher risk-taking profile.

Seven main conclusions can be drawn from the available scientific literature:

- There are currently insufficient properly controlled studies to draw any firm conclusions regarding the effects of energy drinks mixed with alcohol
- A relative minority of students occasionally mix energy drinks with alcohol, and there is no evidence that energy drinks are consumed more than other caffeinated drinks (eg, colas) combined with alcohol
- There is some evidence that energy drinks may antagonize some, but not all, aspects of alcohol-induced performance impairment
- There is no consistent evidence that energy drinks alter the perceived level of intoxication of people who mix energy drinks with alcohol
- Whilst there are associations between the levels of alcohol and energy drink consumption, there is no evidence that coconsumption of energy drinks causes increased alcohol consumption
- There is no direct evidence that coconsumption of alcohol and energy drinks initiates drug and alcohol dependence or abuse
- A personality with higher levels of risk-taking behavior may be the primary reason for increased alcohol and drug abuse. The coconsumption of energy drinks may be one of the many expressions of their lifestyle and personality type.

These conclusions are drawn from the limited evidence available at this time. Hence, more and better research is needed. Properly controlled clinical studies, surveys, and prospective studies are required before definite conclusions can be drawn. In order to define the effects of an energy drink, such clinical studies must include sessions of administration of both energy drink or placebo drink (ie, an energy drink without the active ingredients) as well as alcohol alone, and whenever possible applying a within-subject design. Such designs are more complex but essential if the focus is on the effects of energy drinks on alcohol consumption. Until these data are available, interventions with the primary goal of reducing alcohol consumption and related problems should focus on the availability and consumption of alcohol per se.

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COMMITTEE ON TOXICITY OF CHEMICALS IN FOOD, CONSUMER PRODUCTS AND THE ENVIRONMENT

COT Statement on the interaction of caffeine and alcohol and their combined effects on health and behaviour

Introduction

1. The Committee was asked by the Food Standards Agency to comment on concerns that caffeine in energy drinks may interact with alcohol[1] in causing adverse behavioural or toxic effects.

Background

2. Since 2004, energy drinks have been the fastest growing sector of the drinks market in the UK, with an average growth of 12% per year (BSDA, 2011). The popularity of consuming energy drinks mixed with alcoholic beverages has also increased, especially amongst young males. Moreover, individuals who consume high quantities of both energy drinks and alcohol, are perceived to engage in a greater degree of risk-taking. This has raised concerns about the health effects of caffeine and alcohol in combination. In particular, a phenomenon described as "wide awake drunk" has been postulated, in which the stimulatory effect of caffeine prevents consumers of alcohol from realising how intoxicated they are, thereby increasing the potential for toxic injury and adverse behavioural effects (Reissig et al, 2009). In a report by the Scottish Prisons Service, "Buckfast Tonic Wine", which contains substantial quantities of caffeine as well as 15% alcohol by volume, was linked with violence in young offenders in Scotland. Among a sample of 172 young offenders, 43% admitted consumption of Buckfast Tonic Wine before their most recent offence (Scottish Prisons Service, 2009). Most energy drinks contain levels of caffeine approximately equivalent to those found in coffee (approximately 80mg caffeine per 250ml can, although drinks with smaller volumes and higher caffeine concentrations have appeared on the market in recent years) along with other substances such as sugar, taurine and glucuronolactone.

3. The Scientific Committee on Food (SCF), which advised the European Commission before the creation of the European Food Safety Authority (EFSA), looked at the safety of energy drinks in 1999 and 2003 (SCF, 1999; SCF, 2003). As part of their second assessment, the SCF examined the evidence for a toxic interaction between caffeine and alcohol. They concluded that most studies

[1] In this document, the term alcohol will refer to ethanol present in alcoholic beverages.

suggested that caffeine would not exacerbate the adverse effects of alcohol, and that at lower blood alcohol levels, caffeine may improve performance of simpler tasks (SCF, 2003).

4. The SCF also looked at evidence for interactions between alcohol and other constituents of energy drinks such as taurine and glucuronolactone. They observed that both taurine and alcohol inhibit the release of the antidiuretic hormone vasopressin, and therefore might act in concert to increase loss of water and sodium from the body, leading to a short-term risk of dehydration. In a 13-week study in rats, taurine was shown to cause behavioural effects in all dose groups tested (300, 600 and 1000 mg/kg bw/day), including persistent increased activity, occasional chewing of limbs, and in the 1000mg/kg bw group only, a possible decrement (not statistically significant) in motor performance on a rotarod[2]. The lowest dose was equivalent to 6 times the mean acute intake from energy drinks (50mg/kg bw). The SCF concluded that some alcohol–taurine interactions were possible, including "behavioural interactions", but these were neither marked nor consistent in human and animal studies. The SCF was of the opinion that focused neurological studies should be carried out on taurine, and concluded that glucuronolactone would not be expected to interact with alcohol or other constituents of energy drinks.

5. The COT was asked to consider the literature published since the SCF opinion of 2003, and to advise on the potential for interactions between caffeine and alcohol.

Current European legislation on caffeine

6. Under European Directive *2002/67/EC on the labelling of foodstuffs containing quinine and foodstuffs containing caffeine*, beverages containing more than 150 mg/l caffeine (other than those based on coffee or tea) must carry the statement 'High caffeine content' in the same field of vision as the name of the product, followed by a reference in brackets to the caffeine content expressed in mg per 100ml. Under the new Food Information Regulation (EU 1169/2011), which comes into effect on the 13 December 2014, beverages containing more than 150 mg/l caffeine (other than those based on coffee or tea) must carry the statement 'High caffeine content. Not recommended for children or pregnant or breast feeding women' in the same field of vision as the name of the beverage, followed by a reference in brackets to the caffeine content expressed in mg per 100ml.

Consumption of caffeine

7. Caffeine (1,3,7-trimethyl xanthine) is probably the most widely used psychoactive substance worldwide (Benowitz, 1990). Its molecular structure is shown in Figure 1:

[2] Animals are trained to stay on a rotating bar which gradually accelerates. Animals that fall off receive a foot-shock. The speed of the rotating bar at which the animals fall off is taken as the performance score. Rotarod trials occur before and after treatment to compare performance.

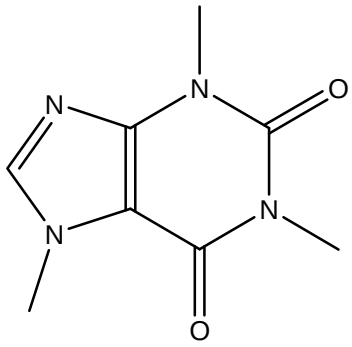

Figure 1: Caffeine

8. In 2004, the Dietary Caffeine and Health Study estimated a mean caffeine intake of 241mg/day in 6,000 individuals from the Bristol area who completed a questionnaire quantifying consumption of coffee, tea, chocolate products, cola drinks and energy drinks (Heatherley et al, 2006b; Heatherley et al, 2006a). This level of intake is similar to those indicated by a UK survey of consumption of coffee, tea and colas, carried out in 1988 – 3.98 mg/kg body weight per day (i.e. 279 mg/day for a 70 kg person) for the general population and 3.43 mg/kg body weight per day (i.e. 240 mg/day for a 70 kg person) for pregnant women (Barone and Roberts, 1996). In terms of instant coffee, this would be equivalent to 2-2.5 average sized mugs (260ml), assuming an average content of 100 mg caffeine per mug. The survey did not address other sources of caffeine such as chocolate, cold and flu remedies, headache treatments and energy drinks. In a more recent study, mean caffeine intakes were found to be 238 mg/day in women before they became pregnant, and reduced to 159 mg/day during pregnancy (CARE Study Group, 2008).

9. Recently, estimates of caffeine intake in the UK were derived from the rolling National Diet and Nutrition Survey (NDNS)[3]. These were based on the first two years of the survey and applied to respondents who reported consuming foods containing caffeine in 4-day food diaries (in which quantities were gauged approximately and not by weighing). The intake assessment was restricted to foods within 35 NDNS food groups that potentially contained caffeine (these included coffee, tea, cocoa, energy and soft drinks and dietary supplements). The caffeine content of dietary constituents was estimated from various sources, including information received from food manufacturers and earlier MAFF surveys (MAFF, 1998). The mean (± standard deviation) total caffeine intakes of men and women aged 19-64 were estimated to be 130 (±88) and 122 (±87) mg/d respectively. The corresponding figures for older men and women in the 65+ age range were 143 (±94) and 131 (±88) mg/d. Boys and girls in the age range of 11-18 years had lower intakes (46 (±43) and 44 (±45) mg/d) (Fitt et al, 2012). A breakdown of caffeine intake from caffeinated beverages in all NDNS respondents who reported consumption of such products indicated that coffee contributed more caffeine (49.5

[3] The NDNS provides detailed, quantitative information on food consumption, nutrient intakes, nutritional status and related characteristics. The NDNS is, in its current form, a four year rolling survey. The sample size for the survey is 500 adults and 500 children per year, covering people of all ages from 1½ years upwards living in private households. People living in institutions are not covered, and pregnant and lactating women are also excluded. The survey includes boosted samples in Scotland, Wales and Northern Ireland to enable cross-country comparisons. So far, only results from the first two years of the survey have been published (Department of Health, 2011).

(±32.3) mg/d) than tea (36.2 (±11.3) mg/d) and energy and soft drinks (34.5 (±21.4) mg/d). The inclusion of a larger range of products containing caffeine (e.g. chocolate products and energy drinks) in the recent analysis of NDNS data, as well as differences in the dietary assessment methods and in the assumed caffeine content of dietary constituents, may account for the differences in estimation of caffeine intake between different studies. High level intakes were not reported in these studies.

Biochemistry and psychopharmacology of caffeine

10. Caffeine is completely absorbed in the small intestine and the peak blood concentration occurs around 1-2 hours after ingestion. Caffeine is distributed throughout total body water and enters the brain quickly after absorption, but rate of metabolic clearance is variable, the half-life ranging from 2.3 to 9.9 hours in adults following single doses of caffeine (Arnaud, 2011), with a mean half-life of 4.3 hrs being reported in healthy non-smoking adult males (Seng, 2009). Extensive inter-individual variation occurs in caffeine metabolism due to factors such as alcohol and smoking habits, pregnancy, genetic polymorphisms and level of caffeine consumption. At low doses (<5mg/kg bw or 3-4 cups of coffee), pharmacokinetics can be represented accurately using a one-compartment model with first order absorption (Csajka et al, 2005). Metabolism of caffeine proceeds through three main pathways illustrated in Figure 2 (percentages refer to the mean proportion of caffeine converted to each metabolite). Some of the metabolites of caffeine themselves have pharmacological activity (Casarett et al, 1996).

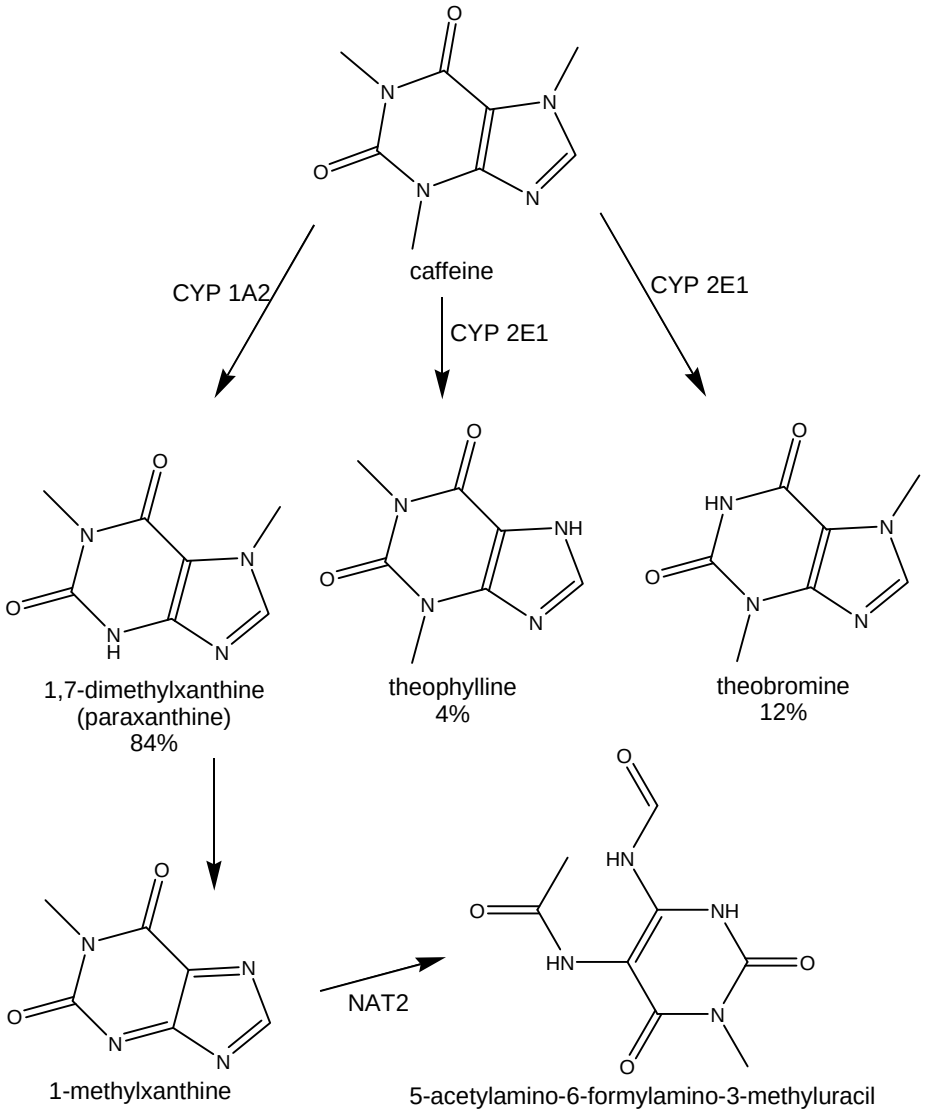

Figure 2: Metabolism of caffeine

11. Caffeine's primary biologically relevant mechanism of action is as a non-specific adenosine antagonist. Adenosine receptors are found throughout the body, and adenosine acts presynaptically to inhibit neuronal release of several neural transmitters, reduces spontaneous firing of neurons, produces sedation and has anticonvulsant activity (Benowitz, 1990). The pharmacologically active dose of caffeine can vary considerably between individuals as tolerance is rapidly developed to its effects. However, levels of 2-3 mg/kg bw have been shown to stimulate central nervous system activity in humans (FDA, 1978).

12. Adenosine is involved in a number of fundamental processes such as ATP-related energy production and RNA synthesis, but it is also released in response to metabolic stress and acts to protect the brain by suppressing neural activity (Latini and Pedata, 2001). Adenosine A_{2A} receptors are largely concentrated in the basal ganglia region and may be involved in the dopamine system (which is involved in reward and arousal). Adenosine may also be involved in the sleep-wake cycle (Basheer et al, 2004; Latini and Pedata, 2001).

13. Caffeine may also have secondary effects that are not related to adenosine, since it acts also as a competitive non-selective phosphodiesterase inhibitor, allowing the build up of cyclic AMP in cells and therefore modulation of many biological processes (Essayan, 2001).

14. In the central nervous system, caffeine acts primarily as a stimulant, increasing arousal and vigilance, reducing fatigue and decreasing motor reaction times in some tasks. At higher doses, caffeine can induce insomnia, anxiety, tremors, and seizures (Benowitz, 1990). The ADORAA2A 1083TT genotype of the adenosine A_{2A} receptor has been associated with lower caffeine intakes, suggesting a genetic link to the degree of caffeine consumption (Cornelis et al, 2007).

15. Studies carried out in adults showed improvements in aerobic endurance, anaerobic performance, choice reaction time, concentration and immediate-recall memory following consumption of an energy drink (80 mg caffeine, equivalent to 1.1 mg/kg bw for a 70 kg adult; (Alford et al, 2001), and 0.58, 1.70 or 1.75mg/kg bw (Howard and Marczinski, 2010)) in comparison with controls consuming a dummy energy drink or water. Following a mental depletion task (designed to require significant concentration on a number of tasks at one time), caffeine was found to increase aggression compared to placebo, but no effects were observed in groups which did not undertake the mental depletion task. In contrast, during a second experiment when a no pill control group was included along with the caffeine and placebo groups, no difference was observed in aggression between the caffeine and no-pill control groups, following the mental depletion task (Denson et al, 2011).

