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Mixing an Energy Drink with an Alcoholic Beverage Increases Motivation for More Alcohol in College Students

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Abstract

Background—There has been a dramatic rise in the consumption of alcohol mixed with energy drinks (AmED) in social drinkers. It has been suggested that AmED beverages might lead individuals to drink greater quantities of alcohol. This experiment was designed to investigate if the consumption of AmED would alter alcohol priming (i.e., increasing ratings of wanting another drink) compared with alcohol alone.

Methods—Participants (n = 80) of equal gender attended one session where they were randomly assigned to receive one of 4 doses (0.91 ml/kg vodka, 1.82 ml/kg energy drink, 0.91 ml/kg vodka mixed with 1.82 ml/kg energy drink (AmED), or a placebo beverage). Alcohol-induced priming of the motivation to drink was assessed by self-reported ratings on the Desire-for-Drug questionnaire.

Results—The priming dose of alcohol increased the subjective ratings of "desire" for more alcohol, consistent with previous research that small doses of alcohol can increase the motivation to drink. Furthermore, higher desire ratings over time were observed with AmED compared to alcohol alone. Finally, ratings of liking the drink were similar for the alcohol and AmED conditions.

Conclusions—An energy drink may elicit increased alcohol priming. This study provides laboratory evidence that AmED beverages may lead to greater motivation to drink versus the same amount of alcohol consumed alone.

Keywords

Alcohol; Energy Drink; Priming; Motivation to Drink; College Students

Introduction

A recent report revealed that the frequency of emergency department visits in the U.S. involving energy drinks has increased tenfold in only five years, with half of these visits involving alcohol mixed with energy drinks (AmED) (SAMHSA, 2011). These observations reinforce concerns raised by researchers and physicians about the safety of mixing energy drinks with alcohol. Incidences of drinking to intoxication, intention to drive while impaired, riding with an intoxicated driver, being physically hurt or injured, requiring medical treatment, and risk for alcohol dependence have all been found to be increased with AmED consumption, even after adjusting for the amount of alcohol consumed (Arria et al., 2010, 2011; O'Brien et al., 2008). However, the nature of the causal relationship between AmED

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consumption and risk-taking remains tentative, in part because these studies compare consumers of AmED versus consumers of alcohol alone users, and these two groups may more generally differ in trait impulsivity or risk-taking propensity (for a review see Verster et al., 2012).

Energy drinks are high caffeine beverages marketed as providing increased alertness (Miller, 2008; Reissig et al., 2009; Seifert et al., 2011). Energy drinks have become popular mixers for alcohol (e.g., Red Bull and vodka), in part because drinkers experience a different subjective response to the alcohol when drinking it as opposed to a beverage that is not mixed with caffeine and other stimulant ingredients (Ferreira et al., 2006; Marczinski, 2011; Marczinski & Fillmore, 2006). Laboratory investigations have demonstrated that AmED beverages increase subjective ratings of stimulation following drinking, reduce the feeling of fatigue, or reduce perceived intoxication when compared to the same dose of alcohol administered alone (Marczinski & Fillmore, 2006; Marczinski et al., 2011, 2012), coinciding with social drinkers' perceptions of the effects of these beverages.

However, feelings of sedation may be an important interoceptive cue that one should stop drinking (Marczinski et al., 2011). If this cue is absent, increased drinking may result, a risk factor for future alcohol dependence (King et al., 2011). Results from two studies indicate that participants self-report drinking significantly more alcohol when using AmEDs compared to drinking episodes in which energy drinks were not used (Price et al., 2010; Velazquez et al., 2012). In addition, results from a field study of bar patrons revealed that AmED consumers were at a 3-fold increased risk of leaving the bar highly intoxicated compared to consumers of alcohol alone (Thombs et al., 2010). To our knowledge, there is no human laboratory research comparing AmED and alcohol blindly administered to measure differences in motivation to want to drink. However, studies using animal subjects have demonstrated that caffeine promotes alcohol consumption (Dietze & Kulkosky, 1991; Kunin et al., 2000).

