Published in final edited form as:

Alcohol Clin Exp Res. 2013 April ; 37(4): 696–702. doi:10.1111/acer.12039.

Artificial sweeteners versus regular mixers increase breath alcohol concentrations in male and female social drinkers

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Abstract

Background—Limited research suggests that alcohol consumed with an artificially sweetened mixer (e.g., diet soft drink) results in higher breath alcohol concentrations (BrACs) compared to the same amount of alcohol consumed with a similar beverage containing sugar. The purpose of this study was to determine the reliability of this effect in both male and female social drinkers and to determine if there are measureable objective and subjective differences when alcohol is consumed with an artificially-sweetened versus sugar-sweetened mixer.

Methods—Participants ($n = 16$) of equal gender attended three sessions where they received one of 3 doses (1.97 ml/kg vodka mixed with 3.94 ml/kg Squirt, 1.97 ml/kg vodka mixed with 3.94 ml/kg diet Squirt, and a placebo beverage) in random order. BrACs were recorded, as was self-reported ratings of subjective intoxication, fatigue, impairment and willingness to drive. Objective performance was assessed using a cued go/no-go reaction time task.

Results—BrACs were significantly higher in the alcohol + diet beverage condition compared with the alcohol + regular beverage condition. The mean peak BrAC was .091 g/210 L in the alcohol + diet condition compared to .077 g/210 L in the alcohol + regular condition. Cued go/no-go task performance indicated the greatest impairment for the alcohol + diet beverage condition. Subjective measures indicated that participants appeared unaware of any differences in the two alcohol conditions, given that no significant differences in subjective ratings were observed for the two alcohol conditions. No gender differences were observed for BrACs, objective and subjective measures.

Conclusions—Mixing alcohol with a diet soft drink resulted in elevated BrACs, as compared to the same amount of alcohol mixed with a sugar sweetened beverage. Individuals were unaware of these differences, a factor that may increase the safety risks associated with drinking alcohol.

Keywords

alcohol; artificially-sweetened beverages; diet drinks; breath alcohol concentration; reaction times

Introduction

Following the consumption of alcohol, an individual's breath alcohol concentration (BrAC) is influenced by a variety of factors, such as whether food was consumed. The presence of food can be so important that reductions in peak BrAC have been reported to be as much as 20–57% when food is present in the stomach as compared to when alcohol is consumed alone (Jones and Jonsson, 1994; Pikaar et al., 1988; Roberts and Robinson, 2007; Sedman et al., 1976). While food delays stomach emptying (thus reducing BrAC), only recently has the role of nonalcoholic drink mixers consumed with alcohol been explored as another potential

factor influencing BrAC. Many alcoholic beverages are mixed with other non-alcoholic beverages (e.g., rum mixed with coke or vodka mixed with orange juice). Preliminary evidence suggests that the mixer might alter BrAC (Matthews et al., 2001; Rossheim and Thombs, 2011; Wu et al., 2006). For example, Rossheim and Thombs (2011) conducted a field study where patrons leaving bars were recruited to report what kinds and how many beverages they had consumed that evening and to provide a breath sample. The authors reported that the BrAC was significantly associated with the number of diet cola-mixed drinks. The greater the number of diet drinks mixed with alcohol, the greater the BrAC recorded. In this study, women were more likely to consume diet cola-cafeinated mixed drinks and women also had higher BrACs.

Given widespread concerns about weight and obesity, individuals have increasingly turned to artificially sweetened foods and beverages. As alcohol contains calories, it is perhaps unsurprising that individuals might consume alcohol with diet mixers to limit the overall number of calories consumed. As a demographic group, women are more likely to be consumers of diet beverages (Fowler et al., 2008). The results of the above field study suggest that many individuals, particularly women, are choosing to consume alcohol with diet beverages (Rossheim and Thombs, 2011). However, the observation that higher BrACs were associated with diet mixers in the field might have been spurious given that women also tend to achieve higher BrACs than men following a dose of alcohol (Baraona et al., 2001; Marczinski, 2011; Pikaar et al., 1988).

