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The Desire to Drink Alcohol is Enhanced with High Caffeine Energy Drink Mixers

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Abstract

Background—Consumption of alcohol mixed with energy drinks (AmED) has been associated with a variety of risks beyond that observed with alcohol alone. Consumers of AmED beverages are more likely to engage in heavy episodic (binge) drinking. The purpose of this study was to investigate whether the consumption of high caffeine energy drink mixers with alcohol would increase the desire to drink alcohol compared to the same amount of alcohol alone using a double-blind, within-subjects, placebo-controlled study design.

Methods—Participants (n = 26) of equal gender who were social drinkers attended 6 double-blind dose administration sessions that involved consumption of alcohol and energy drinks, alone and in combination. On each test day, participants received 1 of 6 possible doses: 1) 1.21 ml/kg vodka + 3.63 ml/kg decaffeinated soft drink, 2) 1.21 ml/kg vodka + 3.63 ml/kg energy drink, 3) 1.21 ml/kg vodka + 6.05 ml/kg energy drink, 4) 3.36 ml/kg decaffeinated soft drink, 5) 3.36 ml/kg energy drink, and 6) 6.05 ml/kg energy drink. Following dose administration, participants repeatedly completed self-reported ratings on the Desire for Drug questionnaire and provided breath alcohol readings.

Results—Alcohol alone increased the subjective ratings of “desire for more alcohol” compared to placebo doses. Energy drink mixers with the alcohol increased desire for more alcohol ratings beyond that observed with alcohol alone.

Conclusions—This study provides laboratory evidence that AmED beverages lead to greater desire to drink alcohol versus the same amount of alcohol consumed alone. The findings are consistent with results from animal studies indicating that caffeine increases the rewarding and reinforcing properties of alcohol.

Keywords

Alcohol; Energy Drinks; Caffeine; Desire to Drink; Social Drinkers

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Introduction

Energy drinks are popular consumer products advertised to increase energy levels and mitigate fatigue. Energy drinks differ in typical ingredients, but most include high doses of caffeine, sugar, vitamins, and other stimulant ingredients that will result in increased wakefulness in users (Howard & Marczinski, 2010; McCusker et al., 2006). In the past decade, it has become increasingly common for alcohol consumers to consume their alcoholic beverages with energy drinks (Marczinski, 2011). Up until November of 2010 in the United States, alcoholic beverages were available premixed with energy drinks. The risks of alcohol mixed with energy drinks (AmED) first were noticed when these premixed beverages were on the market. Underage and young adult drinkers experiencing high levels of alcohol intoxication were admitted to emergency rooms, prompting health care professionals and scientists to raise concerns about these products (Cleary et al., 2012; O'Brien et al., 2008). After the available scientific data was reviewed, the U.S. Food and Drug Administration (FDA) determined that caffeine was an unsafe food additive when combined with alcohol (U.S. FDA, 2010). This determination was based partly on laboratory observations that consumption of AmED results in lowered perceived intoxication or other altered subjective responses to alcohol such as heightened perceived stimulation when compared to alcohol alone (Ferreira et al., 2006; Marczinski & Fillmore, 2003, 2006; Marczinski et al., 2011, 2012, 2013). These subjective changes occurred even though caffeine or energy drinks do not alter objective blood alcohol levels.

Even though premixed AmEDs are no longer available in the U.S., the rise in popularity of combining energy drinks with alcohol has continued to increase. Consumers and bartenders prepare their own AmEDs with varying proportions of alcohol (typically distilled spirits such as vodka) and energy drinks. Mixed drinks may contain 2:1 or 3:1 ratios of energy drink to the alcoholic beverage. Alternatively, a standard 1.5 oz. shot of a spirit can also be served by dropping it into a pint glass filled with an energy drink (e.g., bomb drinks such as a Jagerbomb) which amounts to approximately 5:1 energy drink to alcohol. Underage and young adult drinkers find the various versions of AmEDs to be appealing, as revealed through annual data collected via the Monitoring the Future (MTF) Survey (Johnston et al., 2013a,b). Date from the MTF revealed that approximately one in four high school seniors (i.e., approximately 17–18 years old) reported AmED use during the past 12 months and rates of AmED use were associated with binge drinking (Martz et al., 2015). The hazards associated with AmED use also continue to be observed. Emergency department visits and calls to poison control centers related to AmED consumption continue to rise (SAMHSA, 2013, 2014; Seifert et al., 2013). Repeated consumption of AmEDs has also been associated with the development of serious drinking problems. Results from two separate studies conducted in Taiwan and Australia have revealed that AmED consumers were more likely to screen positive for alcohol dependence when compared to alcohol alone consumers (Cheng et al., 2012; Droste et al., 2014).