Given the above concerns about AmED beverages and the lack of a laboratory-based investigation directly comparing AmED versus alcohol for increased motivation to drink alcohol, we planned a study to address this question using the alcohol priming paradigm. It is commonly assumed that excessive alcohol consumption can occur because the initial drink itself reinforces or "primes" continued alcohol intake in the situation (Ludwig et al., 1974; Marlatt & Gordon, 1980). In a typical priming procedure, a low dose of alcohol or placebo is administered, followed by measures assessing the priming effect. These measures typically include self-reports such as desiring more alcohol, as well as behavioral measures of drug reinforcement, such as the subsequent self-administration of alcohol (Corbin et al., 2008; de Wit, 1996; Fillmore, 2001).

While the exact brain mechanisms underlying priming effects are unclear, brain reward mechanisms have been implicated. It is thought that the incentive properties of a small dose of alcohol positively reinforce consumption of greater amounts of alcohol (Koob & Le Moal, 1997; Robinson & Berridge, 1993; Wise & Bozarth, 1987). In the incentive-sensitization theory of addiction (Robinson & Berridge, 1993, 2003), changes in incentive salience (drug wanting) occur independently of changes in the neural systems that mediate the immediate pleasure when using drugs (drug liking). In this theory, 'liking' is the immediate pleasure gained from consuming alcohol while 'wanting' more alcohol can produce addictive behavior. The motivational quality of the alcohol makes it an attractive goal, transforming the drug experience from a mere sensory experience into something actively sought out. It is unknown if AmEDs enhance alcohol priming. However, any experiment examining alcohol priming for alcohol and AmEDs should include measures of both drug liking and drug wanting (i.e., desire for more).

The purpose of this study was to directly examine the responses to a priming dose of alcohol versus AmED in social drinkers. Eighty college students (of equal gender) were recruited to participate in one session. Participants were randomly assigned to receive one of four beverages (alcohol, energy drink, AmED, or vehicle). The degree to which the low doses of alcohol primed the motivation to drink was determined by repeated ratings on the Desire-for-Drug scale. Participants also completed ratings of stimulation and sedation. We hypothesized that alcohol would prime the motivation to drink and that an AmED would increase motivation to drink more than alcohol alone.

Method

Participants

Eighty adults (40 women) between the ages of 21 and 33 (M = 23.5 years, SD = 3.1) participated in this study. The self-reported racial-ethnic make-up of the sample included 16 African-Americans, 5 Asians, 1 Hispanic and 58 Caucasian participants. 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 standard drinks 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 five or higher or an AUDIT score (Barbor et al., 1989) of eight or higher (Barry & Fleming, 1993; Schmidt et al., 1995). 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). In addition, normal or corrected-to-normal visual acuity and normal color vision was required.

Recent use of amphetamines, barbiturates, benzodiazepines, cocaine, opiates, and tetrahydrocannibol was assessed by urinalysis at the start of the test session. 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. All volunteers provided informed consent before participating. The Northern Kentucky University Institutional Review Board approved this study. Participants received $30 for their participation in one test session.

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).

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).

Biphasic Alcohol Effects Scale (Martin et al., 1993)—Subjective ratings of stimulation and sedation were evaluated using this 14-adjective rating scale where seven adjectives describe stimulation effects (e.g., stimulated, elated) while the remaining seven adjectives describe sedation effects (e.g., sedated, sluggish). Participants rated each item on an 11-point Likert scale ranging from *not at all* (0) to *extremely* (10) and Stimulation and Sedation scores were summed separately (score subscale range = 0 to 70).

Intoxication Rating (Fillmore & Vogel-Sprott, 2000)—This one item scale asks participants to report their perceived level of intoxication by estimating their perceived alcoholic content of the beverage administered in terms of bottles of beer. The scale ranges from 0 to 10 bottles of beer, with 0.5 bottle increments.