Consumption of alcohol

16. Alcohol is widely consumed in the UK with at least one alcoholic drink being reported as consumed in the week before interview by 68% of men and 54% of women in the 2009 General Lifestyle Survey carried out by the Office for National Statistics. In the same report, mean weekly consumption of alcohol in the 12 months before interview was 16.3 units for men and 8.0 units for women, equivalent to 2.33 g/kg bw for a 70kg man and 1.33 g/kg bw for a 60kg woman (Office of National Statistics, 2009). However, these data were for the total population, including those who did not drink alcoholic beverages, and the mean consumption of those who did drink alcohol would have been higher. During the week before interview, 37% of male participants exceeded the recommended limit for men of 4 units (32 g alcohol[4]) in a single day, and 29% of female participants exceeded the corresponding limit for women of 3 units (24 g alcohol).

Biochemistry and psychopharmacology of alcohol

17. Alcohol is rapidly absorbed from the stomach and intestine, and distributed widely through simple diffusion from blood into tissues. It is metabolised to acetaldehyde, primarily through the action of alcohol dehydrogenase (ADH) using the co-enzyme nicotinamide adenine dinucleotide (NAD), but also by CYP 2E1. Acetaldehyde is converted to acetic acid, through the action of the NAD-dependent enzyme acetaldehyde dehydrogenase (AcDH) (Casarett et al, 1996) (see Figure 3).

[4] www.drinkaware.co.uk. One unit of alcohol equals 8g pure alcohol.

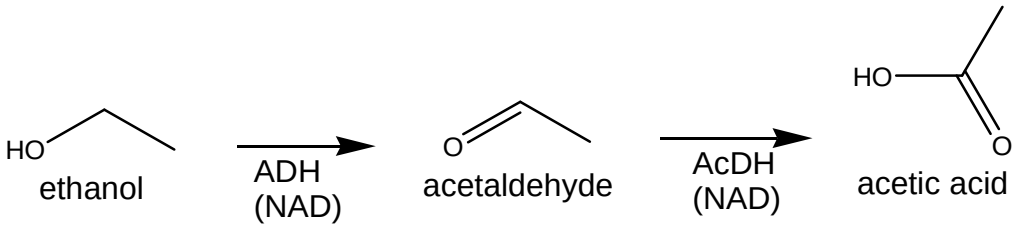

Figure 3: Metabolism of ethanol

18. Alcohol is a central nervous system depressant, but its mode of action has not been fully elucidated. It is thought to act in the central nervous system (CNS) by binding to the GABA-A receptor, which mediates rapid inhibitory neurotransmission throughout the CNS. The outward signs of alcohol intoxication, such as impaired sensory and motor function, slowed cognition and stupefaction, are a result of this receptor-binding activity (Kumar et al, 2009).

19. A major effect of alcohol is to impair inhibitory responses. It is thought that behaviour is governed by two distinct systems: one that activates a response and one that inhibits a response. As an example, in tests for behavioural inhibition, participants are required to respond appropriately to “go” signals on a computer, but when a “stop” signal is observed then they should inhibit their response. The impaired ability to inhibit responses when under the influence of alcohol has received much attention because of the social implications of excessive consumption (Marczinski and Fillmore, 2003). Doses of 0.62 g/kg bw absolute alcohol (43.4 g for a 70 kg adult) have been shown to reduce response inhibition using “stop/go” software as described above under laboratory conditions (Fillmore and Vogel-Sprott, 1999). The neuronal pathways directly responsible for the effects on response-inhibition are not clear.

20. Studies looking at the effects of lower doses of alcohol on attention tasks indicate that attention concentrated on a single source of information is not impaired by alcohol, but in divided attention tasks, especially those where two tasks follow each other closely, reaction time is increased (Moskowitz and Burns, 1971).

Co-consumption of alcohol, caffeine and other psychoactive substances

21. Accurate estimates of the extent to which alcohol and caffeine are consumed together are not available. One of the reasons for this is that drinks containing alcohol and caffeine are often sold separately and mixed by the consumer rather than being formulated in a single product – for example rum with cola or energy drinks with vodka.

22. Four studies looking at the energy drink and alcohol consumption of university students in the US and Canada showed an association between consumption of energy drinks and alcohol. Some of these studies investigated alcohol-related adverse incidents, and showed that high consumers of both energy drinks and alcohol were at greater risk of such incidents than consumers of alcohol alone (Arria et al, 2011; O'Brien et al, 2008; Price et al, 2010; Velazquez et al, 2011). One Canadian study found a significant association of combined energy drink and alcohol consumption with risk-taking behaviours, including consumption of illicit drugs

(Brache and Stockwell, 2011). In another study, general caffeine consumption in 12-13 year olds in high school was significantly associated with the use a year later, not only of caffeine, but also of nicotine and alcohol (Collins et al, 2011).

23. In a field study of 1255 bar patrons, individuals who consumed alcohol mixed with energy drinks were at three-fold increased risk of leaving a bar highly intoxicated and four-fold increased risk of intending to drive, when compared to other patrons who consumed alcohol but not mixed with energy drinks. The mean quantity of alcohol consumed by individuals who drank only alcohol was 95.3g, as compared with 108.3g for those who also consumed energy drinks but not mixed with the alcohol, and 152.2g for those who consumed alcohol mixed with energy drinks. Group sizes for those consuming energy drinks and alcohol were small (46 consumed both but not mixed and 45 consumed both mixed) (Thombs et al, 2010).

24. In contrast, in a survey of 1503 Dutch students, those who consumed alcohol with an energy drink consumed less alcohol than those who drank alcohol alone, although the difference did not reach statistical significance ($p=0.056$). Those who consumed alcohol with a cola beverage consumed significantly more alcohol than those who consumed alcohol alone ($p=0.001$) or those who combined energy drinks with alcohol ($p=0.001$). The group sizes for those consuming cola and energy drinks with alcohol were small; 45 and 24 respectively (Penning et al, 2011).

25. There has been some suggestion that high intake of caffeine might be a marker for the use of other drugs, both legal and illegal, and also for other addictive behaviours such as excessive gambling and excessive use of the internet (Arria et al, 2010; Istvan and Matarazzo, 1984; Kaminer, 2010; Pallanti et al, 2006).

26. Studies based on a cohort of male and female mono- and dizygotic twin pairs, looked at caffeine, smoking, alcohol and drug consumption habits. These investigations suggested that the association between high consumption of caffeine and alcohol depended on familial factors, which were primarily genetic. Modelling indicated two genetic factors – one linked to illicit drug use and the other to use of legal drugs including caffeine and alcohol (Hettema et al, 1999; Kendler et al, 2006; Kendler et al, 2007; Kendler et al, 2008). However, this finding has yet to be independently confirmed.

27. In a cohort of male di- ($n=183$) and monozygotic ($n=173$) twins, heavy consumption of alcohol and heavy smoking were significantly associated [phenotypic Pearson correlation $r=0.22$ ($p<0.001$)], as were heavy smoking and heavy coffee consumption [phenotypic Pearson correlation $r=0.28$ ($p<0.001$)]. In contrast, heavy consumption of coffee and alcohol were more weakly related [phenotypic Pearson correlation $r=0.14$ ($p<0.001$)] (Swan et al, 1997). Further comparisons between di- and monozygotic twins suggested that co-consumption of coffee and alcohol had a genetic basis, and co-consumption of alcohol, coffee and nicotine is determined in part by genetic predisposition (Swan et al, 1996).

28. In a population of 1925 patients who had voluntarily sought treatment for substance abuse disorders, a statistically significant relationship was found between the frequencies of using caffeine, nicotine and alcohol, but there was no significant association of exposure to caffeine and nicotine with exposure to other substances of abuse such as heroin, cannabis and glue (Kozlowski et al, 1993).

29. In a sample of 105 Israeli alcoholics undergoing treatment, caffeine and alcohol consumption were significantly correlated ($p<0.05$). When the sample was subdivided into those with (n=62) and those without (n=43) a family history of alcoholism (defined as at least one primary family member meeting the DSM-IV criteria for alcohol dependence) no differences were observed between the two groups in alcohol or caffeine consumption (Amit et al, 2004)

30. The balance of evidence suggests that higher intake of caffeine is associated not only with higher alcohol intakes but also with use of other psychoactive substances. There is limited evidence that the relationship may be determined, at least in part, by genetic predisposition. It appears that, at least in some population groups, there is a correlation between high consumption of alcohol and of energy drinks specifically. However, it is unclear whether this is because consumption of energy drinks causes people to drink more alcohol, or because people who are inclined to more risky behaviour tend generally to consume larger quantities of psychoactive substances, including caffeine and alcohol.

Health effects of co-consumption of alcohol and caffeine

31. It has been suggested that when consumed together, energy drinks and alcohol might interact in several ways (Weldy, 2010):

- Carbonation tends to increase the absorption of alcohol (although some non-carbonated energy drinks are available, the majority of sales are of carbonated products)
- Diluted alcohol is emptied from the stomach into the faster absorbing small intestine more quickly than alcohol at higher concentrations.
- Caffeine blunts the sedative effects of alcohol
- Caffeine prevents sleep, allowing greater opportunity for consumption of alcohol before loss of consciousness
- At low blood alcohol levels, caffeine appears to decrease some of the physical and mental impairment resulting from alcohol, although at higher blood alcohol levels no such effects are observed.
- Energy drink ingredients give the consumer a false sense of physical and mental competence and decrease their awareness of impairment by alcohol.

Does caffeine counteract the neuro-cognitive effects of alcohol consumption?

32. There is some evidence that caffeine can ameliorate some of the neuro-cognitive effects of alcohol, but the findings have not been consistent in all studies, and the underlying mechanisms are unclear. In a review of the data published up to 1988, the authors concluded that because of variation in the doses of caffeine and alcohol administered, the behavioural effects assessed, and other aspects of study design, it was not possible to determine whether there was a counteracting effect of caffeine (Fudin and Nicastro, 1988).

33. A number of studies published since the SCF opinion of 2003 have investigated the effects of combined alcohol and caffeine consumption on various aspects of neurological function. Doses ranged from 1.1 to 5.6 mg/kg bw for caffeine and 0.18 to 1.07 g/kg bw for alcohol. Many of these studies used driving simulators and doses of approximately 2-3 cups of coffee or 1-2 cans of energy drink with 1-2

standard measures of vodka. Results have been inconsistent, with some studies finding that caffeine did not antagonise the physiological effects of alcohol and others suggesting that some important aspects of alcohol intoxication were ameliorated, especially effects on motor reaction time, mean tracking performance and memory reaction time (Alford et al, 2012; Attwood et al, 2011; Azcona et al, 1995; Burns and Moskowitz, 1990; Ferreira et al, 2004; Ferreira et al, 2006; Fillmore et al, 2002; Fillmore and Vogel-Sprott, 1999; Hasenfratz et al, 1993; Howland et al, 2011; Kerr et al, 1991; Marczinski et al, 2011; Marczinski et al, 2012a; Marczinski et al, 2012b; Marczinski and Fillmore, 2003; Marczinski and Fillmore, 2006). Conflicting results have also been obtained in studies designed to test perceived degree of alcohol intoxication with and without caffeine. The most direct subjective ratings of intoxication[5] were no different when alcohol was consumed with and without caffeine. Where conflicts have been found, these were in less direct subjective[6] measures (Alford et al, 2012; Ferreira et al, 2006; Marczinski and Fillmore, 2006). A recent review concluded that the available literature did not support the argument that energy drinks mask the effects of alcohol intoxication and increase alcohol consumption (Verster et al, 2012). A more detailed description of the primary studies can be found in Annex 1.

34. In conclusion, the heterogeneity of methods and neurological end-points in reported studies prevents firm conclusions on whether caffeine counteracts the acute neuro-cognitive effects of alcohol. It should be noted that because of ethical constraints, the levels of alcohol consumed in these studies were relatively low.

Case reports of deaths and acute illness following consumption of caffeine alone or in combination with alcohol

35. Through a literature search, the National Programme on Substance Abuse Deaths has identified seven cases from the UK in which a coroner named caffeine alone (five cases) or in combination with alcohol (two cases) as a factor contributing to death. In another case report, the parents had linked the death of their son to caffeine consumption (Corkery, 2012). One study in the peer-reviewed literature describes acute renal failure following consumption of three litres of energy drink mixed with one litre of vodka (Schoffl et al, 2011).

36. Analysis of phone calls to the New South Wales Poisons Information Service over a seven year period revealed that of 297 calls concerning caffeinated energy drinks, 73% related to recreational exposures (others concerned accidental consumption by children or deliberate self-poisoning). The median age of the cases was 17 years. Co-ingestion of other substances was reported in 46% of calls relating to recreational exposure, most frequently alcohol (23% of recreational users) and other caffeine-containing products such as cola and caffeine tablets (20%). Features of serious toxicity such as hallucinations, seizures and cardiac ischaemia were described in 21 calls. Among the callers, 128 people sought or were advised to

[5] Examples of direct subjective measures on intoxication include participants being asked how many drinks they had consumed, for an estimate of blood alcohol or being asked to rate their level of intoxication on a scale ranging from least ever to most ever.

[6] Examples of less direct subjective measures of intoxication include participants being asked how competent they felt to drive a car or how fatigued they felt.

seek, urgent medical attention, of whom 70 had co-consumed other substances (Gunja and Brown, 2012).

37. Although some of the cases described in this section suggest acute toxic effects of caffeine and/or alcohol, they do not allow firm conclusions about the contribution of either substance or of whether caffeine increases the acute toxicity of alcohol.

Serious cardiac outcomes

38. In its opinions of 1999 and 2003, the SCF noted anecdotal reports of serious cardiac outcomes in young people following consumption of energy drinks with alcohol, but observed that the reports were incomplete and that consumption of energy drinks and alcohol often occurred in combination with other drugs, thus limiting the conclusions that could be drawn. The Committee identified one paper on cardiac effects of co-consumption of alcohol and caffeine that had been published since the SCF opinion (Wiklund et al, 2009). However, because of the small size of the study that it described, it did not allow useful conclusions.

The role of expectations

39. The Committee noted evidence that individuals' expectations of behavioural effects following consumption of alcohol and/or caffeine may lead them to behave differently when exposed (Fillmore et al, 2002; Fillmore and Vogel-Sprott, 1995; Harrell and Juliano, 2009). However, it was not clear how far psychological mechanisms of this sort contributed to behavioural outcomes following consumption of caffeine and alcohol in combination.

Conclusions

40. The increasing consumption of drinks containing caffeine mixed with alcohol has raised concerns about the physical and mental health effects of these psychoactive substances in combination. A phenomenon known as "wide awake drunk" has been suggested, in which the stimulatory effects of caffeine may prevent consumers of alcohol from realising how intoxicated they are, leading to increased risk of toxic injury and adverse behavioural effects such as increased risk-taking, violence and criminal activity.

41. The balance of evidence suggests that higher intake of caffeine is associated not only with higher alcohol intakes, but also with use of other psychoactive substances. There is limited evidence that the relationship may be determined at least in part, by genetic predisposition. It appears that, at least in some population groups, there is a correlation between high consumption of alcohol and of energy drinks specifically. However, it is unclear whether this is because consumption of energy drinks causes people to drink more alcohol, or because people who are inclined to more risky behaviour tend generally to consume larger quantities of psychoactive substances, including caffeine and alcohol.

42. A number of studies have suggested that caffeine can ameliorate some effects of alcohol, especially on motor reaction time, mean tracking performance and memory reaction time, but other investigations have failed to support this. The evidence that perceptions of alcohol intoxication are modified by caffeine is

conflicting. Overall, the heterogeneity of methods and neurological end-points in reported studies prevents firm conclusions on whether caffeine counteracts the acute neuro-cognitive effects of alcohol

43. Published case reports of deaths and acute illness following consumption of caffeine and alcohol in combination do not allow conclusions as to whether caffeine increases the acute toxicity of alcohol.