One underlying reason why AmEDs may lead to both short and long term problems is that energy drinks increases the reinforcing properties of alcohol (Marczinski et al., 2013). If the experience of drinking alcohol is more rewarding when combined with an energy drink, the consumer may drink more. Caffeine, the primary stimulant drug in energy drinks, is known to increase the preference and consumption of foods and beverages (Panek et al., 2013; Temple et al., 2012). Thus, it would be consistent to find that adding caffeine-containing energy drinks to alcohol increases the preference and consumption of that alcohol. Some evidence suggests this is the case. Field work has revealed that patrons who consume AmEDs are more likely to leave bars while intoxicated (Hughes et al., 2012; Thombs et al., 2010). In field studies, caffeine appears to have a dose dependent relationship with the magnitude of alcohol intoxication, with highly intoxicated consumers being more likely to have mixed caffeine (in the form of colas or energy drinks) with alcohol (Thombs et al., 2011). Longitudinal daily surveys of alcohol consumers have revealed that more alcoholic drinks are consumed by participants on days when energy drinks were mixed with the alcohol when compared with days where alcohol was consumed alone (Patrick & Maggs, 2014). However, this literature is controversial and one recent meta-analysis suggests that AmED consumers just tend to be heavier drinkers in general when compared to alcohol alone consumers, suggesting that AmED beverages may not necessarily increase total alcohol consumption (Verster et al., 2016).

Two recent studies from different laboratories tested the degree to which a “priming” dose of alcohol increased drinkers’ desire for more alcohol when the priming dose also contained caffeine, either as an additive (Heinz et al., 2013) or as part of an energy drink (Marczinski et al., 2013). The studies showed that, compared with alcohol alone, the addition of caffeine/energy drink elevated and prolonged subjects’ subjective desire for more alcohol. However, the assertion that AmED leads to greater desire to drink when compared to alcohol alone is controversial. It has been argued that the magnitude of caffeine doses involved should not be sufficient to increase the reinforcing properties of alcohol, among other concerns, prompting calls for replication of this phenomenon particularly using a double-blind, placebo-controlled, within-subjects design (Griffin, 2013; Peacock & Bruno, 2013; Verster et al., 2013).

Therefore, the purpose of this study was to investigate whether the consumption of energy drinks with alcohol would increase the desire to drink alcohol compared to the same amount of alcohol alone using a double-blind, placebo-controlled study design. Given that consumers ingest various versions of AmED cocktails, and that co-administration of caffeine has been shown to dose dependently increase alcohol intoxication in field studies, it was predicted that desire to drink alcohol would be increased in a dose-dependent manner as the amount of energy drink mixer was increased. For this study, social drinkers were recruited to participate in 6 double-blind dose administration sessions that involved consumption of alcohol and energy drinks, alone and in combination. On each test day, participants received 1 of 6 possible doses: 1) 1.21 ml/kg vodka + 3.63 ml/kg decaffeinated soft drink, 2) 1.21 ml/kg vodka + 3.63 ml/kg energy drink, 3) 1.21 ml/kg vodka + 6.05 ml/kg energy drink, 4) 3.36 ml/kg decaffeinated soft drink, 5) 3.36 ml/kg energy drink, and 5) 6.05 ml/kg energy drink. Following dose administration, participants repeatedly completed self-reported ratings on the Desire for Drug questionnaire and provided breath alcohol concentration (BrAC) readings. Given that the sugar content in soft drink mixers can decrease breath alcohol concentrations by slowing gastric emptying (Marczinski & Stamates, 2013; Rossheim & Thombs, 2011; Wu et al., 2006), BrAC was recorded at multiple time points throughout all test sessions.

Method

Participants

Twenty-six social drinkers (13 women) between the ages of 21 and 30 participated in this study. The self-reported racial make-up of the sample included 1 African-American, 1 Asian, and 24 Caucasian participants. For ethnicity, 1 participant reported being Hispanic and the remaining 25 stated that they were not Hispanic. Potential volunteers completed questionnaires that provided demographic information and physical and mental health status. Exclusion criteria included self-reported psychiatric disorder, diabetes, phenylketonuria, substance abuse disorders, head trauma, or other central nervous system injury. Individuals who reported being extremely infrequent drinkers (i.e., less than two U.S. standard drinks of 14 grams of pure alcohol per month) were excluded. Drinkers with a potential risk of alcohol dependence were also excluded, as determined by a SMAST score (Seltzer et al., 1975) of 5 or higher or an AUDIT score (Barbor et al., 1989) of 8 or higher (Barry & Fleming, 1993). Inclusion criteria consisted of self-reported consumption of at least one energy drink in the past year, and consumption of at least one caffeinated beverage in the past two weeks (e.g., coffee, tea, soft drink, chocolate and/or energy drink).

Recent use of amphetamines, barbiturates, benzodiazepines, cocaine, ecstasy, methamphetamine, opiates, and tetrahydrocannibol was assessed by urinalysis at the start of each test session (uVera Diagnostics, Inc., Norfolk, VA). Any participant who tested positive for the presence of any of these drugs was excluded from the study. No females who were pregnant or breast-feeding participated in this research, as determined by self-report and urine gonadotrophin (HCG) levels. Recruitment of participants relied on notices posted on university community bulletin boards and through university student e-mail distribution lists. Interested volunteers called the laboratory to find out more information about the study. All volunteers provided informed consent before participating. The Northern Kentucky University Institutional Review Board approved this study. Participants received $180 as compensation for completing the entire 6 session study.