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 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. 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. Participants were not given specific information about the type of alcohol or brand of energy drink. 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—A 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. Upon arrival in the laboratory, the participant was asked to provide informed consent. 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 on the BAES and desire for alcohol from the Desire-for-Drug questionnaire. The participants also completed the PDHQ, TLFB, CUQ, Eysenck, and BIS-11 questionnaires.

Dose Administration—Participants were randomly assigned to one of four dose conditions (alcohol, energy drink, AmED, or vehicle) counterbalanced for gender. Dose administration was double-blind and doses were calculated based on body weight. One researcher prepared the dose while another researcher tested the participant. For the alcohol dose, a 0.91 ml/kg dose of vodka (using 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). 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). This 0.91 ml/kg dose of vodka was reduced to 87% for female participants. The vodka dose was mixed with 1.82 ml/kg of Squirt, a decaffeinated soft drink (Dr. Pepper Snapple Group, Plano, TX) resulting in a 2:1 (soft drink:alcohol) ratio.

For the AmED condition, the 0.91 ml/kg dose of alcohol was mixed with 1.82 ml/kg of Red Bull energy drink (Red Bull, Switzerland). This 2:1 ratio (Red Bull:vodka) is the mixed drink typically served in bars. In the energy drink condition, participants received 1.82 ml/kg Red Bull, and in the vehicle condition, participants received 1.82 ml/kg Squirt. For the typical 76 kg participant in this study, the 1.82 ml/kg energy drink dose resulted in the consumption of 46 mg of caffeine. Squirt was chosen as the decaffeinated soda for the vehicle beverage since it is most similar in taste, carbonation, and appearance to the energy drink. 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).

Following all 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. BACs 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 vehicle 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. BAES ratings were given at 35 and 55 min. The subjective intoxication rating was given at 61 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 with the requirement that BAC was below .02 g%.

Criterion Measures and Data Analyses

Desire-for-drug ratings for “desire” were submitted to a 2 (Alcohol Dose: 0.91 ml/kg v. 0.0 ml/kg) × 2 (Energy Drink Dose: 1.82 ml/kg v. 0.0 ml/kg) × 2 (Gender) × 6 (Time: Baseline, 10, 20, 40, 60 v. 80 min.) mixed design ANOVA where Alcohol Dose, Energy Drink Dose and Gender were treated as between-subjects factors and Time was treated as a within-subjects factor. Desire-for-drug ratings for the “like” and “feel” measures were submitted to a 2 (Alcohol Dose) × 2 (Energy Drink Dose) × 2 (Gender) × 5 (Time: 10, 20, 40, 60 v. 80 min.) mixed design ANOVA. BAES ratings of stimulation and sedation were submitted to separate 2 (Alcohol Dose) × 2 (Energy Drink Dose) × 2 (Gender) × 3 (Time: Baseline, 35

and 55 min.) mixed design ANOVAs. Finally, subjective intoxication ratings were submitted to a 2 (Alcohol Dose) × 2 (Energy Drink Dose) × 2 (Gender) between subjects ANOVA. When interactions were obtained, paired sample one-tailed *t* tests were used to compare the ratings at various points compared with baseline for each dose condition, applying the Bonferroni correction for multiple comparisons. The alpha level was set at .05 for all statistical tests and SPSS 17.0 was used to conduct all analyses.

Results

Demographic Characteristics and Self-Reported Caffeine/Alcohol Use

Table 1 lists all demographic, questionnaire, and baseline measures for participants in the four dose conditions. Results of one-way ANOVAs for each demographic, caffeine use, alcohol use, impulsivity measures, and baseline subjective ratings revealed no significant differences among the four dose conditions, *p*s > .07. The sample self-reported a mean (*SD*) typical alcohol dose of 0.93 g/kg (0.49) per occasion, which is approximately equivalent to four standard bottles of beer for the average 76 kg participant in this study. The sample also reported a mean (SD) duration of drinking of 3.37 hours (1.61) with a mean (SD) weekly frequency of drinking of 1.28 days (0.98). The sample also self-reported a mean (SD) typical caffeine dose of 2.93 mg/kg (2.34), which is approximately equivalent to one 16 oz. Starbucks coffee for the average 76 kg participant (McCusker et al., 2006).