44. Individuals' expectations of behavioural effects following consumption of alcohol and/or caffeine may lead them to behave differently when exposed. However, it is unclear how far psychological mechanisms of this sort contribute to behavioural outcomes following consumption of caffeine and alcohol in combination.

45. Overall, the Committee concludes that the current balance of evidence does not support a harmful toxicological or behavioural interaction between caffeine and alcohol. However, because of limitations in the available data, there is substantial uncertainty, and if important new evidence emerges in the future, then this conclusion should be reviewed.

COT statement 2012/04
December 2012

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Annex 1: Studies on the effects of alcohol and caffeine on neurological function.

Reference	Caffeine dose	Alcohol dose	Observed effects
Alford et al, 2012	0, 2.2 mg/kg bw (energy drink)	0, 0.79 g/kg bw	Recognition reaction time slowed by alcohol alone (p=0.02) but similar to baseline following alcohol and caffeine consumption. Word memory was impaired by alcohol regardless of whether or not caffeine was co-consumed (p=0.001). Stroop test error rate was not increased by alcohol alone and was actually improved in the alcohol and energy drink group (p=0.028). Stroop completion times were decreased by energy drink (p=0.004) and were decreased further still by alcohol mixed with energy drink (p=0.024)
Attwood et al, 2012	0,2 mg/kg bw (dissolved caffeine powder	0, 0.6 g/kg bw	Subjective measures of intoxication did not differ between test and control groups. Caffeine appeared to antagonise the effects of alcohol on omission errors in the stop-signal task (p=0.016) but had no effect on simple reaction time (p=0.34) or performance of go – no-go tasks (P=0.95) and worsened the accuracy on the Stroop test (p=0.019).
Azcona et al, 1995	0, 5.6 mg/kg bw (encapsulated caffeine powder)	0, 0.8 g/kg bw	Simple Reaction Time increased by alcohol and ameliorated by caffeine ($p < 0.05$).
Burns & Moscowitz, 1990	0, 2.93, 5.87 mg/kg bw (encapsulated caffeine powder)	0, 0.5, 0.99 g/kg bw	Alcohol had effects on alertness, tracking, visual search, reaction time and information processing. Caffeine ameliorated all but information processing (none of the results were statistically significant).
Ferreira et al, 2004	1.14 mg/kg bw (energy drink)	0.3 g/kg bw	Following a physical test on a cycle ergometer, no differences were observed in physical parameters between the alcohol group and the alcohol and energy drink group.
Ferreira et al, 2006	1.14 mg/kg bw (energy drink)	0, 0.18, 0.3 g/kg bw	Alcohol and energy drink consumed together did not reduce deficits in objective motor co-ordination (p=0.11) and visual reaction time (p=0.12) caused by alcohol alone.

Fillmore, Roach and Rice, 2002	0, 4 mg/kg bw (dissolved caffeine powder)	0.65 g/kg bw	Groups led to expect that caffeine would counteract the effects of alcohol showed greater impairment of performance in a pursuit rotor task than groups led to expect no such counteracting effect ($p=0.037$). No significant differences were found in subjective measures of intoxication between the groups consuming caffeinated and non-caffeinated drinks.
Fillmore & Vogel-Sprott, 1999	0, 4.4 mg/kg bw (dissolved caffeine powder)	0, 0.62 g/kg bw	No effects observed on reaction time. Mean number of inhibitions was significantly reduced following alcohol consumption compared to baseline whereas following alcohol and caffeine consumption number of inhibitions was higher than baseline ($p<0.002$).
Hasenfratz et al, 1993	0, 3.3 mg/kg bw (dissolved caffeine powder)	0, 0.7 g/kg bw	In a rapid information processing (RIP) task, mean reaction time and processing rate were improved by caffeine ($p<0.01$; $p<0.05$); the reaction time was increased by alcohol ($p<0.05$); the combination of alcohol and caffeine did not differ from baseline suggesting that caffeine was able to offset the alcohol induced performance decrements.
Howland et al, 2011	0, 5.47 (men), 5.63 (women) mg/kg bw (Dissolved caffeine powder)	0, 1.07 (men), 0.92 (women) g/kg bw	Alcohol significantly impaired driving and sustained attention/reaction time. Caffeine did not appear to antagonise the effects of alcohol. No significant differences were found in subjective measures of intoxication between the groups consuming caffeinated and non-caffeinated drinks.
Kerr, 1991	0, 5 mg/kg bw (encapsulated caffeine powder)	0, 0.18 g/kg bw	Caffeine appeared to antagonise the effect of alcohol on short term memory and choice reaction time (not statistically significant) and mean tracking performance ($p<0.05$). No effects were observed on critical flicker fusion (measures arousal).
Marczinski and Filmore, 2003	0, 2, 4 mg/kg bw (dissolved caffeine powder)	0, 0.65 g/kg bw	Alcohol impaired inhibitory and activational aspects of behavioural control. Caffeine antagonised response activation ($p=0.03$) but not inhibition ($p>0.81$).
Marczinski and Filmore, 2006	0, 2, 4 mg/kg bw (dissolved	0, 0.65 g/kg bw	Alcohol impaired the speed of reaction time and accuracy of response in go/no-go and auditory discrimination tasks. Caffeine antagonised

	caffeine powder)		the effects of alcohol on speed of reaction time ($p<0.02$), but not accuracy ($p>0.15$).
Marczinski et al, 2011.	0, 1.2 mg/kg bw (energy drink)	0, 0.65 g/kg bw	Alcohol impaired the inhibitory failures and response times compared to placebo in a cued go/no-go task. Caffeine ameliorated some impairment of response times ($p<0.05$) but not inhibition ($p>0.27$).
Marczinski et al, 2012a	0, 0.6 mg/kg bw (energy drink)	0, 0.36 g/kg bw	Subjective measurements of intoxication were not significantly different between those consuming alcohol alone and in combination with caffeine. Subjects consuming energy drink and alcohol were more likely to feel motivation to consume more alcohol at 10, 20, 40 and 60 mins after dosing ($p<0.01$) compared to baseline, whereas the alcohol alone group felt motivation only 10 and 20 minutes after dosing ($p=0.01$).
Marczinski et al, 2012b	0, 1.2 mg/kg bw (energy drink)	0, 0.65 (men), 0.57 (women) g/kg bw	Subjective measurements of intoxication were not significantly different between those consuming alcohol alone and in combination with caffeine, but there were non-significantly reduced perceptions of mental fatigue and stimulation in the caffeine and alcohol group compared with the alcohol alone group. Alcohol slowed dual task information processing and impaired simple and complex motor co-ordination. No antagonistic effects were observed from caffeine.

Annex Two: Search Criteria and databases used

As the Scientific Committee on Food (SCF) looked at alcohol and caffeine interactions in 2003, only references published after this time were included in the literature review. Some references that were not included by the SCF but published prior to 2003 came to light through searching the reference lists of later papers. When considered relevant, these were also reviewed. Because of the availability of human studies, animal studies were not considered unless they were considered particularly relevant.

Searches using Pubmed

Caffeine, alcohol, behaviour (limits 01/01/2003-present)

Caffeine, alcohol, interactions (limits 01/01/2003-present)

Energy drinks, alcohol, behaviour (limits 01/01/2003-present)

Energy drinks, alcohol, interactions (limits 01/01/2003-present)

Caffeine, alcohol, behaviour (limits 01/01/2003-present; human studies only)

Caffeine, alcohol, interactions (limits 01/01/2003-present; human studies only)

Energy drinks, alcohol, behaviour (limits 01/01/2003-present; human studies only)

Energy drinks, alcohol, interactions (limits 01/01/2003-present; human studies only)

Searches using Google Scholar

All in title: Caffeine, alcohol, (NOT rat, mice) (since 2003, articles excluding patents)

All in title: “Energy drinks”, alcohol, (NOT rat, mice) (since 2003, articles excluding patents)

February 2012

Caffeine

- What is **caffeine**?
- How does the **body process** caffeine?
- What are the **risks**?
- Why did EFSA carry out its **risk assessment?**
- What does the assessment **cover?**
- **How much** caffeine do we consume?
- How much caffeine is it **safe** to consume?
- **How much caffeine** is there in…
- Does caffeine have an **adverse effect** when consumed with other constituents of "energy drinks" and/or with alcohol?

What is **caffeine**?

Caffeine is a naturally occurring chemical compound found in plant constituents such as coffee and cocoa beans, tea leaves, guarana berries and the kola nut, and has a long history of human consumption. It is added to a variety of foods, such as baked pastries, ice creams, sweets, and cola drinks. Caffeine is also found in so-called energy drinks, alongside other ingredients such as taurine, and D-glucurono-γ-lactone. It is also present in combination with *p*-synephrine in a number of food supplements that are marketed for weight loss and sports performance. Some medicines and cosmetics contain caffeine.

When consumed by humans, caffeine stimulates the central nervous system, and in moderate doses increases alertness and reduces sleepiness.

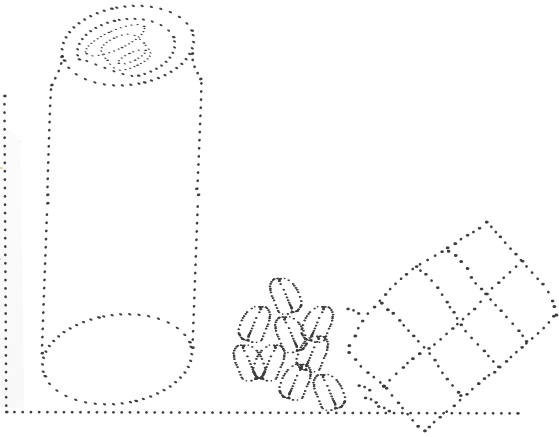
Caffeine is also found in so-called energy drinks, alongside other ingredients such as taurine, and D-glucurono-γ-lactone.

How does the **body process** caffeine?

Taken orally, caffeine is absorbed rapidly and completely by the human body. The stimulatory effects may begin 15 to 30 minutes after ingestion and last a number of hours. In adults the half-life of caffeine – the time it takes for the body to eliminate 50% of the caffeine – varies widely, depending on factors such as age, body weight, pregnancy status, medication intake and liver health. In healthy adults, the average half-life is approximately four hours, with a range of two to eight hours.

What are the **risks?**

Short-term adverse effects on adults and children can include issues related to the central nervous system such as interrupted sleep, anxiety and behavioural changes. In the longer term, excessive caffeine consumption has been linked to cardiovascular problems and, in pregnant women, stunted foetus development.



Why did EFSA carry out its **risk assessment?**

Some EU Member States raised concerns about the safety of caffeine consumption in the general population and in specific groups, such as adults performing physical activity, and individuals consuming caffeine together with alcohol or substances found in energy drinks. The European Commission responded by asking EFSA to assess the safety of caffeine.

What does the assessment **cover?**

EFSA's Scientific Opinion looks at the possible adverse health effects of caffeine consumption from all dietary sources, including food supplements:

- in the general healthy population and in sub-groups such as children, adolescents, adults, the elderly, pregnant and lactating women, and people performing physical exercise;
- in combination with other substances that are present in "energy drinks" (D-glucurono-γ-lactone and taurine), alcohol, or *p*-synephrine.

It does not consider the possible adverse effects of caffeine:

- in groups of the population affected by a disease or medical condition;
- in combination with medicines and/or drugs of abuse;
- in combination with alcohol doses which, by themselves, pose a risk to health (e.g. during pregnancy, binge drinking).

How much caffeine do we consume?

Average daily intakes vary among Member States, but are in the following ranges:

Very elderly (75 years and above):	**22-417mg**
Elderly (65-75 years):	**23-362mg**
Adults (18-65 years):	**37-319mg**
Adolescents (10-18 years):	**0.4-1.4mg/kg bw**
Children (3-10 years):	**0.2-2.0mg/kg bw**
Toddlers (12-36 months):	**0-2.1mg/kg bw**

In most surveys covered by EFSA's Food Consumption Database (see panel overleaf), coffee was the predominant source of caffeine for adults, contributing between 40% and 94% of total intake. In Ireland and the United Kingdom, tea was the main source, contributing 59% and 57% of total caffeine intake respectively.

There are large differences among countries regarding the contribution of different food sources to total caffeine intake among adolescents. Chocolate was the main contributor in six surveys, coffee in four surveys, cola beverages in three, and tea in two. In most countries chocolate (which also includes cocoa drinks) was the predominant source of caffeine for children aged 3 to 10 years, followed by tea and cola drinks.

One reason for the differences in consumption levels – other than cultural habits – is the variable concentrations of caffeine found in some food products. Concentrations in coffee beverages depend on the manufacturing process, the type of coffee beans used, and the type of preparation (e.g. drip coffee, espresso). The levels found in cocoa-based beverages depend on the amount and type of cocoa present in different brands.

How much caffeine is it **safe** to consume?

On the basis of the data available, EFSA's Panel on Dietetic Products, Nutrition and Allergies (NDA) reached the following conclusions:

Adults

- Single doses of caffeine up to 200mg – about 3mg per kilogram of body weight (mg/kg bw) from all sources do not raise safety concerns for the general healthy adult population. The same amount of caffeine does not raise safety concerns when consumed less than two hours prior to intense physical exercise under normal environmental conditions. No studies are available in pregnant women or middle aged/elderly subjects undertaking intense physical exercise.
- Single doses of 100mg (about 1.4mg/kg bw) of caffeine may affect sleep duration and patterns in some adults, particularly when consumed close to bedtime.
- Intakes up to 400mg per day (about 5.7mg/kg bw per day) consumed throughout the day do not raise safety concerns for healthy adults in the general population, except pregnant women.

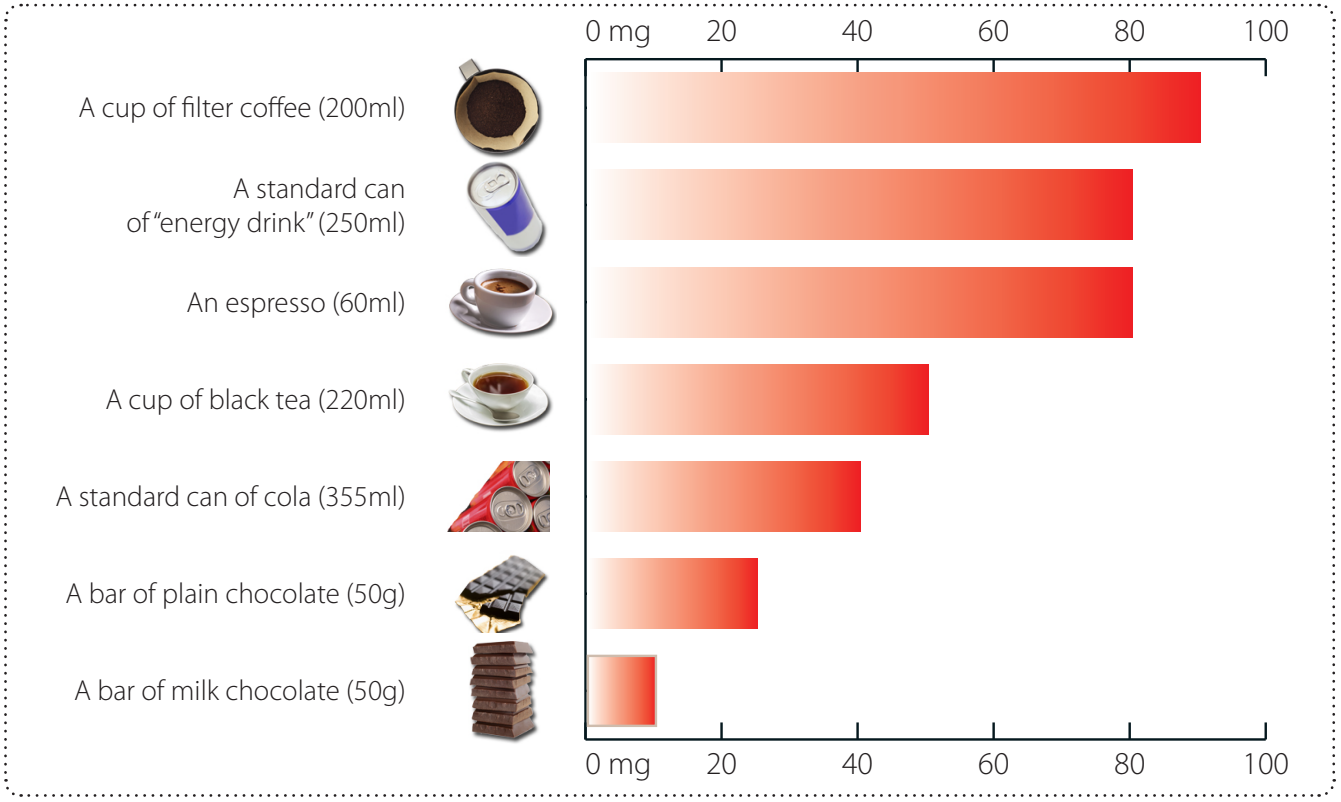
Pregnant/lactating women

Caffeine intakes from all sources up to 200mg per day consumed throughout the day do not raise safety concerns for the foetus.