Apparatus and Materials

Personal Drinking Habits Questionnaire (PDHQ: Vogel-Sprott, 1992)—The PDHQ measures an individual's recent typical drinking habits including number of standard drinks (i.e., bottles of beer, glasses of wine, and shots of liquor) typically consumed during a single drinking occasion, dose (grams of absolute alcohol per kilogram of body weight typically consumed during a single drinking occasion), weekly frequency of drinking, and hourly duration of a typical drinking occasion. The PDHQ also measures history of alcohol use in the number of months that an individual has been drinking on a regular basis or customarily on social occasions.

Timeline Follow-back (TLFB; Sobell & Sobell, 1992)—The TLFB assesses self-reported daily patterns of alcohol consumption during the past 30 days including maximum number of continuous days of drinking, maximum number of continuous days of abstinence, total number of drinking days, total number of drinks consumed in the past month, highest number of drinks consumed in one day, total number of heavy drinking (5+ drinks) days, and total number of "drunk" days (i.e., days on which the participants felt intoxicated).

Caffeine Use Questionnaire (CUQ)—The CUQ assesses self-reported typical average daily caffeine consumption in milligrams per kilogram of body weight. Estimates of the caffeine content in foods and beverages were taken from Barone and Roberts (1996) and McCusker et al. (2006). Manufacturer websites were consulted for caffeine content information for newer products.

Impulsivity Measures—Two measures assessed self-reported impulsivity, with higher scores indicating greater impulsivity. The Eysenck Impulsiveness Questionnaire (Eysenck et al., 1985) assesses impulsivity by posing 19 yes/no questions. The Barratt Impulsiveness Scale-11 (BIS-11; Patton et al., 1995) assesses impulsivity by asking participants to rate how typical 30 different statements are for them on a 4-point Likert scale.

Desire-for-Drug Scale (Chutuape et al., 1994)—This 3-item 100 mm visual analogue scale was used to assess the subjective effects of the dose administered with end anchors of *not at all* (0 mm) and *very much* (100 mm). Participants rated the subjective effects of the drink in terms of how much they "feel the drink" (feel), "like the effects" (like), and "desire more alcohol" (desire). This scale is frequently used to demonstrate increased motivation to drink following an alcohol priming dose, with the desire rating corresponding to actual choices to drink more alcohol (de Wit & Chutuape, 1993; Fillmore, 2001).

Procedure

Pre-laboratory Screening—Individuals who were interested in participating contacted the research assistant to complete an intake-screening interview by telephone. Volunteers were informed that the purpose of the 6 session experiment was to study the effects of alcohol and energy drinks on behavior. Individuals were told that they would be asked to consume a beverage and complete questionnaires on each session. The contents of the drink were never disclosed to participants, but they were informed that the drink might contain an amount of alcohol with the maximum dose of alcohol found in 3 beers and the energy drink might contain the maximum dose of caffeine found in a cup of coffee. They were also informed that they could receive a decaffeinated soft drink. Participants were not given information about the type or brand of possible beverages. Prior to the test session, participants were required to fast for 2 hours, abstain from any form of caffeine for 8 hours and abstain from alcohol for 24 hours.

Baseline Testing—Each participant was tested individually by a research assistant in the Department of Psychological Science laboratories at Northern Kentucky University. Testing began between 10 a.m. and 4 p.m. Testing times within one subject were kept as similar as possible and did not vary more than 4 hours. Upon arrival in the laboratory for the first session, the participant was asked to provide informed consent. The participants also completed the general health questionnaire, PDHQ, TLFB, CUQ, Eysenck, and BIS-11 questionnaires.

At the start of every session, the participant was weighed and completed a medical screening questionnaire to ensure that the participant was in good health and had not recently taken any medications. A zero blood alcohol concentration (BAC) was confirmed from a breath sample, using an Intoxilyzer Model 400 (CMI Inc., Owensboro, KY). The participant was then asked to provide a urine sample in a private bathroom. The research assistant tested for the presence of drug metabolites in all participants and HCG for women only (Bioscreens Inc., Norfolk, VA). The participant completed baseline ratings of desire for alcohol from the Desire-for-Drug questionnaire.