Possible gender differences for the baseline measures reported in Table 1 were compared using independent samples *t* tests. Mean (*SD*) body weight was significantly higher for males compared to females, 82.18 (10.22) versus 70.04 (2.21) respectively, $t(78) = 4.11$, $p < .001$. Mean (*SD*) AUDIT scores were significantly higher for males compared to females, 6.08 (3.38) versus 4.28 (1.88) respectively, $t(78) = 2.95$, $p = .004$. From the PDHQ, males reported a significantly higher mean (*SD*) number of drinks per occasion compared to females, 4.70 (2.21) versus 3.30 (1.95) respectively, $t(78) = 3.00$, $p = .004$. However, there were no significant gender differences in self-reported dose from the PDHQ, $p = .24$, indicating that once gender differences in body weight were considered, the males and females appeared to have similar self-reported drinking habits on a typical drinking occasion. From the TLFB, the males reported significantly less continuous days of abstinence, more total number of drinks, a higher number of drinks in one day, more heavy drinking days, and more drunk days compared to females, *p*s < .05. No gender differences were observed for the impulsivity measures, *p*s > .15.

BACs

No detectable BACs were observed under the energy drink or vehicle conditions. Group and gender differences in BAC under the two active alcohol dose conditions were examined by a 2 (Group) × 2 (Gender) × 4 (Time) mixed design ANOVA. No main effects or interactions involving group or gender were observed, *p*s > .33. There was a main effect of time owing to the fall in BACs over the course of the session, $F(3,34) = 66.50$, $p < .001$ (see Table 2).

Desire-for-Drug Ratings

The results of the 2 (Alcohol) × 2 (Energy Drink) × 2 (Gender) × 6 (Time) ANOVA for "desire for alcohol" ratings revealed a significant Alcohol × Energy Drink × Time interaction, $F(5,68) = 2.41$, $p = .046$, $\eta^2 = .150$. There were no other significant main effects or interactions for this analysis, *p*s > .06. Figure 1 illustrates the desire for more alcohol ratings for the four dose conditions at each of the six time points.

To better understand the Alcohol × Energy Drink × Time interaction, desire ratings at each of the time points were compared with the baseline measure for each of the four dose

conditions using paired samples *t* tests. For the vehicle condition, desire ratings were significantly higher at 10 min. compared to baseline, $t(19) = 2.47$, $p = .011$, but not significantly different for the other time points, $ps > .32$. For the energy drink condition, desire ratings were significantly lower than baseline at 40 ($p = .01$) and 80 min. ($p = .001$), but not different for the other time points. For the alcohol condition, desire ratings were significantly higher at 10 and 20 min. compared to baseline, $ps = .01$, but not different for the other time points. Finally, for the AmED condition, desire ratings were significantly higher at 10, 20, 40, and 60 min. compared to baseline, $ps < .01$. The desire ratings for 80 min. did not differ from baseline for the AmED condition, $p = .37$. In addition to the above analyses, independent samples *t* tests were used to compare desire ratings for the alcohol versus AmED dose conditions for the desire ratings at each of the time points. No differences between alcohol and AmED for any of the time points were observed, although there was a nonsignificant trend for higher ratings for AmED versus alcohol alone at 40 min., $t(38)=1.47$, $p = .075$.