Children and adolescents

The single doses of caffeine considered to be of no concern for adults (3mg/kg bw per day) may also be applied to children, because the rate at which children and adolescents process caffeine is at least that of adults, and the studies available on the acute effects of caffeine on anxiety and behaviour in children and adolescents support this level. A safety level of 3mg/kg bw per day is also proposed for habitual caffeine consumption by children and adolescents.

How much caffeine is there in…



All figures are approximate as caffeine content and portion sizes vary within and between countries

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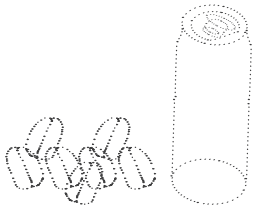
Does caffeine have an **adverse effect** when consumed with other constituents of "energy drinks" and/or with alcohol?

- Consumption of other constituents of "energy drinks" at concentrations commonly present in such beverages would not affect the safety of single doses of caffeine up to 200mg.
- Alcohol consumption at doses up to about 0.65g/kg bw, leading to a blood alcohol content of about 0.08% – the level at which you are considered unfit to drive in many countries – would not affect the safety of single doses of caffeine up to 200mg. Up to these levels of intake, caffeine is unlikely to mask the subjective perception of alcohol intoxication.



How did EFSA calculate consumption levels?

First, EFSA used a survey conducted in the UK to calculate caffeine levels in different food products. This survey contained information on caffeine concentrations from 400 samples of teas – loose leaves, bags, vending machines, and instant tea – and coffees – filter coffee, vending machines, espresso, and instant coffee – prepared at home, in workplaces or bought in cafes and other retail outlets. For foods for which the UK survey did not report caffeine levels, an average of mean values reported in other representative surveys was used, except for "energy drinks", for which the caffeine concentration (320mg per litre) of the most popular brand was chosen.

The EFSA Food Consumption Database was then used to calculate caffeine intake from food and beverages. The database contains data from 39 surveys in 22 European countries covering 66,531 participants. These surveys do not provide information about the consumption of caffeine-containing food supplements. A 2013 EFSA report was used to calculate acute caffeine intakes from "energy drinks" in adults.

You can read the full EFSA Scientific Opinion on the safety of Caffeine at http://www.efsa.europa.eu/en/publications/efsajournal.htm

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Review

Effects of mixing alcohol with caffeinated beverages on subjective intoxication: A systematic review and meta-analysis

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ABSTRACT

It has been suggested that mixing alcohol with energy drinks or other caffeinated beverages may alter the awareness of (or 'mask') intoxication. The proposed reduction in subjective intoxication may have serious consequences by increasing the likelihood of engaging in potentially dangerous activities while intoxicated. A literature search was conducted to collect all studies measuring subjective intoxication after administration of alcohol with energy drinks, or with other caffeinated alcoholic drinks compared with alcohol alone. The studies were critically reviewed and, where possible, included in a meta-analysis in order to determine whether masking exists after mixing alcohol with caffeinated beverages. Sixteen articles were identified, of which nine could be used for the meta-analysis. When including the higher caffeine dose studies, the meta-analysis revealed no significant masking effect ($p = 0.404$). Similarly, when including the lower caffeine dose studies, no significant masking effect was found ($p = 0.406$). Despite the large range of caffeine doses (2.0–5.5 mg/kg resulting in absolute levels of 46–383 mg) and alcohol levels 0.29–1.068 g/kg (resulting in blood alcohol concentration (BAC) from 0.032 to 0.12%) investigated, caffeine had no effect on the judgement of subjective intoxication.

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1. Introduction

There is debate regarding the alleged risks of consuming alcohol mixed with energy drink (AMED) consumption (Verster et al., 2012). A major concern is the proposition that when consuming AMED people may not be aware of their level of intoxication (Curry and Stasio, 2009; Attwood et al., 2012). Specifically co-consuming energy drinks may partially reverse subjective intoxication, an effect known as 'masking', leading to increased alcohol-related problems. The proposed rationale for this hypothesis is that the stimulant effects of caffeine, one of the functional ingredients of energy drinks, may counteract the sedative effects of alcohol. This could lead to individuals becoming 'uncalibrated' and feeling less intoxicated than they actually are, but with the functional impairment associated with alcohol remaining. If a masking effect exists, it would not be without consequences. If people underestimate their level of intoxication after consuming AMED or alcohol and caffeine compared to alcohol only, they may be more likely to engage in potentially dangerous alcohol-related activities.

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0149-7634/

Driving after consuming alcohol is an example of such an activity, because it is well-known that the risk of having a car-accident is significantly related to the amount of alcohol consumed (Penning et al., 2010). The potential dangers of misperception or 'masking' after consuming alcohol mixed with energy drink are evident when considering driving. If a person had a blood alcohol concentration (BAC) of 0.10% but subjectively experienced intoxication similar to a BAC of only 0.04% then they may feel fit to drive when in fact being seriously impaired (typical maximum legal limits for Europe and the USA 0.05–0.08%). This example illustrates the need for a critical review of the literature on subjective intoxication.

This issue is very much on the public agenda with the increased consumption of energy drinks in young adults who regularly mix energy drinks with alcohol (Malinauskas et al., 2007). The concept of masking also raises the question of whether co-consumption of CNS stimulants and depressants are mutually antagonistic at the behavioural and/or subjective level.

The purpose of the current paper is therefore to review the available scientific evidence and perform a meta-analysis on studies that measured subjective intoxication after administration of alcohol mixed with caffeinated beverages, and was therefore was restricted to studies where a direct measure of subjective intoxication was included. Since caffeine is the ingredient that is widely regarded as responsible for any masking effect, the current review includes studies where alcohol was mixed with energy drink (AMED), and studies that mixed alcohol with other caffeinated beverages.

2. Methods

A literature search was conducted (14th October, 2013) to capture all studies measuring subjective intoxication after administration of alcohol only compared with after AMED (or other caffeinated alcoholic drinks). To this end, PubMed and Embase were searched using the key words "alcohol" AND "caffeine", AND "intoxication". Additional searches were performed replacing "caffeine" with "energy drinks", and adding the keywords "drunkenness", and "masking". Cross references were checked for additional potentially relevant papers and the internet was searched for unpublished studies. To be included, studies had to be double-blind, controlled trials, conducted in healthy volunteers, and include a measure of subjective intoxication.

The meta-analysis was performed using the software programme *Comprehensive Meta-analysis* (Biostat Inc., Englewood, NJ) as described by (Borenstein and Rothstein, 1999). Studies were included if the mean (SD) and sample size was reported or could be retrieved otherwise from the paper or through contacting authors. The effect sizes (ES) were calculated for each of the caffeinated alcoholic drink versus alcohol only comparisons, using standardized mean differences of subjective intoxication scores. When computing the effect size, differences between AMED/caffeine plus alcohol and alcohol only conditions were weighted according to the number of subjects that participated in each study. In addition, the ninety-five percent confidence interval (95% CI) was computed for each ES. If the confidence interval did not include zero, the ES was considered statistically significant ($p < 0.05$).

Homogeneity/heterogeneity analyses were performed to determine if each individual ES had the same distribution as the combined overall ES. In a homogenous distribution, the dispersion of effect sizes around their mean is not greater than that expected from sampling error alone. If the Q statistic resulting from this analysis is not significant ($p \geq 0.05$), a homogenous distribution can be assumed and a fixed effects model to perform the meta-analysis is justified. However, if the Q statistic is significant ($p < 0.05$), variation in effect size is greater than would be expected from subject-level sampling error alone, and a random effects model is applied correcting for additional variation between the studies (Lipsey and Wilson, 2000). Meta-analysis requires that from each clinical trial only one AMED versus alcohol only comparison can be included. Therefore, if studies included more than one comparison between AMED and alcohol only, the comparison corresponding to the higher caffeine dose was included. A second meta-analysis was conducted including the lower doses of caffeine.

3. Results

Fig. 1 presents the PRISMA flowchart illustrating each stage of the literature search.

The literature search revealed 16 relevant publications. Qualitative analysis led to the exclusion of seven of these. Three studies did not measure subjective intoxication directly, rather it was inferred by other intoxication-related symptoms (Liguori and Robinson, 2001; Ferreira et al., 2006; Alford et al., 2012). Four studies did not provide sufficient data for inclusion in the meta-analysis (Azcona et al., 1995; Marczinski and Fillmore, 2003; Attwood et al., 2012; Rush et al., 1993). The remaining nine articles were included in the meta-analysis (Fillmore and Vogel-Sprott, 1999; Fillmore et al., 2002; Marczinski and Fillmore, 2006; Howland et al., 2010; Marczinski et al., 2011, 2012a,b; Heinz et al., 2013; Peacock et al., 2013).

3.1. Excluded studies

Liguori and Robinson (2001) tested healthy volunteers who consumed 0.6 g/kg alcohol (for a target BAC of 0.08%) alone and with two levels of caffeine (absolute doses of 200 mg and 400 mg). The study did not include a direct measure of subjective intoxication. Outcome measures included the profile of mood states (POMS) and ten visual analogue scales (VAS) gauging int5oxication-related states including 'alert', 'feel a drug effect' and 'being high'. Ratings on these scales did not differ significantly between alcohol-alone and the alcohol–caffeine conditions.

Ferreira et al. (2006) did not include any direct measure of subjective intoxication. Instead, they administered 18 VAS items; Bond and Lader's (1972) visual analogue scales of somatic symptoms (ASSS) presented with an additional five items ('agitation', 'alterations in motor coordination', 'hearing and speech' and 'sensation of well-being'). These were completed following 0.6 g/kg or 1.0 g/kg alcohol (producing peak BAC of 0.05% and 0.10% respectively), with or without 3.57 ml/kg red bull energy drink (corresponding to 1.14 mg/kg caffeine). When compared with alcohol alone, AMED consumption reduced the perception of three items, specifically 'headache', 'dry mouth', and 'alterations in motor coordination'. There were no significant difference between AMED and alcohol alone on any of the other 15 measures. Including those which may be closely related to subjective intoxication (for example 'dizziness', 'tiredness', 'alterations in sight', 'alterations in walking', and 'well-being').

Alford et al. (2012) administered alcohol at two levels (producing BAC levels of 0.046% and 0.087%) over two drinks mixed with Red Bull energy drink (each containing 80 mg caffeine) or placebo. No direct measure of subjective intoxication was included. Comparison of the energy drink group ($N = 10$) with placebo group ($N = 10$) revealed no differences between alcohol-alone and AMED on measures of 'clearheaded', 'clumsy', 'drowsy', 'energetic', and 'mentally slow'.

Rush et al. (1993) examined behavioural and cardiac effects of 0.5 and 1.0 g/kg alcohol (producing BACs of approximately 0.03 and 0.1%) with and without caffeine (equivalent to absolute doses of 250 mg and 500 mg per 70 kg) in eight participants. Intoxication-related measures included 'drunkenness' and 'drug strength' which

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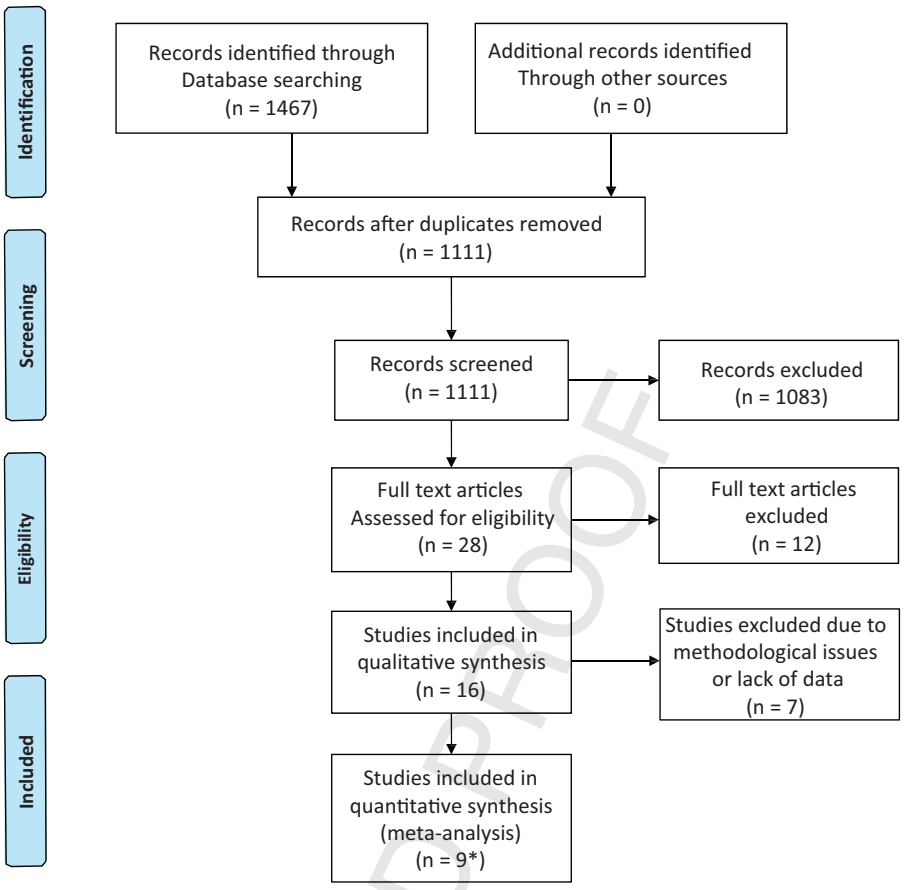

Fig. 1. PRISMA flow diagram showing number of articles at each stage of the search. *Note that the nine articles include the two studies from Marczinski and Fillmore (2006).

were measured using 100-mm visual-analogue scales. The publication does not contain sufficient detail to be included in the meta-analysis. There were no significant differences between the alcohol-alone and alcohol–caffeine conditions on either VAS measure.

Attwood et al. (2012) examined the effects of 0.6 g/kg alcohol with or without caffeine (2 mg/kg) in 28 healthy volunteers. Subjective intoxication was measured using a 100-mm scale ranging from 'not at all' to 'extremely' intoxicated. Not enough data were provided in the paper to allow inclusion in the meta-analysis. Subjective intoxication did not differ significantly between the alcohol-alone and alcohol–caffeine conditions at either 10 min post-ingestion or following a subsequent behavioural test battery.

In a double-blind, crossover trial in eight healthy volunteers, (Azcona et al., 1995) used a VAS to determine subjective feelings of 'sober-drunk' after administration of alcohol (0.8 mg/kg) and caffeine (400 mg) both alone and in combination according to a double placebo factorial design. Not enough detail is presented to allow inclusion in the meta-analysis. Both the alcohol-alone and the alcohol–caffeine condition significantly increased feelings of drunkenness when compared to double placebo and caffeine alone. There was no significant difference between the alcohol-alone and alcohol–caffeine conditions at any time point.

In a study investigating behavioural control, Marczinski and Fillmore (2003) administered two doses of caffeine (2.0 mg/kg and 4.0 mg/kg), one dose of alcohol (0.65 g/kg) and placebo of both caffeine and alcohol over six testing sessions. Outcome measures included subjective intoxication as measured using the Beverage Rating Scale. The manuscript contains insufficient information to allow inclusion in the meta-analysis, however there were no significant differences in perceived intoxication between the alcohol-alone and alcohol–caffeine conditions.