Dose Administration—After baseline measures were completed, participants received a beverage to consume. On each test day, participants received 1 of 6 possible doses: 1) 1.21 ml/kg vodka + 3.63 ml/kg decaffeinated soft drink, 2) 1.21 ml/kg vodka + 3.63 ml/kg energy drink, 3) 1.21 ml/kg vodka + 6.05 ml/kg energy drink, 4) 3.36 ml/kg decaffeinated soft drink, 5) 3.36 ml/kg energy drink, and 6) 6.05 ml/kg energy drink. Dose administration was double-blind and dose order was counterbalanced between participants. Doses were calculated based on body weight. For the alcohol dose, 1.21 ml/kg of vodka (40% alcohol/volume Smirnoff Red Lab vodka, No. 21, Smirnoff Co., Norwalk, CT) was chosen as this dose has been previously shown to elicit the priming effects of alcohol in social drinkers at a low BAC (.04 g%) (Fillmore, 2001; Marczinski et al., 2013). This target BAC was chosen because the low-dose reinforcing effects at this BAC level have been suggested to precipitate binge drinking episodes (Marlatt & Gordon, 1980). The alcohol dose was reduced to 87% for female participants. The alcohol dose was mixed with 3.63 ml/kg of Squirt, a decaffeinated soft drink (Dr. Pepper Snapple Group, Plano, TX) resulting in a 3:1 (soft drink:alcohol) ratio.

For the AmED conditions, the 1.21 ml/kg dose of alcohol was mixed with 3.63 ml/kg or 6.05 ml/kg of Red Bull energy drink (Red Bull, Switzerland). These 3:1 and 5:1 ratios (energy drink:vodka) are typical of mixed drinks and bomb drinks (a shot dropped into a pint glass served depth-charge style) typically served in bars. In addition, there were three control conditions where the energy drink or decaffeinated soft drinks were consumed. In the energy drink conditions, participants received 3.63 and 6.05 ml/kg Red Bull, and in the placebo condition, participants received 3.63 ml/kg Squirt. For the typical 72 kg participant in this study, the 3.63 ml/kg energy drink dose resulted in the consumption of 84 mg of caffeine whereas the 6.05 ml/kg energy drink dose resulted in the consumption of 140 mg of caffeine. Squirt was chosen as the decaffeinated soda for the vehicle beverage because of its similarity to the energy drink with respect to calories, taste, carbonation, and appearance. The decaffeinated soda differed from the energy drink in caffeine and other stimulant ingredients as these products were used as sold by their manufacturers. Furthermore, the 6.05 ml/kg dose of energy drink contained more calories when compared with the 3.63 ml/kg energy drink and 3.63 ml/kg decaffeinated soft drink conditions. In both the energy drink and vehicle conditions, 10 ml of vodka was floated on the surface of the beverage to give the drink an alcohol scent, with previous research having demonstrated that individuals report that this beverage contains alcohol (Marczinski et al., 2011). In the current study, we confirmed that all participants thought that they had consumed at least 0.5 alcoholic drinks and at least 0.5 energy drinks in each condition using a standard beverage rating scale that asked a participant how many standard drinks of alcohol and energy drink they thought we gave them.

Following baseline subjective measures, participants were given their beverage in a plastic cup and were asked to consume the drink within 5 minutes. The exact content of the beverage was never disclosed to participants. BrACs were measured at 20, 40, 60, and 80 min. after drinking was initiated. Breath samples were also provided by participants given the energy drink and placebo beverages at those same intervals, ostensibly to measure their BACs.

Post Administration Subjective Ratings—Desire-for-Drug questionnaire ratings were assessed at 10, 20, 40, 60, and 80 min. after drinking began. Upon completion of the testing period at 90 min. post drinking, all participants were given a meal. Participants were then debriefed and released once BrAC was below .02 g%.

Data Analyses

Gender was included as an initial factor in all analyses. However, no main effects or interactions for gender were obtained. Therefore, gender is only reported in the analyses for the baseline measures related to drinking habits and the BrACs to confirm that our alcohol dose reduction for women participants resulted in approximately equivalent BrACs for women and men.

For the Desire-for-drug ratings, the baseline ratings on each test day for 'desire for alcohol' were analyzed with a one-way repeated measures ANOVA. After dose administration on each test session, desire-for-drug ratings for 'desire for alcohol', 'feel the drink', and 'like the drink' were submitted to separate 2 (Alcohol Dose: 1.21 ml/kg v. 0.0 ml/kg) x 3 (Energy Drink Dose: 6.05 ml/kg energy drink v. 3.63 ml/kg energy drink v. 3.63 ml/kg decaffeinated soft drink) x 5 (Time: 10, 20, 40, 60 v. 80 min.) within-subjects ANOVA. The alpha level was set at .05 for all statistical tests and SPSS 17.0 was used to conduct all analyses. When post-hoc LSD tests were used, a Bonferroni adjustment for multiple comparisons was applied.

Results

Demographic Characteristics and Baseline Measures

Table 1 lists all demographic and baseline questionnaire measures for the male and female participants in the study. Possible gender differences for the baseline measures reported in Table 1 were compared using independent samples *t* tests. It was observed that males weighed significantly more than females, $t(24) = 2.44$, $p = .023$. For the remaining tests, no significant differences were obtained for any of the measures, ps > .12. Self-reported daily caffeine use for the sample was highly variable with a range of 0.22 mg/kg to 16.00 mg/kg daily.