Desire-for-drug ratings for the “like” and “feel” measures were submitted to separate 2 (Alcohol) × 2 (Energy Drink) × 2 (Gender) × 5 (Time) mixed design ANOVAs. For the like ratings, the analysis revealed a significant Alcohol × Time interaction, $F(4,69) = 2.73$, $p = .036$, $\eta^2 = .137$. There were no other significant main effects or interactions for this analysis, $ps > .19$. Table 2 reveals that the like ratings were higher under the active alcohol dose conditions, especially at the earlier time points, compared to when alcohol was not administered. Independent samples *t* tests were used to compare the active alcohol dose conditions to the conditions that did not include alcohol. At 20 min., like ratings were significantly higher under alcohol compared to the no alcohol conditions, $t(78) = 1.84$, $p = .034$. However, there were no other significant differences between alcohol and no alcohol conditions for the other time points, $ps > .10$.

For the feel ratings, the analysis revealed a significant Alcohol × Time interaction, $F(4,69) = 14.93$, $p < .001$, $\eta^2 = .464$. There were no other significant main effects or interactions for this analysis, $ps > .21$. Table 2 illustrates that the feel ratings were higher under the active alcohol dose conditions, compared to when alcohol was not administered. This observation was confirmed by independent samples *t* tests that compared the active alcohol dose conditions to the conditions that did not include alcohol, resulting in a significant difference at each time point, $ps < .02$.

Subjective Intoxication Ratings

Subjective intoxication ratings were submitted to a 2 (Alcohol Dose) × 2 (Energy Drink Dose) × 2 (Gender) ANOVA. This analysis revealed a main effect of alcohol, $F(1,72) = 58.74$, $p < .001$, $\eta^2 = .449$. The mean intoxication ratings were higher following alcohol administration compared to when alcohol was not administered (see Table 2). There were no other significant effects in this analysis, $ps > .10$.

BAES Ratings

Ratings of stimulation and sedation were submitted to separate 2 (Alcohol) × 2 (Energy Drink) × 2 (Gender) × 3 (Time) ANOVAs. For stimulation, a main effect of Time was observed, $F(2,71) = 5.72$, $p = .005$, $\eta^2 = .139$. Mean (SD) stimulation ratings at baseline, 35 and 55 min. were 21.53 (16.83), 23.67 (17.85), 20.35 (16.11) respectively. There were no other significant main effects or interactions in this analysis, $ps > .07$. For ratings of sedation, this analysis revealed no significant main effects or interactions, $ps > .13$.

Discussion

This study examined alcohol-induced priming of the motivation to drink in social drinkers. The question was whether alcohol mixed with an energy drink (AmED) would alter alcohol priming (i.e., desire to drink more alcohol) compared with alcohol alone. The results from the Desire-for-Drug scale ratings indicated that a low priming dose of alcohol elicited higher desire for alcohol ratings when alcohol was administered compared to conditions when no alcohol was administered. More importantly, we observed that a priming dose of AmED increased these desire ratings for a longer time period compared to a priming dose of alcohol alone.

Contrasting with the results from the "desire" ratings, "like" and "feel" ratings were similar when alcohol was administered alone or as AmED. Thus, participants desired more alcohol following AmED compared to alcohol alone, although they liked and felt the two types of alcoholic beverages in a similar fashion. In addition, no significant effects of alcohol and energy drinks, alone or in combination, were observed for ratings of stimulation and sedation. This outcome for ratings of sedation/stimulation is in contrast to previous research utilizing higher doses of both of these drugs (Marczinski et al., 2011, 2012). Since no appreciable changes in feelings of stimulation and sedation occurred at the low doses used in the current study, it may be that AmEDs are just more rewarding and reinforcing than alcohol alone. Given that the desire ratings were increased for a longer period of time for AmED compared to alcohol alone, this suggests that the energy drink mixer might increase the reinforcing aspect of alcohol. Considering that drug wanting (i.e., incentive salience) produces addictive behavior (Robinson & Berridge, 1993), the results of our study might therefore provide an explanation for why consumers of AmEDs are more likely to become alcohol dependent (Arria et al., 2011). Moreover, consumers of AmEDs are also likely to be high in risk-taking relative to non-consumers (Brache & Stockwell, 2011), suggesting that preexisting personality characteristics combined with the use of these beverages may both contribute to alcohol dependence risk.