3.2. Included studies

The characteristics of the nine studies (including two caffeine doses employed in Marczinski's (2006) study which were included in the meta-analysis) are presented in Table 1. Alcohol doses were typically 0.65 g/kg (for 5 out of 9 studies including one study which used the dose twice) and ranged from 0.29 to 1.068 g/kg. These produced peak BAC (%) ranging from 0.032 to 0.12. Caffeine doses ranged from 0.6 to 5.5 mg/kg. Subjective intoxication was measured using a variety of means. The Beverage Rating Scale (BRS) was used in six studies (Fillmore and Vogel-Sprott, 1999; Marczinski et al., 2011, 2012a,b; Marczinski and Fillmore, 2006; Peacock et al., 2013). The BRS gauges perceived intoxication in terms of equivalence to subjective experience of consumption of bottles of beer containing 5% alcohol. The scale ranges from 0 to 10 bottles of beer, in 0.5-bottle increments. One study employed a 'feel any effects' VAS (Fillmore et al., 2002), while Howland et al. (2010) asked subject to estimate their current BAC using the self estimate of blood alcohol concentration (SEBAC) scale. Heinz et al. (2013) administered a Subjective Intoxication Scale (SIS), a 10-point scale ranging from 1 ('not at all intoxicated') to 10 ('as intoxicated as I've ever been').

Over the past 15 years, Marczinski and Fillmore have conducted a series of studies examining the interaction between alcohol and caffeine with different BAC levels and caffeine dosages. Participants completed the Beverage Rating Scale to report their perceived intoxication (Marczinski and Fillmore, 2003, 2006; Fillmore and Vogel-Sprott, 1999; Fillmore et al., 2002; Marczinski et al., 2011,

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Table 1
Characteristics of the studies included in the meta-analysis.

Study	Alcohol (g/kg)	Peak BAC (%)	Caffeine (mg/kg)	Design	Alcohol-alone		Alcohol + caffeine		Primary aim of study	Scale
					N	Rating	N	Rating		
Fillmore and Vogel-Sprott (1999)	0.62	0.073	4.4	B	7	5.21 (2.18)	7	5.23 (1.68)	Effects of alcohol/caffeine on impaired inhibitory control	BRS (0–10)
Fillmore et al. (2002)	0.65	0.079	4.0	B	7	55.8 (9.1)	7	58.2 (6.3)	Manipulation of caffeine expectancy in alcohol	"Feel any effects" VAS (0–100)
Marczinski and Fillmore (2006) lower caffeine	0.65	0.071	2.0	W	12	5.4 (2.3)	12	4.6 (2.4)	Caffeine/alcohol effects on information processing	BRS (0–10)
Marczinski and Fillmore (2006) higher caffeine	0.65	0.071	4.0	W	12	5.4 (2.3)	12	4.8 (1.7)	Caffeine/alcohol effects on information processing	BRS (0–10)
Marczinski et al. (2011)	0.65	0.08	1.2	B	14	3.61 (1.62)	14	3.32 (1.6)	Effects of energy drink on alcohol impairment of behavioural control	BRS (0–10)
Howland et al. (2010)	1.068	0.12	5.0	B	35	0.1 (0.02)	28	0.11 (0.02)	Effects of caffeine on alcohol impairement of driving, sustained attention/RT	Self estimate BAC (0–0.15%)
Marczinski et al. (2012a)	0.65	0.064	1.2	B	18	3.53 (1.59)	18	3.28 (1.36)	Energy drink/alcohol on information processing, motor coordination, subjective intoxicaiton	BRS (0–10)
Marczinski et al. (2012b)	0.29	0.032	0.6	B	20	2.95 (1.59)	20	2.2 (1.01)	Energy drink/alcohol effects on motivation for more alcohol	BRS (0–10)
Heinz et al. (2013)	NR	0.088	M – 5.5 F – 5.0	B	72	4.65 (1.66)	74	4.11 (1.46)	Effects of either caffeinated alcohol or expectation of, on risk behaviour	SIS (1–10)
Peacock et al. (2013)	0.5	0.068	3.57	W	28	2.8 (1.0)	28	2.9 (1.2)	Energy drink/alcohol effects on risk-taking	BRS (0–10)

Mean levels of alcohol and caffeine administration are presented as absolute mean ratings of subjective intoxication (with standard deviations in parentheses). Abbreviations: NR, not reported; M, male; F, female; B, between-subjects; W, within-subjects; BAC, blood alcohol concentration; *N*, number of subjects; BRS, Beverage Rating Scale; SIS, Subjective Intoxication Scale.

2012a,b). In these studies, the Beverage Rating Scale (BRS) was completed approximately 1 h after treatment administration to coincide with peak BAC and caffeine levels.

Fillmore and Vogel-Sprott (1999) administered 0.62 g/kg alcohol to four groups of seven young males while one group received placebo. Of the four groups receiving alcohol, two were co-administered caffeine (4.4 mg/kg) and intoxication was measured using the Beverage Rating Scale. There were no significant group differences.

Fillmore et al. (2002) examined subjective intoxication after administering 0.65 g/kg alcohol and 2.0 and 4.0 mg/kg caffeine. Neither dose of caffeine had a significant effect on the Beverage Rating Scale measure of subjective intoxication. In 2006, Marczinski and Fillmore again examined subjective intoxication after administering 0.65 g/kg alcohol and 2.0 and 4.0 mg/kg caffeine. Intoxication rates were significantly reduced after combining alcohol with the lower dose of caffeine but not after combining alcohol with the higher dose of caffeine. Closer inspection of the data reveals that the authors appear to have conducted a one-tailed *t*-test (although this is not specified in the paper) between the alcohol-alone and alcohol–caffeine group and erroneously reported a t statistic of 1.77 as producing a *p* value of 0.05. In fact the correct *p* value for a *t* of 1.77 with 11 degrees of freedom is 0.052; the critical value of *t* for a one-tailed test at 0.05 with 11 degrees of freedom is 1.796, thus the reported difference between the alcohol only and alcohol–energy drink conditions is questionable.

Three subsequent studies in healthy volunteers (Marczinski et al., 2011, 2012a,b) focused on the effects of alcohol mixed with energy drinks. In contrast to the previous, within-subjects design, the later studies used a between-groups design. In the first of these, Marczinski et al. (2011) examined subjective intoxication after administering 0.65 g/kg alcohol to reach a peak BAC of approximately 0.08%, with or without 3.57 ml/kg energy drink (1.14 mg/kg caffeine) equivalent to a 250 ml can containing 80 mg caffeine for a 70 kg person, reflecting popular brands. No significant differences in subjective intoxication were observed between those who consumed alcohol with energy drink and those who consumed alcohol only.

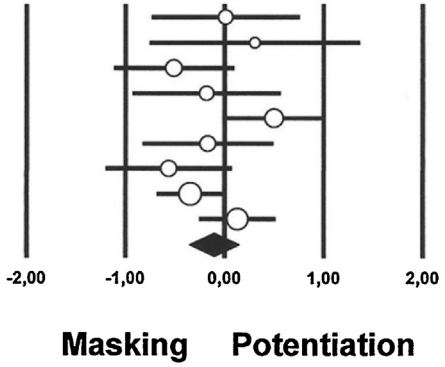
This study was replicated in 2012 with a lower peak BAC (approximately 0.065%), and no significant differences in subjective intoxication were observed between those who consumed AMED and those who consumed alcohol only (Marczinski et al., 2012a). In a third study, (Marczinski et al., 2012b) examined subjective intoxication after administering 0.91 ml/kg alcohol (vodka, 40%; equivalent to a dose of 0.29 g/kg pure alcohol) to reach a peak BAC of around 0.03%, with or without 1.82 ml/kg energy drink (0.6 mg/kg caffeine) equivalent to approximately half a can of popular energy drink. There were no significant differences in subjective intoxication between those who consumed alcohol with energy drink and those who consumed alcohol alone.

Howland et al. (2010) examined the effects of caffeinated versus non-caffeinated beer in 127 heavy drinkers. Peak BAC was 0.12% and mean total caffeine content consumed was 360 mg. Participants were asked to estimate their BAC level on a scale ranging from 0 to 0.15% (using the self estimate of blood alcohol concentration, SEBAC). No significant differences in were found between those who consumed caffeinated beer and those who consumed non-caffeinated beer (estimates were 0.11 and 0.10%, respectively).

In a study primarily investigating caffeine expectancy, Heinz et al. (2013) administered 146 social drinkers with alcohol (equivalent to a BAC of 0.088 g/dL) and randomly assigned the participants to one of four conditions, two of whom received caffeine (absolute dose of 220 mg). Subjective intoxication was measured using the Subjective Intoxication Scale (SIS), ranging from 1 ('not at all intoxicated') to 10 ('as intoxicated as I have ever been'). The scale was completed before and after the drink as well as at the end of

a. lower caffeine doses

Study name	Std diff in means	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
Fillmore & Vogel-Sprott (1999)	0,010	0,378	0,143	-0,731	0,751	0,027	0,978
Fillmore et al. (2002)	0,307	0,538	0,289	-0,747	1,360	0,570	0,568
Marczinski & Fillmore (2006)	-0,511	0,307	0,094	-1,113	0,091	-1,665	0,096
Marczinski et al. (2011)	-0,180	0,379	0,143	-0,922	0,562	-0,476	0,634
Howland et al. (2011)	0,500	0,257	0,066	-0,005	1,005	1,942	0,052
Marczinski et al. (2012)	-0,169	0,334	0,112	-0,823	0,486	-0,506	0,613
Marczinski et al. (2013)	-0,563	0,322	0,104	-1,195	0,069	-1,746	0,081
Heinz et al. (2013)	-0,346	0,169	0,028	-0,676	-0,016	-2,053	0,040
Peacock et al. (2013)	0,129	0,193	0,037	-0,250	0,508	0,667	0,505
	-0,104	0,125	0,016	-0,350	0,142	-0,832	0,406



b. higher caffeine doses

Study name	Std diff in means	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
Fillmore & Vogel-Sprott (1999)	0,010	0,378	0,143	-0,731	0,751	0,027	0,978
Fillmore et al. (2002)	0,307	0,538	0,289	-0,747	1,360	0,570	0,568
Marczinski & Fillmore (2006)	-0,518	0,307	0,095	-1,121	0,084	-1,686	0,092
Marczinski et al. (2011)	-0,180	0,379	0,143	-0,922	0,562	-0,476	0,634
Howland et al. (2011)	0,500	0,257	0,066	-0,005	1,005	1,942	0,052
Marczinski et al. (2012)	-0,169	0,334	0,112	-0,823	0,486	-0,506	0,613
Marczinski et al. (2013)	-0,563	0,322	0,104	-1,195	0,069	-1,746	0,081
Heinz et al. (2013)	-0,346	0,169	0,028	-0,676	-0,016	-2,053	0,040
Peacock et al. (2013)	0,129	0,193	0,037	-0,250	0,508	0,667	0,505
	-0,105	0,126	0,016	-0,351	0,141	-0,835	0,404

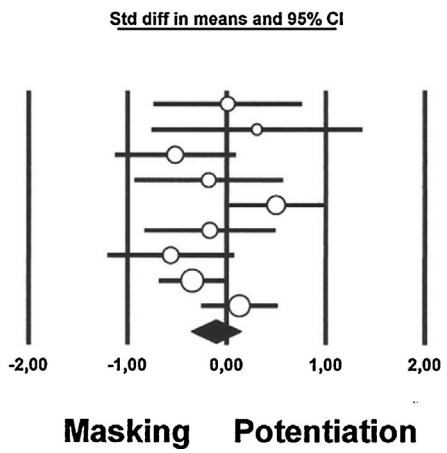


Fig. 2. Results of the meta-analysis. Panel (a) includes the lower (2 mg/kg) caffeine dose condition, and (b) includes the higher (4 mg/kg) caffeine dose from Marczinski and Fillmore (2006). Symbol sizes represent standardized differences and are proportional to the study weight. The overall effect is shown in the last row (black symbol). *Note*: differences are significant if $p < 0.05$ (i.e. in which case the 95% confidence interval does not include zero).

the testing session. Intoxication scores significantly increased post drink for all participants and those who were co-administered caffeine with alcohol reported significantly lower levels of intoxication compared to those who received alcohol alone.

Peacock et al. (2013) investigated the effects of 0.5 g/kg alcohol and 3.57 ml/kg energy drink given to 28 participants. Intoxication was measured using the Beverage Rating Scale and a Subjective Effects Scale where participants rated their level of intoxication on a 100 mm visual analogue scale. While the alcohol condition significantly increased feelings of intoxication as measured by both scales, the addition of the energy drink to the alcohol did not result in any significant difference. For the purpose of comparability, the results from the Beverage Rating Scale were included in this meta-analysis.

3.3. Results of meta-analysis

Nine articles described studies that were suitable for the meta-analysis (Fillmore and Vogel-Sprott, 1999; Fillmore et al., 2002; Marczinski and Fillmore, 2006; Marczinski et al., 2011, 2012a,b; Howland et al., 2010; Heinz et al., 2013; Peacock et al., 2013).

Since the *Q*-values assessing heterogeneity were not significant, a fixed effects model was applied. Meta-analyses were conducted twice – once with the higher and once with the lower caffeine dose from Marczinski and Fillmore (2006). When including the higher caffeine dose (4 mg/kg) from (Marczinski and Fillmore, 2006), the meta-analysis revealed no significant masking effect ($p = 0.404$). Similarly, when including the lower caffeine dose (2 mg/kg) from (Marczinski and Fillmore, 2006), no significant masking effect was found ($p = 0.406$). Of the individual studies, Heinz et al. (2013) reported a significant masking effect and Marczinski and Fillmore (2006) reported an effect at the margins of significance using an approximation to the critical value in a one-tailed test (Fig. 2).

4. Discussion

The current meta-analyses showed no significant differences in subjective intoxication when consuming alcohol with caffeine (including in energy drinks) compared to alcohol only. This suggests that the stimulant effects of caffeine did not modify the subjective experience of the intoxicating effects of the alcohol and that a masking effect does not exist across a range of caffeine doses (46–383 mg) and alcohol levels (0.032–0.12% BAC). The studies

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suggest that, at least under controlled laboratory conditions, subjects are generally capable of correctly judging their level of intoxication when combining caffeine and alcohol. The one study which showed evidence of masking (Heinz et al., 2013) used a relatively high level of caffeine, 5.0 and 5.5 mg/kg for females and males respectively which reduced the effects of alcohol at a BAC of 0.088%. This represents a mean absolute dose of caffeine of 220 mg. It remains to be seen whether higher levels of caffeine are indeed capable of masking alcohol intoxication in further replications, while noting that Howland et al. (2010) did not report masking after higher levels of both alcohol and caffeine.

Regarding the relevance to real-life levels of alcohol and caffeine consumption, recent research suggests that, on average, students consume about six alcoholic drinks on an evening out resulting in an estimated peak BAC of 0.10% (Verster et al., 2009; Penning et al., 2011). When consuming alcohol with energy drinks, the vast majority limit energy drink consumption to one or two 250 ml cans (Penning et al., 2011; Arria et al., 2011). For popular energy drink brands, this means a total caffeine intake between 80 and 160 mg.

Some studies have reported that mixing alcohol with energy drinks increases ratings of stimulation (Marczinski et al., 2011, 2012a,b; Peacock et al., 2013). These effects are consistently found, and may also be evident when energy drinks are not mixed with alcohol (Verster et al., 2012). The results of the current meta-analysis show that stimulant effects of caffeine can be dissociated from changes in subjective intoxication.

The risk of bias within individual studies is minimal, since they were all performed using controlled experimental designs with clear inclusion and exclusion criteria for participants. Also, several studies were performed by the same laboratory and others used a comparable study set-up and outcome measure of subjective intoxication. Hence, the quality of the individual studies can be regarded as sufficient to be included in the meta-analysis. It is also unlikely that publication bias or the existence of unpublished data may have affected the outcome of the presented meta-analysis. It has been shown that published data is generally biased towards studies showing statistically significant findings (Lipsey and Wilson, 2000; Mcnemar, 1960). Hence, the results of unpublished data generally have lower effect sizes than those reported in published data (Smith, 1980). Since the outcome of our meta-analysis is a null finding (i.e. mixing alcohol with energy drink does not affect perceived intoxication), it is very unlikely that publication bias and sampling bias, if existing, would affect our findings.