BrACs

No detectable BrACs were observed under the energy drink or placebo conditions. For only the alcohol conditions, the results of a 2 (Gender) x 3 (Energy Drink) x 4 (Time) mixed design ANOVA revealed a significant Energy Drink x Time interaction, $F(6,144) = 11.07$, $p < .001$, $\eta^2 = .835$ (see Table 2). There were no other main effects or interactions for this analysis. Subsequent repeated measures ANOVAs were run for each time point to examine the effect of the energy drink dose. At 20 minutes, a significant effect of dose was obtained, $F(2,50) = 20.57$, $p < .001$, $\eta^2 = .451$. Post-hoc LSD tests revealed that the BrAC in the 6.05 ml/kg energy drink condition was significantly lower than the other energy drink and placebo conditions. The same pattern was observed at 40 minutes, as a significant effect of energy drink dose was obtained, $F(2,50) = 4.96$, $p = .011$, $\eta^2 = .166$. Post-hoc LSD tests revealed that BrAC in the 6.05 ml/kg energy drink condition was significantly lower than the placebo condition. There were no significant energy drink dose differences observed in the ANOVAs examining the 60 and 80 min. time points, ps > .75.

Desire-for-Drug Ratings

Desire for Alcohol Ratings—Baseline ratings of desire to drink alcohol were assessed at the start of each of the six dose sessions (see Table 2). Baseline ratings were subjected to a one-way repeated measures of ANOVA and no differences in these ratings were observed, $F(5,125) = 5.16$, $p = .765$, $\eta^2 = .020$.

The results of the 2 (Alcohol Dose) x 3 (Energy Drink Dose) x 5 (Time) ANOVA for "desire for alcohol" ratings revealed a significant Alcohol x Energy Drink interaction, $F(2,48) = 3.30$, $p = .045$, $\eta^2 = .121$, a significant Alcohol x Time interaction, $F(4,96) = 3.26$, $p = .015$, $\eta^2 = .120$, and a significant Energy Drink x Time interaction, $F(8,192) = 2.62$, $p = .010$, $\eta^2 = .099$. As shown in Figure 1, the ratings of desire for alcohol revealed that desire for alcohol was increased when alcohol was consumed by participants. Moreover, desire for alcohol was further increased when an energy drink was coadministered with the alcohol.

Given the study hypothesis that energy drink mixers would increase the desire to drink alcohol more than alcohol alone, a 3 (Energy Drink Dose) x 5 (Time) ANOVA for only the alcohol conditions was conducted and revealed a significant main effect of the Energy Drink, $F(2,50) = 4.64$, $p = .014$, $\eta^2 = .157$, and a significant main effect of Time, $F(4,100) = 10.57$, $p < .001$, $\eta^2 = .297$. No significant interaction as observed, $F(8,200) = 1.70$, $p = .102$, $\eta^2 = .063$. To better understand the main effect of Time, post-hoc LSD tests examining the different time points revealed that the desire ratings were significantly lower at the 60 and 80 min. times when compared to the peak desire rating measured at 20 min, ps < .012. To better understand the Energy Drink main effect, post-hoc LSD tests examining the three different levels of energy drink revealed that the desire ratings were significantly higher for the 6.05 ml/kg energy drink condition compared to placebo, $p = .047$, and there was a nonsignificant trend for the 3.36 ml/kg energy drink condition desire ratings to be higher compared to placebo, $p = .085$. The two energy drink conditions did not differ, $p = .626$. Given that visual inspection of Figure 1 illustrates that the desire ratings for both energy drink conditions appeared to be significantly higher than alcohol alone at the 20 min. time point, a one-way repeated measures ANOVA for only this 20 min. data was conducted, resulting in a significant effect of the energy drink, $F(2,50) = 3.70$, $p = .032$, $\eta^2 = .129$. Post-hoc LSD tests revealed that the desire ratings at 20 min. for the 3.36 ml/kg energy drink condition were significantly higher than placebo, $p = .042$, and the other conditions did not differ, *p*s > .130.

To confirm that desire for alcohol ratings were not altered by the energy drink for the three conditions where alcohol was not administered, a 3 (Energy Drink Dose) x 5 (Time ANOVA was conducted. No main effects and no interaction were observed, *p*s > .202.

Feel Ratings—The results of a 2 (Alcohol Dose) x 3 (Energy Drink Dose) x 5 (Time) ANOVA for "feel the drink" ratings revealed an Alcohol x Energy Drink x Time interaction, $F(8,200) = 5.97$, $p < .001$, $\eta^2 = .193$ (see Table 2). To better understand this 3-way interaction, the feel ratings were analyzed separately for the doses where alcohol was administered or not.

When alcohol was administered, the 3 (Energy Drink) x 5 (Time) ANOVA revealed an Energy Drink x Time interaction, $F(8,200) = 6.27$, $p < .001$, $\eta^2 = .200$. As shown in Table 2, the feel ratings were higher when energy drinks mixers were consumed with the alcohol as opposed to alcohol alone. At each time point, a repeated measures ANOVA was conducted to examine the effect of the energy drink mixer. The ANOVAs examining the 10 min., 20 min. 40 min., and 80 min. feel ratings did not find any effect of the energy drink mixers, $p > .082$. At 60 min., there was a significant effect of the energy drink mixer on feel ratings, $F(2,50) = 5.47$, $p = .007$, $\eta^2 = .179$. Post-hoc LSD tests revealed that the 6.05 ml/kg energy drink mixer resulted in higher feel ratings when compared to the placebo condition, $p = .010$.