Energy drinks contain a variety of compounds, but the high levels of caffeine are thought to the principal active ingredient (Seifert et al., 2011; Reissig et al., 2009). Therefore, our finding that energy drinks alter desire for more alcohol is consistent with other research that has demonstrated that caffeine increases alcohol consumption in ad lib alcohol administration models using rodents (Dietze & Kulkosky, 1991; Kunin et al., 2000). However, it is remarkable that the energy drink increased desire for more alcohol for a longer period of time in this study, even though the amount of caffeine consumed by participants was relatively low (i.e., 46 mg caffeine for a typical participants). Previous research suggests that this amount of caffeine alone would not reliably alter physiological or subjective state (Fredholm et al., 1999; Nehlig, 1999). As such, central nervous system interaction between alcohol and the adenosinergic system upon which caffeine acts may be playing an important role in the results obtained (Arolfo et al., 2004; Butler & Prendergast, 2012; Sharma et al., 2010). The results of the current study suggest that increased translational research may better elucidate possible underlying mechanisms explaining why AmEDs may lead to increased drinking.

As with any study, there are limitations that must be considered. We examined one type of energy drink and one low priming dose of alcohol. Other studies have utilized higher priming doses of alcohol, resulting in increased desire ratings for alcohol. We weighed the choice of priming dose carefully and decided on the low dose to provide increased ecological validity. In addition, we chose to utilize a 2:1 energy drink:vodka ratio, as this is a commonly prepared drink in bars. However, this practice is not universal and AmED beverages are also often prepared using a standard 1 ½ oz. shot of vodka or Jagermeister

mixed with an entire 250 ml can of Red Bull (i.e., 5:1 ratio of energy drink:alcohol). Given that our 2:1 energy drink:vodka ratio elevated desire ratings for a longer period of time than alcohol alone, it seems reasonable to hypothesize that the differences between alcohol and AmED beverages may be more pronounced in real life cases where the beverage is prepared using a greater proportion of energy drink, although this remains to be tested in the laboratory. Moreover, future research should examine individual differences in response to various priming doses of alcohol, including sensation-seeking status, impulsivity, typical caffeine use, and typical drinking habits.