If artificially-sweetened mixers result in higher BrAC, the mechanism for this may be similar to the manner which absence or presence of food in the stomach alters alcohol absorption and metabolism. One laboratory study examined gastric emptying time and alcohol absorption for artificially sweetened versus regular mixers (Wu et al., 2006). In this study, eight male subjects were administered vodka twice in randomized order, with the vodka being mixed with either a sucrose beverage or a diet mixer on each test session. Peak blood alcohol concentration was found to be greater following consumption of the diet alcoholic drink (.053 g%) compared to the regular drink (.034 g%). Gastric half-emptying time (using ultrasound) was recorded and found to be faster for the diet drink compared to the regular drink. Thus, it appears that a regularly sweetened beverage might be treated by the stomach somewhat like food. Moreover, these results are consistent with the notion that rate of gastric emptying is a major determinant of the absorption of alcohol (Horowitz et al., 1989; Oneta et al., 1998).

While artificially-sweetened alcoholic beverages may result in higher BrAC compared to the same amount of alcohol consumed with a regular mixer, the role of gender remains unclear. Moreover, if diet drinks can increase BrAC, this has implications for the safe consumption of alcohol. It is unknown whether differences in BrAC might result in differential levels of behavioral impairment, although it is plausible that higher BrAC would be associated with greater impairment. In addition, it is unknown whether consumers would be aware of differences in BrAC. A variety of studies have demonstrated that individuals have difficulty assessing their BrAC level (Grant et al., 2012; Mallett et al., 2009). Moreover, underestimations of BrAC can be associated with an increased willingness to drive a car, which is a major safety concern (Marczinski and Fillmore, 2009). Therefore, any laboratory study examining BrAC differences associated with different mixers should also assess objective and subjective impairment.

The purpose of this study was to examine directly the acute effects of an alcohol + diet beverage, an alcohol + regular beverage and a placebo beverage. Sixteen social drinkers (of equal gender) were recruited to participate in three sessions where they received 1.97 ml/kg vodka mixed with 3.94 ml/kg diet Squirt, 1.97 ml/kg vodka mixed with 3.94 ml/kg Squirt,

and a placebo beverage in random order. BrACs were recorded, as were self-reported ratings of subjective intoxication, fatigue, impairment, and willingness to drive. The effects of these beverages were also examined on the cued go/no-go task, a behavioral task known to be sensitive to the impairing effects of alcohol (Marczinski and Fillmore, 2003; Marczinski et al., 2011). We predicted that the alcohol + diet beverage would result in higher BrACs compared to the alcohol + regular beverage condition. Moreover, we wished to determine if greater impairment on the cued go/no-go task in the alcohol + diet condition would be observed compared to the alcohol + regular condition. Finally, we predicted that participants might rate their levels of intoxication and impairment similarly in the two alcohol conditions, given the literature that social drinkers are poor estimators of BrAC.

Method

Participants

Sixteen adults (eight women) between the ages of 21 and 33 ($M = 23.2$ years, $SD = 3.4$) participated in this study. All participants self-reported their racial-ethnic make-up as Caucasian. 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 CNS 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 (Selzer et al., 1975) of five or higher or an AUDIT score (Barbor et al., 1989) of eight or higher (Barry and Fleming, 1993; Schmidt et al., 1995). Inclusion criteria consisted of self-reported consumption of at least one soft drink in the past month and one diet soft drink in the past year. In addition, normal or corrected-to-normal visual acuity and normal color vision were required.

Recent use of amphetamines, barbiturates, benzodiazepines, cocaine, opiates, and tetrahydrocannabinol was assessed by urinalysis at the start of each 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 \$90 for their participation in this three 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 by the number of months that an individual has been drinking on a regular basis or customarily on social occasions.

Cued Go/No-go Task (Marczinski & Fillmore, 2003)—Behavioral control was measured by a cued go/no-go reaction time task that assesses the ability to activate and inhibit responses. This task is sensitive to the impairing effects of moderate doses of alcohol and energy drinks (Marczinski et al., 2011). The task was operated using E-Prime 2.0

software (Schneider et al., 2002) on a Dell Latitude laptop computer. A test consisted of 500 trials involving four possible cue-target combinations and took approximately 25 minutes to complete. A trial involved the following sequence of events: (i) a fixation point (+) for 800 ms, (ii) a blank screen for 500 ms, (iii) a cue (a horizontal or vertical white rectangle), displayed for one of five stimulus onset asynchronies (SOAs = 100, 200, 300, 400 and 500 ms), (iv) a go or no-go target (green or blue rectangle), visible until a response occurs or 1,000 ms elapses, and (v) an intertrial interval of 700 ms.