When alcohol was not administered, the 3 (Energy Drink) x 5 (Time) ANOVA revealed a significant main effect of Time only, $F(4,100) = 9.42$, $p < .001$, $\eta^2 = .274$. Post-hoc LSD tests revealed that the feel ratings were significantly higher at the 20 min. time point when compared to the 40, 60, and 80 min. time points, *p*s < .049.

Like Ratings—The results of a 2 (Alcohol Dose) x 3 (Energy Drink Dose) x 5 (Time) ANOVA for "like the drink" ratings revealed a main effect of Energy Drink, $F(2,50) = 4.52$, $p = .016$, $\eta^2 = .153$, and an Alcohol x Time interaction, $F(4,100) = 3.12$, $p = .018$, $\eta^2 = .111$ (see Table 2). Similar to the above analyses, we analyzed the like ratings separately for the alcohol conditions and the no alcohol conditions. For the alcohol conditions, the results of the 3 (Energy Drink) x 5 (Time) ANOVA revealed a significant main effect of the Energy Drink, $F(2,50) = 5.98$, $p = .005$, $\eta^2 = .193$, and a significant main effect of Time, $F(4,100) = 7.43$, $p < .001$, $\eta^2 = .229$. No interaction was observed, $p = .273$. Post-hoc LSD tests comparing the three Energy Drink conditions revealed that like ratings were significantly higher for both energy drink conditions compared to placebo, *p*s < .039. The two energy drink conditions did not differ for like ratings, $p = .999$. Post-hoc LSD tests comparing the different times revealed that like ratings were significantly higher at 20 min. when compared with 60 and 80 min., *p*s < .020.

For the conditions where no alcohol was administered, the results of the 3 (Energy Drink) x 5 (Time) ANOVA revealed a significant Energy Drink x Time interaction, $F(8,200) = 2.34$, p

= .020, $\eta^2 = .086$. Visual inspection of the like ratings (see Table 2) suggests that the interaction may have arisen because the like ratings for the highest energy drink dose were higher for most time points. However, separate repeated measures ANOVAs for the like ratings at each time point did not reveal any significant effect of the energy drink doses, *p*s > .127.

Discussion

This study examined alcohol-induced priming of desire to drink alcohol in social drinkers. The question was whether alcohol mixed with an energy drink (AmED) would increase the desire to drink alcohol more than a similar dose of alcohol alone. The observed results clearly revealed that consumption of an energy drink with alcohol increased the desire to drink alcohol more than alcohol alone. In addition, energy drink mixers also influence subjects' responses to the question of how they 'feel' and 'like' the drink. The alcoholic beverages that included the energy drink mixers received higher feel and like ratings in this study.

Interestingly, AmED still increased desire to drink with the 6.05 ml/kg dose of energy drink with alcohol even though the BrAC was lower in this condition. This lowered BrAC was expected given that the alcohol is less concentrated in this beverage and this outcome has been observed in other research (Peacock et al., 2015). In addition, it is known that high calorie content soft drink mixers can lower BrAC when compared to lower calorie mixers (Marczinski & Stamates, 2013; Stamates et al., 2015). In this study, drinks were consumed on an empty stomach. In the real world, alcohol consumers may also consume food with their alcohol which may alter whether the type of mixer will influence resulting BrACs or not. Little is known whether use of caloric and/or caffeinated mixers with alcohol influences appetite.

The results of this laboratory research suggest an explanation for the observations in field studies and surveys that consumption of AmEDs is associated with greater drinking and higher BrACs when compared to alcohol alone. AmED beverages appear to be more rewarding than alcohol alone. While the exact reason for this remains to be elucidated, it should be noted that enhanced stimulation is an almost universal observation in laboratory studies that have compared subjective state for AmED (or alcohol+caffeine) when compared to alcohol alone (Attwood et al., 2012; Heinz et al., 2013; Marczinski & Fillmore, 2003, 2006; Marczinski et al., 2011, 2012; Peacock et al., 2013; Smith, 2013). Drug-induced stimulation is a sought-after effect from use of a psychoactive drug by drug users and drug-induced stimulation is associated with rewarding effects (Newlin & Thomson, 1999). Thus, the risks of drinking alcohol may be higher with consumption of AmED when compared to alcohol alone because the perceived stimulation is enhanced with an energy drink mixer. Giving the important of drug-induced stimulation, it is notable that findings from several animal studies from different laboratories have reported that locomotor stimulation changes are enhanced for alcohol caffeine combinations when compared to either drug alone (Fritz et al., 2016; Hilbert et al., 2013; May et al., 2015). In one study, it was observed that binge consumption of alcohol by both adolescent and adult mice increased with caffeine, but only the adolescent mice exhibited robust locomotor stimulant responses to alcohol caffeine combinations (Fritz et al., 2016). As such, phase of human brain development and drinking history may be only a few of the important factors to examine in the future in an effort to understand when and by how much desire for alcohol is enhanced with energy drink mixers and how stimulation plays a role in these outcomes.