This review and meta-analysis suggests that consuming alcohol with caffeinated beverages does not impair judgement of subjective intoxication. This finding was found to be consistent at various levels of alcohol and caffeine.

Conflicts of interests

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Motives for mixing alcohol with energy drinks and other non-alcoholic beverages and its effects on overall alcohol consumption among UK students

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ABSTRACT

Introduction: A UK student survey examined the motivations for consuming energy drinks alone and mixed with alcohol, and aimed to determine whether the type of motive had a differential effect on overall alcohol consumption.
Methods: The online survey (N = 1873) assessed alcohol consumption and motivations for consumption when mixed with energy drinks (AMED) and mixed with other non-alcoholic beverages (AMOB) using a within-subject design.
Results: The most frequent neutral motives reported for AMED consumption included "I like the taste" (66.5%), and "to celebrate a special occasion" (35.2%). 52.6% of AMED consumers reported consuming AMED for at least one of five negative motives, primarily "to get drunk" (45.6%). Despite these negative motives those students reported consuming significantly less alcohol and fewer negative alcohol-related consequences on AMED occasions compared to alcohol-only (AO) occasions. Although the motives for consuming AMED and AMOB were comparable, more participants reported consuming AMED "to celebrate a special occasion", "to get drunk", because they "received the drink from someone else" or "because others drink it as well". However, significantly more students reported consuming AMOB than AMED because "It feels like I can drink more alcohol". Alcohol consumption was significantly less on AMED occasions compared to AMOB occasions, and both occasions significantly less than AO occasions.
Conclusion: The majority of reasons for consuming AMED relate to neutral motives. Although 52.6% of students reported one or more negative motives for AMED consumption (predominantly "to get drunk") this had no differential effect on total alcohol consumption. The differences in motives suggest AMED is consumed more to enjoy special occasions and as a group-bonding experience, however alcohol consumption is significantly lower on such occasions in comparison to when AMOB or AO are consumed.

1. Introduction

The prevalence of energy drink consumption worldwide has increased significantly in the past decade. Within the UK, energy drinks are the fastest growing sub-sector of the soft drinks market, worth over £1.4 billion annually (British Soft Drinks Association, 2014). As the sale of energy drinks has increased so has the popularity of consuming alcohol mixed with energy drinks (AMED), especially among young adults. Differing prevalence rates for AMED consumption among University students have been reported worldwide. For example, among college students in the US prevalence rates ranged from 15 to 24% for AMED consumption in the past month (O'Brien, McCoy, Rhodes, Wagoner, & Wolfson, 2008; Velazquez, Poulos, Latimer, & Pasch, 2012). Despite the continued growth of the energy drinks market and subsequent proliferation of brands increasing consumer choice, to date no research has reported on AMED prevalence within the UK.

The popularity of AMED consumption within the UK has led to public health concerns regarding its use (Drinkaware, 2014; National Health Service, 2014). Some researchers have suggested

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that AMED consumption increases overall alcohol consumption and the likelihood of engaging in negative alcohol-related consequences (Berger, Fendrich, Chen, Arria, & Cisler, 2011; Snipes & Benotsch, 2013; Thombs et al., 2010). However, the majority of research supporting these conclusions has used between-subjects designs, comparing AMED consumers with alcohol-only (AO) consumers. The problem of using a between-subjects design is that the two groups may differ from each other across a number of variables that may explain the observed differences in the frequency and quantity of alcohol consumed (de Haan, de Haan, van der Palen, Olivier, & Verster, 2012). Indeed, between-subjects research has demonstrated that AMED consumers have higher levels of sensation-seeking and risk-taking behaviours, compared to AO consumers (Arria et al., 2010, 2011; Berger et al., 2011; de Haan, de Haan, Olivier, et al., 2012; de Haan, de Haan, van der Palen, Olivier, & Verster, 2012; Miller, 2008; Snipes & Benotsch, 2013). Therefore compared to AO consumers they are more likely to engage in behaviours, such as alcohol and drug use, that are more akin to a risk-taking personality, potentially explaining the differences observed in the between-subjects research. In order to determine whether mixing alcohol with energy drinks plays a role in effecting overall alcohol consumption, studies that utilise a within-subjects design are required. By comparing alcohol consumption on AMED occasions with other occasions on which the same individuals consume AO, pre-existing differences between individuals or groups, such as personality and risk-taking propensity, are controlled for. The current studies that have adopted this design have yielded contrasting findings. Brache and Stockwell (2011) found that, when controlling for inherent personality variables such as risk-taking, students reported consuming more alcoholic beverages on a typical drinking occasion where they were consuming AMED than on a typical drinking occasion where they were not consuming energy drinks. Similarly Peacock, Bruno, and Martin (2012) also reported significantly greater alcohol intake in AMED versus alcohol sessions within-subjects. However, although statistically significant, as noted by the authors the differences in alcohol consumption levels across the two drinking occasions were not considered clinically meaningful. The only other study (Price, Hilchey, Darredeau, Fulton, & Barrett, 2010) that found clinically meaningful increases in alcohol consumption on AMED occasions compared to AO occasions was underpowered (N = 9), In contrast, more robust within-subjects surveys (de Haan, de Haan, Olivier, et al., 2012; de Haan, de Haan, van der Palen, et al., 2012; Woolsey, Waigandt, & Beck, 2010) have found significantly less alcohol consumption on AMED occasions compared to AO occasions. For example, Woolsey et al. (2010) found that when reporting on the greatest number of alcoholic drinks consumed on a single occasion in the past year, the AMED group reported significantly less alcohol consumption (10.83 drinks) when combining alcohol with energy drinks compared with a session of alcohol without energy drinks (18.23 drinks), a reduction of 41%. Therefore, the latter findings suggest that the between subjects differences in alcohol consumption between those who consume AMED and those who consume AO do not appear to be driven by the addition of energy drinks to alcohol but by pre-existing differences between the groups.

Conversely, there may be other reasons that can explain the differences in alcohol consumption and engagement in negative alcohol-related consequences, such as the motivations underlying the decision to consume AMED. However, until now there has been limited research on AMED motives. Importantly, following a call for additional research (Marczinski, 2011) there has been a recent shift within the AMED research community to investigate motivations for AMED use and their potential influence on alcohol consumption and negative outcomes.

One of the first studies to investigate motives for AMED consumption was conducted by O'Brien et al. (2008). Of the 24% of American students that reported consuming AMED, 55% did so to "hide the flavour of alcohol". Other reasons were reported by 41%, including "it was being served at a party", "it was the only mixer available" and "that's how you make a Jager bomb". A minority of students reported a number of negative motives for consuming AMED. These included "to drink more and not feel as drunk" (15%), "not to get a hangover" (7%) and "to drink more and not look as drunk" (5%).

Investigating motivations in regular AMED consumers Marczinski (2011) found that, on a Likert scale ranging from 1 (highly disagree) to 4 (highly agree), the highest agreement motivations were "I like the taste" (3.02), "to celebrate" (3.00), "to socialise" (2.95) and "to get drunk" (2.82). However, a relatively small (N = 66) sample size of AMED consumers was used.

In a Canadian sample, Brache, Thomas and Stockwell (2012) found that the most common reasons for AMED use were because students enjoyed the taste (35%) and to get an energy boost while drinking (27.7%). Other reported reasons included "to stay awake when drinking" (20.2%), "to party longer" (18.4%) and "to hide the flavour of alcohol" (18.1%). Using a qualitative methodology, Jones and Barrie (2009) found similar rationales for AMED consumption among an Australian sample including to extend their nights out and to have more energy to party longer. The focus groups also identified that AMED consumption is used as a group-bonding experience to make nights out more enjoyable.

An Australian study by Peacock, Bruno, and Martin (2013) used focus groups and an extensive literature search to develop 30 reasons that motivated participants to consume AMED. Motives from 403 AMED users were collected via an online survey and grouped into different theme areas using exploratory factor analysis. The primary motives for AMED consumption based on this analysis were improved functionality motives, with 70% of participants reporting consuming AMED to "feel more energetic" and 54% to "stay out later". Taste and sensation motives were also highly endorsed (69%) including "because I like the taste of alcohol and energy drinks together". Other frequently reported motives were situational ("because they are the ingredients in a drink e.g. Jager bomb" 72%, and "sharing AMED with drinking companions" 53%) and hedonistic motives ("to have more fun" 46%, "to get more drunk" 32%). Fewer participants reported consuming AMED for intoxication/impairment motives including "so I could drink more" (20%), "to feel less drunk" (12%), "to look less drunk" (8%) and "to avoid getting a hangover" (6%).

A more recent study by Droste et al. (2014) identified 4 groups of motivational constructs that showed differential associations with alcohol harms. Specifically it was found that those who consumed AMED for hedonistic motives were at increased risk of negative outcomes, including heavier ED consumption during AMED episodes, risk of alcohol dependence, alcohol-related injury and aggression. Intoxication—reduction motives were also significantly associated with experiencing alcohol-related injury, but not with heavier AMED consumption patterns or risk of alcohol dependence.

A large scale Dutch survey (de Haan, de Haan, Olivier, & Verster, 2012; Verster, Benson, & Scholey, 2014) recently found similar findings to the majority of previous research in that the most frequently reported motives for consuming AMED were "I like the taste" (81.1%), "I wanted to drink something else" (35.3%) and "to celebrate a special occasion" (14.6%). When the reported motives were categorised into neutral or negative motives, it was found that a minority (21.6%) of students reported at least one of the five negative motives for consuming AMED. However, despite these negative motives, within-subject comparisons revealed that alcohol consumption and negative alcohol-related consequences

were significantly lower on AMED occasions compared to AO occasions. Hence, in contrast to Droste et al. (2014) the type of motive (neutral or negative) had no differential effect on total alcohol intake. An important advantage of this survey was that it made direct comparisons between the motives for consuming AMED and those for consuming alcohol mixed with other non-alcoholic beverages (AMOB). This is of importance given that energy drinks are a relatively new mixer option and are not generally the first choice mixer. Interestingly, no relevant differences in drinking motives and overall alcohol consumption were found between occasions on which students consumed AMED or AMOB suggesting that energy drinks are not unique from the many other mixers consumers can choose from.

In summary, although the outlined studies report on a wide range of motives across a variety of geographies, the primary reasons for consuming AMED appear to be related to consumers appreciation of AMED taste, and expectations regarding the positive effects of the drinks functional ingredients, such as providing energy and to extend nights out. Importantly, the belief that AMED consumption increases overall alcohol intake is not supported by the motives given by the consumers themselves, with relatively few students reporting consuming AMED in order to drink more alcohol. In addition, there is mixed findings as to whether certain types of motives are associated with increased alcohol consumption and increased risk of negative outcomes.

Given the public health concerns on AMED consumption in the UK, the lack of available data and the wide variety in reported prevalence and motives given for consuming AMED in different countries, a replication of the Dutch student survey (de Haan, de Haan, Olivier, et al., 2012; de Haan, de Haan, van der Palen, et al., 2012; Verster et al., 2014) was conducted among UK students. The aim of the study was to examine the motives reported by UK students for consuming energy drinks, both alone and mixed with alcohol. In addition, the study aimed to determine whether, among those who reported negative motives for consuming AMED, there was a difference in alcohol consumption on occasions they consumed AO with occasions they consumed AMED, using a within-subjects design. Lastly, motives and alcohol consumption patterns were compared when mixing alcohol with energy drinks and other non-alcoholic beverages.

2. Methods

2.1. Sample

UK university student unions (N = 139) were contacted via email and asked if they would be willing to advertise the AMED student survey via their social media platforms. In total 30% of student unions, including institutions from each country (England, Wales, Scotland, Northern Ireland) responded and agreed to disseminate a short summary of the surveys content and web link. Prior to commencing the study ethical approval was granted by the University of the West of England ethics committee. On opening the link participants were informed of the purpose and content of the survey, and were told that participation was anonymous and voluntary. Upon completion of the study, participants were offered the opportunity to be entered into a prize draw (1 × £500, 10 × £50). Entrance to the survey required participants to provide an email address. To ensure anonymity, the email address provided was not linked to the participant's survey responses.

A total of 2371 respondents opened the link to the survey; however 498 were excluded from data analysis due to not meeting the same inclusion criteria applied in previous research (de Haan, de Haan, Olivier, et al., 2012; de Haan, de Haan, van der Palen, et al., 2012; Verster et al., 2014). Among these, 7 participants did not agree to participate in the study after reading the informed consent page, 78 were outside the age range of the target energy drink market (1 was younger than 18 years, 77 were older than 30 years), and 211 participants did not answer the questions that were necessary to classify them as part of one of the drinking groups. Finally 10 participants stated that they did not answer the questions truthfully and 192 were non-students. Therefore the valid, complete dataset is based on 1873 participants.

3. Survey questions

Following informed consent, demographic data and participants' medication, smoking and drug use, as well as educational status (University, level of study, full/part-time) and membership to University society/sports group were assessed.

Standardised consumption questions, adapted from the Quick Drinking Screen (Roy et al., 2008; Sobell et al., 2003), then assessed consumption habits (frequency and quantity) across differing timescales (one occasion, 30 days, 12 months) considering the particular drink in question. If applicable, the standardised consumption questions (listed in Table 1) were asked for consuming energy drinks, AO, AMED and AMOB. Participants were asked whether they consumed the particular beverage in question (i.e. do you consume energy drinks? or do you consume alcohol?) and were therefore considered current consumers. Within this study, alcohol consumption was defined using standardised UK alcohol units (1 standard unit = 10 mg of pure alcohol) (National Health Service, 2013) and one energy drink standardised to 250 ml. With regards to mixing alcohol with other non-alcoholic beverages, participants had the choice of a wide range of mixers that are popular in the UK to choose the one mixer they usually preferred. They could also state their own preferred mixer if this was not available in the list of mixers provided. Participants then completed the consumption questions concerning their chosen preferred mixer. In line with previous research (de Haan, de Haan, Olivier, et al., 2012; de Haan, de Haan, van der Palen, et al., 2012; Verster et al. 2014) mixing on both AMED and AMOB occasions was defined as consuming the mixer (ED or other chosen non-alcoholic beverage) within a time period of 2 h before, through to 2 h after, drinking alcohol.

To investigate negative consequences of alcohol consumption, the Brief Young Adult Alcohol Consequences Questionnaire (BYAACQ: Kahler, Strong, & Read, 2005) was completed. The BYAACQ contains 24 possible consequences of alcohol consumption, with participants indicating whether the statement was applicable to them in the past year. In addition to the standard BYAACQ, following the Dutch student survey (de Haan, de Haan, Olivier, et al., 2012; de Haan, de Haan, van der Palen, et al., 2012; Verster et al. 2014) two additional items were included to determine whether participants were injured or got into a fight after alcohol consumption. A higher score in the range of 0–24 indicated higher engagement in negative alcohol-related consequences. Depending on the participant's specific drinking behaviour, the BYAACQ and additional items were completed for AO, AMED and AMOB.

Lastly, participants answered questions regarding the reasons/motivations for consuming energy drinks, as well as the reasons/motivations for mixing alcohol with energy drinks and other non-alcoholic beverages. Participants could report multiple reasons and add additional motives behind their beverage consumption patterns. To establish consistency with previous research (de Haan, de Haan, Olivier, et al., 2012; de Haan, de Haan, van der Palen, et al., 2012; Verster et al., 2014) and allow for direct cross-cultural comparisons, the standardised motive statements were categorised as neutral or negative according to their presumed effect on overall

Table 1
Consumption questions.