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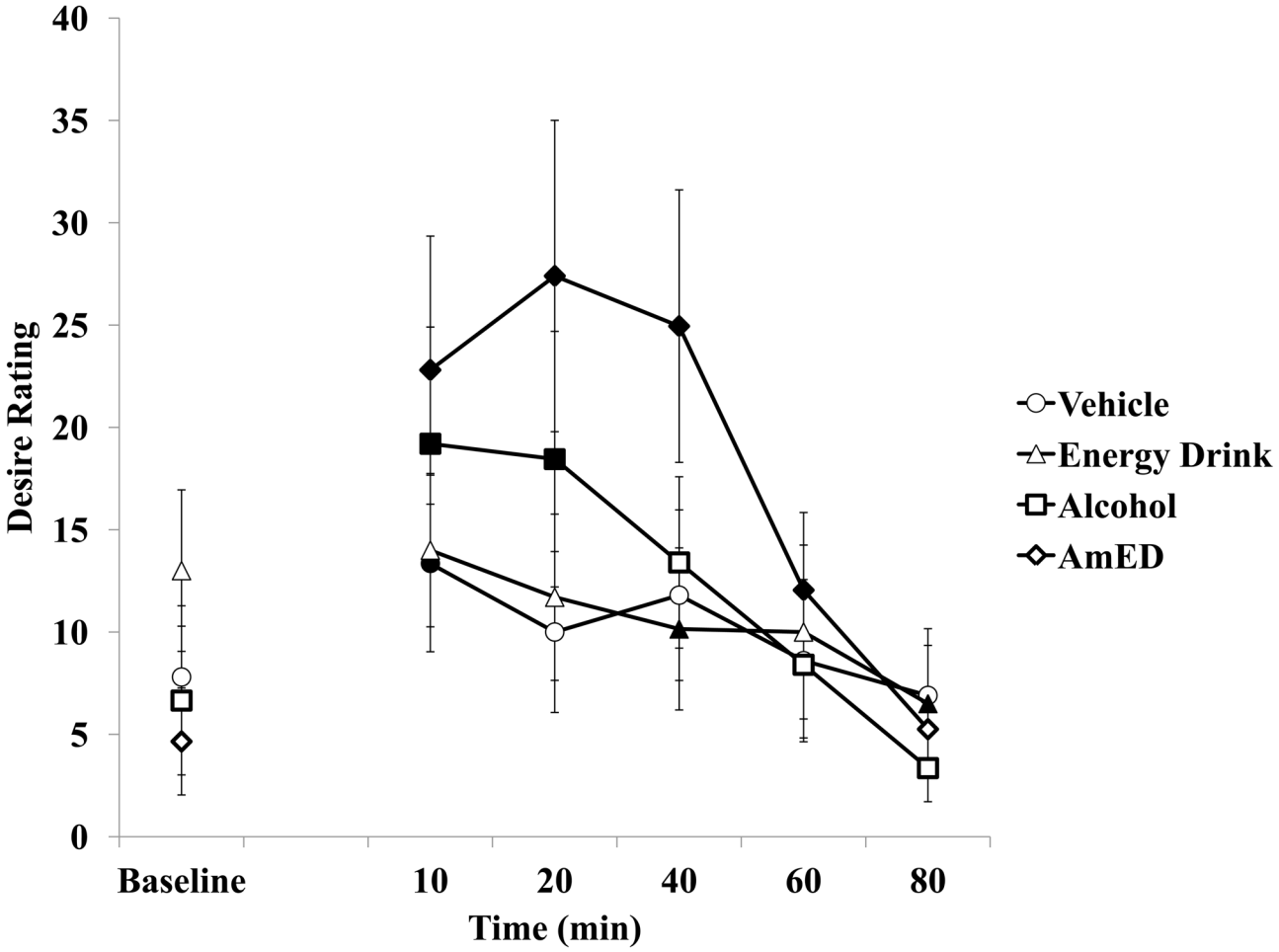

Figure 1.
Mean "desire for alcohol" ratings from the Desire-for-Drug visual analogue scale for each dose at baseline, 10, 20, 40, 60, and 80 min. after dose administration. Standard errors are represented in the figure by the error bars attached to each symbol. A filled symbol indicates a significant change from baseline as measured by a paired samples *t* test ($p < .05$).

Table 1

Demographic characteristics, self-reported alcohol/caffeine use, and baseline ratings for the four dose conditions.