Finally, the findings of this research are consistent with the available animal studies that have investigated whether caffeine coadministration with alcohol increases alcohol intake. Results from many different laboratories have demonstrated that moderate doses of caffeine (similar to human consumption of energy drink mixers) increases the intake of alcohol in ad libitum administration models using rats and mice (Dietze et al., 1991; Fritz et al., 2016; Kunin et al., 2000; Rezvani et al., 2013). While these findings might suggest that there is something unique about caffeine in increasing the reinforcing properties of alcohol, it is also possible that all stimulant drugs may have this effect in the presence of alcohol. Most individuals who are dependent on alcohol are also smokers and nicotine increases the self-administration dose of alcohol in rodent models (Ostroumov et al., 2015). Further, it is known that the coadministration of alcohol with cocaine results in the production of a cocaine metabolite, cocaethylene, which is more reinforcing than cocaine alone (Jatlow et al., 1991; Raven et al., 2000). In sum, more research is needed to better understand how various stimulant drugs that are often used in combination with alcohol are influencing the abuse potential of alcohol.

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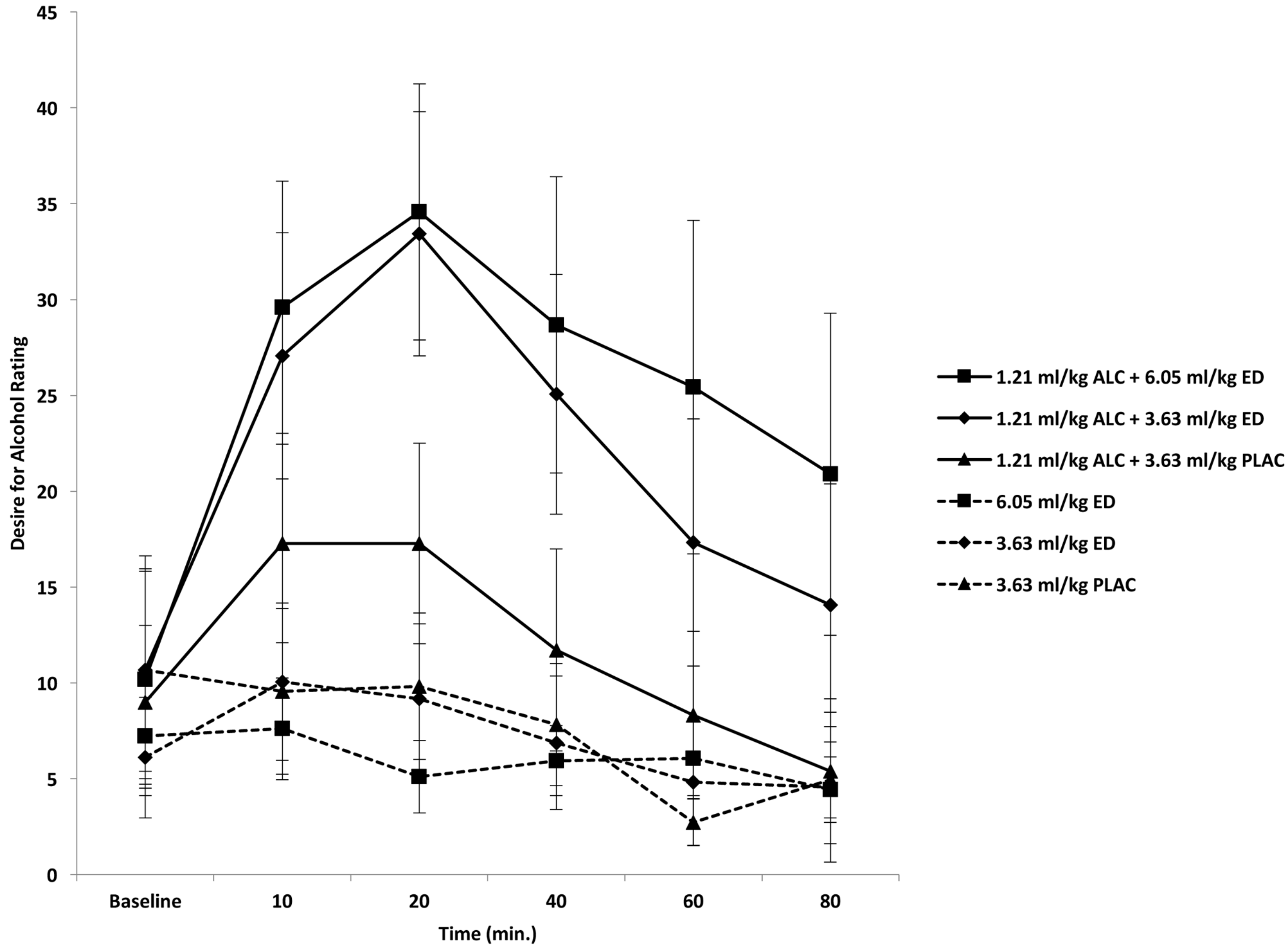

Figure 1.
Mean desire for alcohol ratings for all 6 dose conditions.