Alcohol only	Energy drinks only	Alcohol mixed with energy drinks	Alcohol mixed with other beverages
1. At what age did you first consume alcohol?	1. How many energy drinks do you usually have on one occasion?	1. When you combine, how many alcoholic drinks and energy drinks do you usually have on one occasion?	1. What non-alcoholic beverage do you most often combine with alcohol?
2. At what age did you consume alcohol regularly?	2. In the past 30 days, how many days did you drink energy drinks?	2. In the past 30 days, how many days did you combine energy drinks and alcohol?	2. When you combine, how many alcoholic drinks and glasses of [X] do you usually have on one occasion?
3. How many standard drinks do you usually have on one occasion?	3. In the past 30 days, how many times did you have 3 or more energy drinks on one occasion?	3. In the past 30 days, while combining, how many days did you get drunk?	3. In the past 30 days, how many days did you combine [X] and alcohol?
4. In the past 30 days, how many days did you drink alcohol?	4. In the past 30 days, what is the greatest number of energy drinks you had on one occasion?	4. While combining in the past 30 days, how many times did you have more than 5 (males)/4 (females) alcoholic drinks on one occasion?	4. In the past 30 days, while combining alcohol with [X], how many days did you get drunk?
5. In the past 30 days, how many days did you get drunk?	5. In the past 12 months, what was the greatest number of energy drinks you consumed on one occasion?	5. While combining in the past 30 days, what was the greatest number of alcoholic drinks you consumed on one occasion?	5. While combining in the past 30 days, how many times did you have more than 5 (males)/4 (females) alcoholic drinks on one occasion?
6. In the past 30 days, how many times did you have more than 5 (males)/4 (females) alcoholic drinks on one occasion?		6. On that occasion (previous question), how many hours did you consume alcohol?	6. While combining in the past 30 days, what was the greatest number of alcoholic drinks you consumed on one occasion?
7. In the past 30 days, what is the greatest number of alcoholic drinks you had on one occasion?		7. While combining in the past 30 days, what was the greatest number of energy drinks you consumed on one occasion?	7. On that occasion (previous question), how many hours did you consume alcohol?
8. On that occasion (previous question), how many hours did you consume alcohol?		8. While combining in the past 12 months, what was the greatest number of alcoholic drinks and energy drinks you consumed on one occasion?	8. While combining in the past 30 days, what was the greatest number of [X] you consumed on one occasion?
9. In the past 12 months, what was the greatest number of alcoholic drinks you consumed on one occasion?			9. While combining in the past 12 months, what was the greatest number of alcoholic drinks and [X] you consumed on one occasion?

Note: [X] applies to the mixer preferred by the participant.

alcohol consumption. Negative motives were those associated with increased alcohol consumption. All other motives were labelled as neutral, as no effect on the direction of total alcohol consumption could be predicted from previous research.

3.1. Data collection and statistical analysis

The online survey tool SurveyMonkey® (Palo Alto, CA) was used to collect participant responses between 7th April 2014 and 12th May 2014. Once the survey had closed the data was cleaned in Microsoft Excel and analysed using the Statistical Package for the Social Sciences version 20 (SPSS Inc, Chicago, IL). For the analysis in this paper, data were used for the energy drinks-only group (consumed energy drinks but never mixed energy drinks with alcohol) and AMED group (consumed energy drinks and also consumed AMED) using a within-subjects design (i.e., comparing – within the same subjects – alcohol consumption on occasions when only alcohol was consumed versus other occasions where alcohol was mixed with an energy drink or other non-alcohol beverages).

The mean, standard deviation and frequency distribution were computed for all variables. Variables with a normal distribution were tested with the analysis of variance. For nominal variables, a Chi Square test was used. The percentage of participants that indicated each motive for energy drink consumption was computed. The same data analysis was applied to motives for mixing alcohol with an energy drink or other non-alcoholic beverages. Following this, within the AMED group, participants were classified as having either neutral or negative reasons for mixing alcohol with energy drinks. Mixing for negative reasons was defined as participants confirming that they consumed AMED for at least one of the following reasons: “to get drunk”, “to prevent getting drunk”, “it feels like I can drink more alcohol”, “it feels like energy drinks reduce the negative effects of alcohol”, and “to sober up”. Although classified as the negative motives group, participants could choose as many motives as applied to them and therefore could also have endorsed neutral reasons for mixing. To determine whether alcohol consumption within the AMED-“negative motives” subgroup differed between occasions on which they consumed AO versus occasions when they consumed AMED, paired samples t-tests were used. Lastly to determine whether there were any differences in alcohol consumption between AMED, AMOB and AO occasions, a repeated-measures ANOVA was conducted. All comparisons were two-tailed and regarded as significant at $P < 0.05$.

4. Results

A total of 896 participants reported consuming energy drinks. Of these, 732 indicated that they mixed alcohol with energy drinks as well as consuming energy drinks by themselves, with the remaining ($N = 164$) stating that they had never mixed them with alcohol. All participants were alcohol consumers. The demographics of both groups can be found in Table 2.

4.1. Motives for consuming energy drinks

Fig. 1 summarises the motives for consuming energy drinks (without alcohol). The most frequency reported motives for consuming energy drinks included “to keep me awake” (61.9%), “I like the taste” (55.6%) and “it gives me energy” (47.1%).

4.2. Motives for mixing alcohol with energy drinks (AMED)

The motives for consuming alcohol mixed with energy drinks (AMED) were answered by 732 participants. As can be seen in Fig. 2, the most frequently reported neutral motives for consuming AMED were “I like the taste” (66.5%), followed by “to celebrate a special

Table 2
Between-group demographics of those who consume energy drinks only and those who consume AMED.

	Energy drinks only group (N = 164)	AMED group (N = 732)	Cohen's *d*	*P* value
Male/female ratio M%/F% (CI%)	39%/61% (±7.46%)	45.9%/54.1% (±3.61%)	0.11	0.109
Age (years), $\bar{x}$ (SD)	21.2 (2.4)	20.6 (2.0)	0.27	0.001*
Member of student union % (CI%)	66.3% (±7.26%)	59.6% (±3.56%)	0.13	0.152
Member of sports/society group % (CI%)	48.8% (±7.65%)	53.8% (±3.61%)	0.08	0.248
Medication use (past year) % (CI%)	17.7% (±5.84%)	19.5% (±2.87%)	0.04	0.586
Illicit drug use (past year) % (CI%)	17.7% (±5.84%)	24.9% (±3.13%)	0.13	0.050
Current smoker % (CI%)	14.0% (±5.31%)	25.8% (±3.17%)	0.22	0.001*

Notes: % = yes. 95% CIs. *Significant differences (P < 0.05) between the groups.
Abbreviations: AMED, alcohol mixed with energy drinks; N, number; $\bar{x}$, mean; SD, standard deviation; CI, confidence intervals.

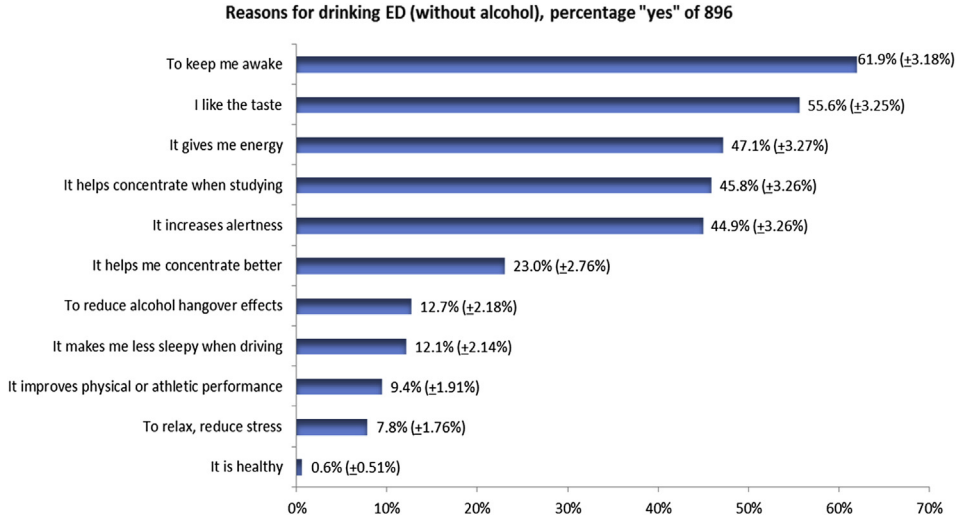

Fig. 1. Motives for energy drink consumption (without alcohol). Notes: % = yes (CI%). Abbreviations: ED, energy drinks; CI, confidence interval.

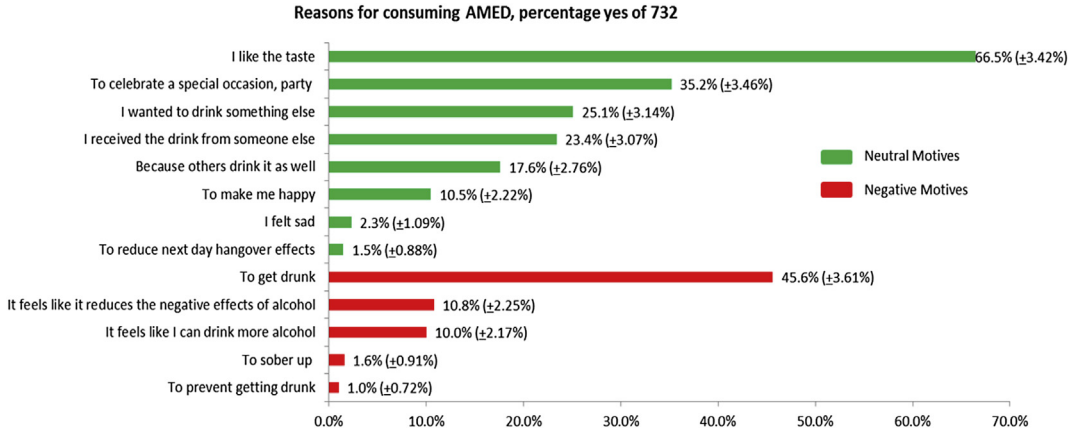

Fig. 2. Endorsement of neutral and negative motives for mixing alcohol with energy drinks (AMED). Notes: % = yes (CI%). Abbreviations: AMED, alcohol mixed with energy drinks.

occasion, party" (35.2%), "I wanted to drink something else" (25.1%) and "I received the drink from someone else" (23.4%). With regard to negative motives, "to get drunk" was reported by 45.6% of participants. All other negative motives were reported by a relatively small minority of participants.

4.3. Negative motives for mixing alcohol with energy drinks

52.6% of participants reported consuming AMED for at least one of the five negative motives illustrated in Fig. 2. When comparing these with the remaining AMED consumers who only reported neutral motives (47.4%), it was found that those who consume AMED for negative motives are significantly more often younger, male, smoke more tobacco, consume alcohol regularly at an earlier age and experience more negative alcohol-related consequences on both AO and AMED occasions (see Table 3.).

In order to determine whether the type of motive had a differential effect on overall alcohol consumption within-subjects comparisons on alcohol consumption questions and total BYAACQ score were conducted among those who consumed AMED for negative motives (N = 385) and those who consumed AMED for neutral motives (N = 347). As can be seen in Figs. 3 and 4, regardless of whether participants consumed AMED for negative or neutral motives on the occasions they drank AMED they consumed

Table 3
Comparison of subjects who consume AMED for negative and neutral motives.

	Mixing for negative motives (N = 385)	Mixing for neutral motives (N = 347)	Cohen's *d*	*P* value
Male/female ratio M%/F% (CI%)	50.6%/49.4% (±4.99%)	40.6%/59.4% (±5.17%)	0.20	0.007*
Age (years), $\bar{x}$(SD)	20.4 (1.9)	20.8 (2.1)	−0.20	0.004*
Member of student union % (CI%)	57.9% (±4.93%)	61.4% (±5.14%)	0.09	0.486
Member of sports/society group % (CI%)	51.7% (±4.99%)	56.1% (±5.23%)	0.09	0.236
Medication use (past year) % (CI%)	19.2% (±3.93%)	19.9% (±4.2%)	0.02	0.821
Illicit drug use (past year) % (CI%)	27.5% (±4.46%)	21.9% (±4.35%)	0.13	0.078
Current smoker % (CI%)	30.4% (±4.59%)	20.7% (±4.26%)	0.22	0.003*
Age first consumed alcohol $\bar{x}$(SD)	13.7 (3.0)	14.1 (2.8)	−0.14	0.097
Age consumed alcohol regularly $\bar{x}$ (SD)	16.9 (1.7)	17.2 (1.5)	−0.19	0.006*
BYAACQ score alcohol only $\bar{x}$ (SD)	10.35 (5.5)	7.05 (4.7)	0.65	<0.001*
BYAACQ score AMED $\bar{x}$ (SD)	8.4 (5.1)	5.2 (4.4)	0.67	<0.001*

Notes: % = yes. 95% CI. *Significant differences (P < 0.05) between negative and neutral motives.
Abbreviations: N, number; $\bar{x}$, mean; SD, standard deviation; CI, confidence interval; AMED, alcohol mixed with energy drinks; BYAACQ, brief young adult alcohol consequences questionnaire.

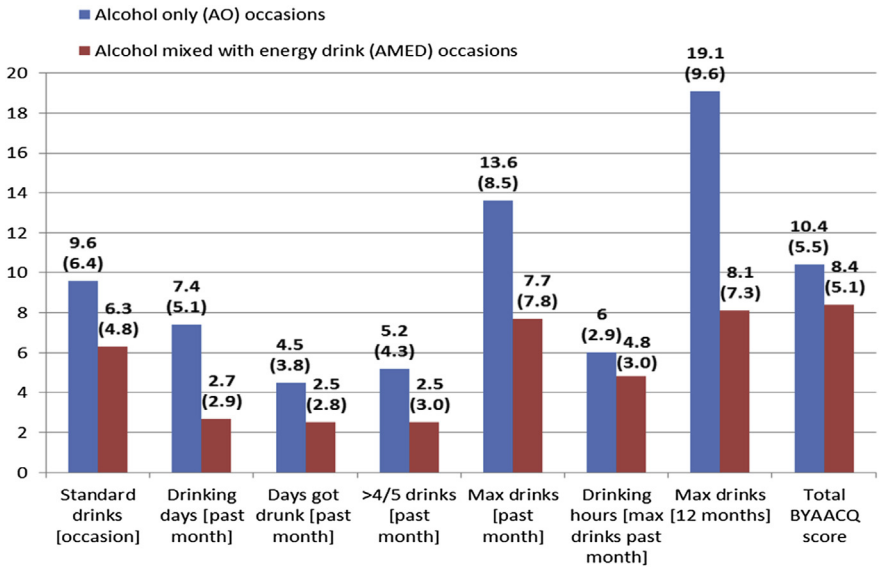

Fig. 3. Within-subjects comparisons of drinking behaviour of participants who consumed AMED for negative reasons. Notes: Occasions when they consumed AMED are compared with the occasions when they only consumed alcohol. $\bar{x}$ (SD). All two-tailed comparison were significant different (P < 0.001). N = 385. Abbreviations: BYAACQ, brief young adult alcohol consequences questionnaire; $\bar{x}$, mean; SD, standard deviation.

significantly less alcohol and experienced fewer negative alcohol-related consequences compared to those occasions on which they consumed AO. However, those who endorsed negative motives were more likely to consume more alcohol and engage in more negative alcohol-related consequences on AO and AMED occasions compared to those who endorsed neutral motives.

4.4. Comparison with other mixers

In order to assess whether there were any differences in the motives and alcohol consumption patterns between occasions on which participants mixed alcohol with energy drinks and other occasions on which they consumed alcohol mixed with other non-alcoholic beverages, within-subjects comparisons were conducted on those who consumed both AMED and AMOB (N = 550).

As can be seen in Table 4, the motives for consuming alcohol with other mixers were in-line with those reported for consuming AMED. However, there were some statistically significant differences in the motives reported for consuming AMED and AMOB. With regard to neutral motives, more participants reported consuming AMED to "celebrate a special occasion", because "others drink it as well", they "got the drink from someone else" or because they "felt sad" when compared to consuming AMOB. However, more participants reported consuming AMOB because they "like the taste" compared to AMED. For negative motives, more participants reported consuming AMED "to get drunk" and "to reduce the negative effects of alcohol" compared to consuming AMOB. Conversely, more participants reported that "it feels I can drink more alcohol" for AMOB when compared to AMED.

A repeated-measures ANOVA with a Huynh-Feldt correction determined that all alcohol consumption questions differed statistically significantly between AO, AMED and AMOB consumption occasions (Table 5). Post hoc tests using the Bonferroni correction revealed that each pairwise difference was significant, P < 0.001. On the occasions participants drank AMED they consumed significantly less alcohol and were drunk less often compared to those occasions when they consumed AMOB. In addition, the frequency and quantity of alcohol consumed on both AMED and AMOB occasions were significantly less than occasions on which participants consumed AO.