The orientation of the cue (horizontal or vertical) correctly signaled the target 80% of the time. Participants were instructed to press the forward slash (/) key on the keyboard as soon as a go (green) target appeared and to suppress (inhibit) any response if a no-go (blue) target appeared. Activational and inhibitory tendencies show rapid development of cue dependence as cues help an individual prepare for the execution or inhibition of behavior (Miller et al., 1991). For response activation, the slowing effect of alcohol on reaction time is typically observed in the no-go cue condition. For response inhibition, the go cue generates response prepotency, yet subjects must overcome this response prepotency in order to successfully inhibit the response when a no-go target is displayed. Typically, the acute effects of alcohol result in impairments in response inhibition, particularly for this go-cue condition.

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.

Visual Analogue Scale Subjective Ratings (Beirness, 1987; Fillmore, 2001)—This five 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 their perceived level of fatigue, perceived level of impairment, how much they feel the drink, how much they like the drink, and their willingness to drive a car at the time of the rating.

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).

Procedure

Pre-laboratory Screening—Individuals who were interested in participating in this study 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 soft drinks on behavior. Individuals were told that they would be asked to consume a beverage and complete questionnaires and a computer task. They were informed that the drink might contain an amount of alcohol comparable to the maximum dose of alcohol found in four beers and the soft drink may be a diet or sugar sweetened drink. Participants were not given specific information about the types or brands of alcohol and soft drink. Prior to each 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 breath alcohol concentration (BrAC) 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 (uVera Diagnostics, Norfolk, VA). On the first session, the participant completed the PDHQ and practiced a full-length version of the cued go/no-go task.

Dose Administration—Participants received one of the three doses (alcohol + regular drink, alcohol + diet drink, or placebo) in counterbalanced order. Dose administration was double-blind and doses were calculated based on body weight. For the alcohol dose, a 1.97 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 raise BrACs to approximately .08 g/210 L, the legal limit for driving, and is known to result in impairments in inhibitory control and reaction times on the cued go/no-go task (Marczinski and Fillmore, 2003; Marczinski et al., 2011). This 1.97 ml/kg dose of vodka was reduced to 87% for female participants so that males and females were not likely to have different BrACs. For the alcohol + regular drink condition, the vodka dose was mixed with 3.94 ml/kg of Squirt, a carbonated soft drink (Dr. Pepper Snapple Group, Plano, TX) resulting in a 2:1 (soft drink:alcohol) ratio. For the alcohol + diet drink condition, the vodka dose was mixed with 3.94 ml/kg of diet Squirt, a carbonated soft drink containing no calories. A 12 oz. can of Squirt contains 140 calories and 37 grams of sugar whereas the same size can of diet Squirt contains zero calories and is sweetened with aspartame. Both drinks are similarly carbonated and do not contain caffeine (Dr. Pepper Snapple Group, Plano, TX). Finally, for the placebo condition, 3.94 ml/kg of Squirt was administered. To give the appearance that alcohol was being consumed in the placebo condition, 10 ml of vodka was floated on the surface of the beverage to provide an alcohol scent, with previous research having demonstrated that individuals report that this beverage contains alcohol (Marczinski et al., 2011). On each session, participants were given their assigned 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.

Post Dose Administration Testing—BrACs were measured at 30, 40, 70, 80, 90, 120, 150 and 180 min. after drinking was initiated. Breath samples were also provided by participants given the placebo drink at those same intervals, ostensibly to measure their BrAC. Cued go/no-go task performance was assessed at 45 min. after drinking began. All subjective ratings (intoxication, VAS and BAES) were given after the cued go/no-go task at 70 min. after drinking began. Upon completion of the testing period at 180 min. post drinking, all participants were given a meal. Participants were released when BrAC was below .02 g/210 L.