Table 1

Demographic characteristics, self-reported alcohol/caffeine use, and baseline ratings for the male (*n* = 13) and female (*n* = 13) participants.

	Males		Females	
	M	**SD**	**M**	**SD**
Age	23.77	3.61	24.23	2.74
Weight (kg)	77.42	10.74	66.45	12.18
Body Mass Index	24.03	3.98	24.55	3.92
Daily caffeine use (mg/kg)	2.94	3.37	3.32	2.02
No. energy drinks/week	0.90	1.60	1.25	1.15
SMAST	0.15	0.56	0.15	0.56
AUDIT	4.62	2.47	3.54	1.51
PDHQ:				
History (months)	72.31	51.01	69.23	33.30
Frequency (occasions/wk)	1.48	1.78	1.23	0.70
Drinks per occasion	3.73	2.09	3.65	2.10
Alcohol dose (g/kg)	0.86	0.50	0.88	0.53
Duration (hr)	3.12	1.53	2.58	0.79
Timeline Follow-back:				
Continuous drinking days	1.54	0.66	1.46	0.52
Continuous abstinence days	10.08	5.68	10.08	4.96
Total no.drinking days	5.00	3.11	5.00	2.20
Total no.drinks	16.92	13.02	12.54	8.24
Highest no. drinks in 1 day	6.08	4.27	4.00	1.63
Heavy drinking days	1.08	1.55	0.77	1.42
Drunk days	0.92	1.04	1.38	1.81
Eysenck	3.08	2.78	4.38	4.48
BIS-11	50.23	8.83	48.85	10.62

Table 2

Mean BrACs and self-reported Desire-for-Drug ratings for the 6 dose conditions.

	Dose Conditions											
	0.0 ml/kg Alcohol						1.21 ml/kg Alcohol (40% abv. vodka)					
	3.36 ml/kg Placebo		3.36 ml/kg Energy Drink		6.05 ml/kg Energy Drink		3.36 ml/kg Placebo		3.36 ml/kg Energy Drink		6.05 ml/kg Energy Drink	
Variable	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
BrAC (g%)												
20 min.							.044	.009	.041	.010	.034	.006
40 min.							.045	.008	.044	.009	.040	.009
60 min.							.039	.007	.040	.006	.039	.008
80 min.							.032	.007	.032	.005	.032	.009
Desire rating												
Baseline	14.96	28.73	11.19	22.39	10.92	20.02	14.15	25.09	14.42	26.25	13.27	25.48
10 min.	13.88	25.08	13.46	22.90	14.00	22.41	25.23	29.93	28.54	30.63	27.92	26.98
20 min.	16.31	26.43	12.46	22.32	10.85	19.60	23.81	29.10	34.54	30.89	35.81	29.43
40 min.	7.85	14.54	10.60	18.88	9.23	15.73	17.46	25.80	26.00	27.81	34.38	34.03
60 min.	4.38	10.47	6.58	15.63	8.31	12.67	12.35	20.19	19.96	29.55	28.65	36.10
80 min.	5.65	10.91	5.00	16.17	5.65	10.58	7.73	17.27	12.96	23.89	23.77	33.68
Feel rating												
10 min.	1.77	4.26	5.62	11.89	5.62	16.56	42.31	25.51	33.12	27.34	28.42	25.48
20 min.	5.69	10.24	8.23	14.65	5.65	15.33	51.46	25.40	44.23	25.80	43.54	28.02
40 min.	2.15	4.32	7.12	14.57	3.42	9.77	40.58	23.52	45.19	27.35	49.50	25.65
60 min.	0.96	1.73	3.81	11.79	2.92	8.39	26.58	24.09	34.19	24.09	43.31	23.82
80 min.	0.42	1.24	2.77	7.95	1.42	3.64	15.42	18.39	19.96	16.32	24.31	18.46
Like rating												
10 min.	32.54	32.07	32.81	33.73	40.15	30.82	38.96	26.12	40.85	25.25	41.35	25.69
20 min.	35.77	33.75	31.19	30.50	37.12	31.51	41.35	27.17	48.62	27.77	47.92	25.45
40 min.	28.15	33.93	27.73	32.65	36.69	29.56	31.69	23.50	46.08	26.66	47.54	25.39
60 min.	25.50	33.38	31.73	37.41	36.42	29.49	24.08	20.21	38.00	25.60	37.27	26.82
80 min.	24.81	33.59	30.58	37.41	28.19	28.71	22.23	27.46	31.42	24.42	35.31	30.01