5. Discussion

The results of this study indicate that the primary motives for consuming energy drinks relate to the expected positive effects of the drinks functional ingredients, including to keep me awake and

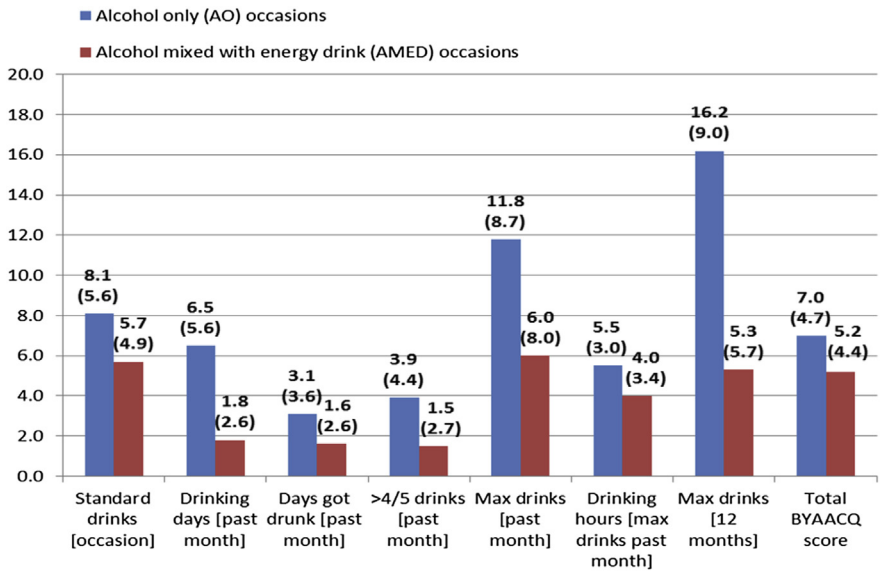

Fig. 4. Within-subjects comparisons of drinking behaviour of participants who consumed AMED for neutral reasons. Notes: Occasions when they consumed AMED are compared with the occasions when they only consumed alcohol. $\bar{x}$ (SD). All two-tailed comparison were significant different ($P < 0.001$). $N = 347$. Abbreviations: BYAACQ, brief young adult alcohol consequences questionnaire; $\bar{x}$, mean; SD, standard deviation.

Table 4
Endorsement of neutral and negative motives for mixing alcohol with energy drinks or other non-alcoholic beverages (N = 550).

	Energy drinks	Other beverages	Cohen's *d*	*P* value
Neutral motives for mixing with				
I like the taste % (CI%)	73.5% (±3.69%)	89.5% (±2.56%)	0.60	<0.001*
I wanted to drink something else % (CI%)	27.6% (±3.74%)	23.8% (±3.56%)	0.14	0.101
To celebrate a special occasion, party % (CI%)	40.5% (±4.1%)	29.6% (±3.82%)	0.41	<0.001*
Received the drink from someone (and did not want to refuse it) % (CI%)	26.5% (±3.69%)	11.1% (±2.63%)	0.70	<0.001*
To make me happy % (CI%)	11.3% (±2.65%)	12.2% (±2.74%)	0.04	0.649
Because others drink it as well % (CI%)	20.4% (±3.37%)	16.0% (±3.06%)	0.19	0.024*
To reduce next day hangover effects % (CI%)	1.3% (±0.95%)	1.6% (±1.05%)	0.29	0.774
I felt sad % (CI%)	2.7% (±1.35%)	0.7% (±0.7%)	0.22	0.007*
Negative motives for mixing with				
To get drunk % (CI%)	53.1% (±4.17%)	34.2% (±3.96%)	0.72	<0.001*
It feels like it reduces the negative effects of alcohol % (CI%)	11.1% (±2.62%)	6.0% (±1.98%)	0.29	0.001*
It feels like I can drink more alcohol % (CI%)	10.9% (±2.6%)	18.9% (±3.27%)	0.36	<0.001*
To prevent getting drunk % (CI%)	0.9% (±0.79%)	1.6% (±1.05%)	0.07	0.424
To sober up % (CI%)	2.0% (±1.17%)	1.5% (±1.02%)	0.05	0.581

Notes: % = yes. 95% CI. *Significant differences ($P < 0.05$).
Abbreviations: N, number; CI, confidence interval.

Table 5
Within-subjects comparisons of alcohol consumption on alcohol only, AMED and AMOB occasions.

Alcohol consumption among those who consume AMED and AMOB (N = 550).	Alcohol-only occasion ($\bar{x}$, SD)	AMED occasion ($\bar{x}$, SD)	AMOB occasion ($\bar{x}$, SD)	Cohen's *f*	*P* value
How many standard drinks do you usually have on one occasion?	9.0 (6.1)	6.1 (5.0)	6.7 (5.0)	0.40	<0.001
In the past 30 days, how many days did you drink alcohol?	7.2 (5.2)	2.3 (2.8)	4.1 (3.8)	0.82	<0.001
In the past 30 days, how many days did you get drunk?	3.9 (3.6)	2.1 (2.7)	3.0 (3.3)	0.53	<0.001
In the past 30 days, how many times did you have more than five (male)/four (female) alcohol drinks on one occasion?	4.7 (4.2)	2.0 (2.9)	3.0 (3.2)	0.59	<0.001
In the past 30 days, what is the greatest number of alcoholic drinks you had on one occasion?	13.0 (8.4)	7.1 (8.0)	8.3 (7.6)	0.65	<0.001
On that occasion (previous question), how many hours did you consume alcohol?	5.8 (2.8)	4.5 (3.1)	5.0 (3.0)	0.39	<0.001
In the past 12 months, what was the greatest number of alcoholic drinks you consumed on one occasion?	18.0 (9.4)	6.9 (6.8)	9.3 (7.1)	1.00	<0.001

Abbreviations: AMED, alcohol mixed with energy drinks; AMOB, alcohol mixed with other non-alcoholic beverage; N, number; $\bar{x}$, mean; SD, standard deviation.

to give me energy, as well as consumers appreciation of the energy drink taste.

The motives for mixing alcohol with energy drinks and other non-alcoholic beverages were similar in their distribution across motive statements. For example, the most frequently reported neutral motives on both AMED and AMOB occasions were "I like the taste", "to celebrate a special occasion", "I wanted to drink something else", "I got the drink from someone else" and "because others

drink it". However, significantly more students reported consuming AMED "to celebrate a special occasion", "because others drink it as well" and because "I got the drink from someone else" compared to when consuming AMOB. Similar to previous research (Jones & Barrie, 2009) these findings suggest that students often drink mixers (energy drinks or other non-alcoholic beverages) with alcohol as a group bonding experience to make special nights out, such as birthdays more enjoyable. But that energy drinks are more frequently the chosen mixer for these motives in comparison to other non-alcoholic beverages. Drinking AMED and AMOB "to celebrate a special occasion" can be deduced by the significantly lower number of reported occasions consuming them (2.3 and 4.1, respectively) in the past 30 days, compared to the frequency of consuming alcohol alone (7.2).

In regard to negative motives, of concern were the high number of students who reported consuming both AMED and AMOB "to get drunk". This may be explained by the fact that Britain is one of the worst countries in the world for binge drinking (World Health Organization, 2014) and that drinking alcohol to get drunk is a well-established characteristic of student life. However, despite a high number of students reporting drinking "to get drunk" in both drinking occasions, drinking AMED "to get drunk" was reported significantly more often than drinking AMOB "to get drunk". On the other hand significantly more students reported consuming AMOB than AMED "because it feels they can drink more alcohol". The latter is supported by the within-subjects finding that alcohol consumption was significantly lower on occasions when students consumed AMED compared with occasions when they consumed AMOB. Therefore although more students reported consuming AMED than AMOB "to get drunk", more students reported consuming AMOB to increase the quantity of alcohol they consume than when consuming AMED and this was reflected in overall alcohol consumption levels.

In addition, alcohol consumption was also significantly lower on occasions when students consumed AMED compared with the occasions when they consumed AO. Even when looking at the 52.6% who consumed AMED for one or more of the negative motives, including "to get drunk" and "because it feels I can drink more alcohol", alcohol consumption was still significantly lower on AMED occasions compared to occasions when they consumed AO. These findings are in contrast to previous claims that mixing alcohol with energy drinks might increase overall alcohol consumption (Berger et al., 2011; Snipes & Benotsch, 2013; Thombs et al., 2010), and that the type of motive has a differential effect on alcohol consumption or risk of negative outcomes (Droste et al., 2014). Interestingly, alcohol consumption levels were also significantly lower on AMOB occasions compared to AO occasions, suggesting that although students may consume AMOB to increase the quantity of alcohol consumed this is not reflected in actual consumption levels when compared to AO consumption occasions.

One further finding was that more students reported consuming AMED than AMOB "to reduce the negative effects of alcohol". A possible explanation is that the expected positive effects of energy drinks functional ingredients, including staying awake and having more energy, may underlie the motive to consume AMED to reduce the negative effects of alcohol when enjoying a special occasion. However, only an additional 5% of students reported consuming AMED "to reduce the negative effects of alcohol", therefore although significantly different this may not be of real life relevance. No other significant differences in the negative motives for consuming AMED and AMOB were found.

5.1. Strengths

This is the first UK survey with a relatively large sample size that has provided useful insights into AMED consumption patterns and motivations for use among students from across the UK.

One advantage of the present study over previous research is that it utilised a within-subjects design. This allowed comparisons of the frequency and quantity of alcohol consumed by the same individuals on occasions when they consumed alcohol alone, occasions they mixed alcohol with energy drinks, and occasions they mixed alcohol with other non-alcoholic beverages. This is an advantage over the between-group design employed by previous research, as it controls for the many demographic and personality variables that may differ between those who consume AMED and those who consume AO, allowing us to determine whether the observed differences were related to the co-consumption of energy drinks or not. Within-subjects comparisons were also made for motives on AMED occasions and AMOB occasions.

5.2. Limitations

The current survey collected absolute alcohol consumption values and incidence of negative alcohol-related consequences across all consumption occasions. This method was chosen as it provides a clear real-world comparison of consumption levels and incident for each drinking occasion. Some researchers (Rossheim, Suzuki, & Thombs, 2013) have argued that this approach fails to take into account the relative frequency of AMED and AMOB consumption versus AO consumption. Indeed, within the current survey participants reported using AMED (2.3) and AMOB (4.1) less often in the past 30 days than AO (7.2). However, research by Peacock et al. (2015) that controlled for the frequency of use failed to support the hypothesis that the differences in alcohol consumption and negative alcohol-related consequences can be explained by the relative infrequency of AMED drinking occasions compared to AO occasions. Further analysis of the current dataset, controlling for the frequency of use, may contribute to this debate.

In addition the survey did not collect data on the motives for consuming alcohol alone. This may be of importance as a baseline measure in trying to understand why students decide to consume alcohol-only on some occasions but combine with energy drinks or other non-alcoholic beverages on other occasions. Caution must also be taken when inferring relationships between consumption motives and the amount of alcohol consumed. This is because participants in this survey were asked whether each motive applied to consuming AMED or AMOB. No information was obtained on what occasions or how important each motive was, and how this was linked to the amount of alcohol consumed on those occasions. Future research, possibly utilising a qualitative methodology, is needed to further explore the importance given to the motives underlying alcohol consumption patterns on specific occasions, such as during a celebratory party versus a regular visit to the pub.

As with all previous research on the motives for consuming AMED, the present survey relied on students to retrospectively recall the number and type of drinks consumed, either in the past 30 days or 12 months. The ability to reliably recall this information is likely to have been affected by the high volume of alcohol reportedly consumed. However, given the within-subjects design employed there is no reason to assume the ability to recall such information differed on AMED, AMOB and AO occasions. Prospective diary studies, possibly using smartphone technology to collect alcohol and energy drink consumption data, may be useful in addressing participants ability to recall information shortly after the drinking occasion.

When considering the differences found in alcohol consumption and motivations for use between AMED and AMOB occasions, it must be considered that within the AMOB occasions students could report that they consume caffeinated (cola) or non-caffeinated

(orange juice) beverages with alcohol. Therefore no conclusions should be drawn on the role caffeine is playing in effecting alcohol consumption or motivations for use between AMED and AMOB occasions in this survey. Further statistical analysis of the current dataset is required to explore this.

Furthermore, although the decision to categorise each motive as neutral or negative was based on previous research, caution must be taken when discussing these findings as it may not be so easy to determine how negative one motive is, in terms of its effects on overall alcohol consumption, compared to another. For example, I like the taste was reported by the majority of students as a reason for consuming AMED and AMOB. Although it can be reasonably assumed that this is a neutral motive, it could also be argued that enjoying the taste could actually put one at risk of consuming further quantities of alcohol. On the other hand, both 'to reduce next day hangover effects' and 'to sober up' are categorised as negative motives but could be deemed as 'positive' and 'functional' motives. In addition, the list of possible motives in the survey were not exhaustive, therefore there may be other motives that could be important in determining the reasons for consuming AMED and AMOB. However, despite the survey providing the opportunity for participants to report any additional motives outside of the standard motive statements in an open ended question, no motives of significant interest were reported.

Lastly, the current sample focused on university students and therefore results cannot be generalised beyond the student population. Given the unique drinking practices among students, it is likely that differences will be observed in the general population.

In summary, these results are similar to previous research on the motives for mixing alcohol with energy drinks (Brache et al., 2012; Marczinski, 2011; O'Brien et al., 2008; Peacock et al., 2013; Verster et al., 2014) in that the majority of reported motives were neutral in nature. However, some important differences have been highlighted. In comparing our findings with the only other study (Verster et al., 2014) to examine motives for AMED consumption and make direct comparisons between the motives for consuming AMED and AMOB, two substantial differences were observed. Firstly, a significantly higher percentage (52.6% compared to 21.6%) of AMED consumers reported consuming AMED for at least one of the five negative motives, with a vast majority of these reporting consuming AMED "to get drunk". However, similar to Verster et al. (2014) the type of motive (negative or neutral) had no differential effect on overall alcohol consumption. Secondly, significant differences in the motives for consuming AMED and AMOB were identified, suggesting that UK students may be unique in their consumption of AMED as a group bonding experience on special occasions, such as parties. To investigate this further, cross-cultural differences will be examined between the United Kingdom, The Netherlands and Australia. In addition further research is required to examine the social and situational factors that may moderate UK student motives for AMED consumption.

6. Conclusion

In-line with previous research, this first-known UK student survey, found that the primary reasons for mixing alcohol with energy drinks and other non-alcoholic beverages relate to neutral motives, and that the type of motive (neutral or negative) had no differential effect on total alcohol consumption. A high percentage of students reported consuming both AMED and AMOB to get drunk. This was reflected in the fact that, independent of motives or drinking occasion, students consumed alcohol at substantially higher levels than those recommended as safe in the UK. Interesting differences in the drinking motives and overall alcohol consumption were observed between the occasions when energy drinks or non-alcohol beverages were mixed with alcohol. These suggest that AMED is the preferred mixer during special occasions and used as a group-bonding experience, but that alcohol consumption is significantly lower on such occasion in comparison to occasions when AMOB or AO are consumed.

Authors' contributions

SJ led the study presented in this paper; collected, analysed, interpreted the data and drafted the manuscript. CA, JV and KS participated in the design and coordination of the study and helped to draft and review the manuscript. Each author has participated sufficiently in the work to take public responsibility for appropriate portions of the content. All authors read and approved the final manuscript.

Competing interests

Sean J Johnson has undertaken sponsored research for a number of companies including Pfizer, AstraZeneca, Merck, Gilead, Novartis, Roche and Red Bull GmbH.

Chris Alford has undertaken sponsored research, or provided consultancy, for a number of companies and organisations including Astra, British Aerospace/BAeSystems, Civil Aviation Authority, Duphar, FarmItalia Carlo Erba, Ford Motor Company, ICI, Janssen, LERS Synthélabo, Lilly, Lorex/Searle, Ministry of Defense, Quest International, Red Bull GmbH, Rhone-Poulenc Rorer, Sanofi-Aventis.

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Karina Stewart has no competing interests.

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