	Dose Condition							
	Vehicle		Energy Drink		Alcohol		AmED	
	M	(SD)	M	(SD)	M	(SD)	M	(SD)
Age	23.50	(3.25)	23.00	(2.41)	24.45	(3.99)	23.10	(2.73)
Gender (male:female)	10:10		10:10		10:10		10:10	
Weight (kg)	76.96	(15.49)	75.99	(10.93)	76.07	(12.19)	77.21	(15.45)
Daily caffeine use (mg/kg)	3.23	(2.62)	3.12	(2.22)	2.60	(2.57)	2.78	(2.02)
SMAST	1.05	(2.14)	0.75	(1.68)	0.50	(1.10)	0.65	(1.46)
AUDIT	4.65	(1.39)	6.00	(4.19)	4.70	(2.20)	5.35	(2.91)
PDHQ:								
History (months)	53.85	(36.90)	63.35	(39.45)	73.20	(43.83)	60.25	(39.68)
Frequency (occasions/wk)	1.16	(1.05)	1.24	(0.56)	1.23	(1.06)	1.50	(1.19)
Drinks per occasion	3.65	(1.98)	4.40	(2.48)	3.60	(2.06)	4.35	(2.23)
Alcohol dose (g/kg)	0.83	(0.44)	0.99	(0.54)	0.93	(0.51)	0.98	(0.49)
Duration (hr)	3.50	(1.83)	3.63	(1.66)	2.85	(1.66)	3.50	(1.24)
Timeline Follow-back:								
Continuous drinking days	1.50	(0.95)	1.95	(1.23)	2.00	(1.49)	1.90	(1.33)
Continuous abstinence days	10.05	(4.85)	10.20	(4.94)	10.65	(5.59)	10.50	(6.99)
Total no. drinking days	5.35	(3.15)	5.75	(2.85)	5.95	(5.40)	6.00	(3.49)
Total no. drinks	17.25	(13.53)	27.65	(28.11)	19.45	(23.63)	21.55	(16.92)
Highest no. drinks in 1 day	5.25	(2.43)	7.17	(3.68)	4.40	(2.82)	6.00	(4.14)
Heavy drinking days	1.20	(1.61)	2.40	(2.82)	1.85	(3.47)	2.05	(2.76)
Drunk days	1.60	(2.48)	2.30	(2.32)	2.05	(4.05)	2.45	(2.86)
Eysenck	4.30	(3.08)	6.00	(3.88)	6.35	(4.32)	3.95	(3.80)
BIS-11	51.90	(7.97)	53.75	(9.10)	54.25	(11.61)	47.40	(7.97)
Stimulation rating	24.55	(18.76)	18.95	(13.17)	18.10	(17.14)	24.50	(17.91)
Sedation rating	10.85	(9.39)	11.00	(12.58)	10.45	(14.45)	9.30	(10.53)
Desire for alcohol rating	7.80	(15.58)	13.00	(17.66)	6.65	(16.25)	4.65	(11.69)

Table 2

Mean BACs, Self-reported Desire-for-Drug ratings, Subjective Intoxication, and BAES ratings for the four dose conditions.

	Dose Condition							
	Vehicle		Energy Drink		Alcohol		AmED	
	M	(SD)	M	(SD)	M	(SD)	M	(SD)
BAC (g%)								
20 min.					.043	(.016)	.040	(.013)
40 min.					.040	(.014)	.038	(.009)
60 min.					.033	(.013)	.031	(.008)
80 min.					.027	(.009)	.025	(.008)
Like Rating								
10 min.	32.75	(22.18)	34.90	(24.77)	32.70	(27.14)	47.65	(26.50)
20 min.	26.60	(25.26)	31.00	(22.14)	34.95	(28.67)	43.60	(25.50)
40 min.	26.85	(23.59)	30.40	(23.48)	26.00	(18.41)	36.30	(23.89)
60 min.	21.50	(24.04)	27.85	(21.80)	22.00	(19.88)	27.70	(16.77)
80 min.	20.70	(24.52)	24.10	(22.52)	11.70	(14.51)	21.05	(19.98)
Feel Rating								
10 min.	10.00	(13.31)	5.55	(8.21)	36.95	(30.96)	42.70	(29.53)
20 min.	10.85	(17.00)	7.70	(11.82)	48.35	(30.80)	52.85	(31.00)
40 min.	11.05	(16.29)	6.70	(13.55)	35.25	(18.40)	42.75	(24.82)
60 min.	8.05	(14.16)	3.85	(8.16)	23.45	(19.72)	26.05	(19.71)
80 min.	4.02	(9.79)	4.40	(11.88)	11.55	(15.33)	10.70	(10.25)
Subjective Intoxication	0.68	(0.83)	0.58	(0.83)	2.95	(1.59)	2.20	(1.01)
Stimulation Rating								
35 min.	20.60	(19.06)	20.65	(15.76)	22.05	(19.09)	31.40	(16.23)
55 min.	19.20	(17.22)	19.25	(14.65)	15.35	(14.56)	27.60	(16.48)
Sedation Rating								
35 min.	14.75	(13.01)	9.15	(9.24)	13.35	(12.42)	12.05	(9.23)
55 min.	13.45	(14.15)	9.35	(10.83)	14.95	(17.46)	14.30	(11.47)