Criterion Measures and Data Analyses

The two measures of interest from the cued go/no-go task were participants' speed in responding to go targets (response execution) and participants' failure to inhibit responses to no-go targets (failures of response inhibition). Response execution was measured by the mean reaction time (RT) to go targets in the go and no-go cue conditions for each test. Mean RTs were analyzed by a 3 (Dose: alcohol + regular drink, alcohol + diet drink, placebo) $\times$ 2 (Cue: go vs. no-go) $\times$ 2 (Gender) mixed design ANOVA where Dose and Cue were treated as within-subjects factors and Gender was treated as a between-subjects factor. Failures of response inhibition were measured as the proportion (p) of no-go targets in which a

participant failed to inhibit a response in the go and no-go cue conditions for each test. The mean p-inhibition failure scores were analyzed by a 3 (Dose) $\times$ 2 (Cue) $\times$ 2 (Gender) mixed design ANOVA. Mean subjective ratings were submitted to separate 3 (Dose) $\times$ 2 (Gender) mixed design ANOVAs. Finally, mean BrACs were submitted to a 3 (Dose) $\times$ 8 (Time) $\times$ 2 (Gender) mixed design ANOVA. For all analyses, when main effects were obtained that required post-hoc analysis, LSD tests were used. When interactions were obtained, paired sample *t* tests were used, 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 Alcohol Use

The sample self-reported a mean (*SD*) typical alcohol dose of 0.78 g/kg (0.49) per occasion, which is approximately equivalent to four standard bottles of beer for the average 74 kg participant in this study. The sample also self-reported a mean (*SD*) typical duration of drinking of 2.81 (1.24) hours, a mean (*SD*) weekly frequency of drinking of 1.25 (0.70) days, and mean (*SD*) history of drinking of 56.63 (39.95) months. Possible gender differences were examined using independent samples *t* tests. Mean (*SD*) body weight was significantly higher for males compared to females, 81.18 (14.30) versus 67.44 (10.10) respectively, $t(14) = 2.22$, $p = .044$. There were no significant gender differences on any of the self-reported drinking habits from the PDHQ, p s $> .08$.

Breath Alcohol Concentrations

No detectable BrACs were observed in the placebo condition. Dose and gender differences in BrACs under the two active alcohol dose conditions were examined by a 2 (Dose) $\times$ 2 (Gender) $\times$ 8 (Time) mixed design ANOVA. No main effects or interactions involving gender were observed, p s $> .22$. There was a main effect of time owing to the rise and fall in BrACs over the course of the session, $F(7,8) = 115.56$, $p < .001$, $\eta^2 = .990$. More importantly, there was main effect of dose, $F(1,14) = 12.78$, $p = .003$, $\eta^2 = .477$. As shown in Figure 1, the mean BrAC for the alcohol + diet drink condition was higher at each time point compared to the coinciding BrAC for the alcohol + regular drink condition. These observations were confirmed when paired samples *t* tests were used to compare the two conditions at each time point, with a significantly higher value being observed at each time point for the alcohol + diet condition compared to the alcohol + regular drink condition, p s $< .014$. It is notable that the peak BrAC achieved at 40 min. after initiation of drinking in the alcohol + diet drink condition was .091 g/210 L whereas the peak BrAC in the alcohol + regular drink condition was .077 g/210 L, reflecting an 18% increase in BrAC (see Table 1).

Cued Go/No-go Task Performance

The results of the 3 (Dose) $\times$ 2 (Cue) $\times$ 2 (Gender) ANOVA for mean RTs from the cued go/no-go task revealed a significant main effect of Dose, $F(2,13) = 4.18$, $p = .040$, $\eta^2 = .391$, and a significant main effect of Cue, $F(1,14) = 39.54$, $p < .001$, $\eta^2 = .739$. There were no other significant main effects or interactions for this ANOVA, p s $> .05$. The main effect of Cue reflected that mean (*SD*) RTs were significantly faster in the go cue condition compared to the no-go cue condition, 285.38 ms (40.44) versus 314.66 ms (32.12) respectively. To better understand the main effect of Dose, post-hoc LSD tests revealed that mean RTs were significantly slower for the alcohol + diet drink condition compared to the placebo condition, $p = .01$. However, mean RTs were not significantly different for the alcohol + regular drink condition when compared with the placebo condition and the alcohol + regular drink condition also did not significantly differ from the alcohol + diet drink condition, p s $> .21$. Table 1 reports the mean RTs for each dose and cue condition.

The results of a $3 \times 2 \times 2$ ANOVA for p-inhibition failures from the cued go/no-go task revealed a significant Dose $\times$ Cue interaction, $F(2,13) = 8.21$, $p = .005$, $\eta^2 = .558$. There were no other significant main effects or interactions for this analysis, $ps > .48$. To better understand the Dose $\times$ Cue interaction, post-hoc paired samples t -tests were used to compare the dose conditions separately for each cue. These analyses revealed that for the go cue condition, p-inhibition failures were significantly higher in the alcohol + regular drink condition compared to the placebo condition and significantly higher in the alcohol + diet drink condition compared to the placebo condition, $ps < .002$. For this go cue condition, there was no significant difference when the alcohol + regular drink and alcohol + diet drink conditions were compared, $p = .181$. By contrast, the comparisons for the no-go cue condition revealed that the alcohol + diet drink condition p-inhibition failures were significantly higher than the placebo scores, $p = .036$. For this cue condition, p-inhibition failures were not significantly different when the alcohol + regular drink condition was compared with the placebo condition or the alcohol + regular drink condition was compared with the alcohol + diet drink condition, $ps > .13$ (see Table 1).

Subjective Ratings

All mean subjective ratings were submitted to separate 3×2 ANOVAs and mean ratings are reported in Table 1. The results of this analysis for the subjective intoxication ratings revealed a main effect of Dose, $F(2,13) = 76.95$, $p < .001$, $\eta^2 = .922$. LSD tests revealed that mean intoxication ratings were higher following both alcohol conditions compared to the placebo condition, $ps < .001$. There was no significant difference in intoxication ratings when the alcohol + regular drink and the alcohol + diet drink conditions were compared, $p = .30$. There were no other significant effects from this ANOVA, $ps > .35$.

Results of the ANOVA for impairment ratings revealed a main effect of Dose, $F(2,13) = 23.02$, $p < .001$, $\eta^2 = .780$. LSD tests revealed that impairment ratings were significantly higher following both alcohol conditions compared to the placebo condition, $ps < .001$. There was no significant difference in impairment ratings when the alcohol + regular drink and the alcohol + diet drink conditions were compared, $p = .19$. There were no other significant effects in this ANOVA, $ps > .23$.

Results of the ANOVA for the fatigue ratings revealed a significant main effect of Dose, $F(2,13) = 4.79$, $p = .028$, $\eta^2 = .424$. LSD tests revealed that fatigue ratings were significantly higher following both alcohol conditions compared to the placebo condition, $ps < .02$. There was no significant difference in fatigue ratings when the alcohol + regular drink and the alcohol + diet drink conditions were compared, $p = .31$. In the results of this ANOVA, there was also a significant main effect of Gender, $F(1,14) = 4.71$, $p = .048$, $\eta^2 = .252$, owing to the fact that women reported greater fatigue as compared to men. There was no significant interaction in this ANOVA, $p = .21$.

Results of the ANOVA for the willingness to drive ratings revealed a significant main effect of Dose, $F(2,13) = 27.63$, $p < .001$, $\eta^2 = .810$. LSD tests revealed that willingness to drive ratings were significantly lower in the two alcohol conditions compared to the placebo condition, $ps < .001$. However, there was no significant difference between the alcohol + regular drink and alcohol + diet drink conditions, $p = .617$. There were no other significant effects in this ANOVA, $ps > .66$.

Results of the ANOVA for the sedation ratings revealed a significant main effect of Dose, $F(2,13) = 8.15$, $p = .005$, $\eta^2 = .556$. LSD tests revealed that sedation ratings were significantly higher in the two alcohol conditions compared to the placebo condition, $ps < .003$. However, there was no significant difference between the alcohol + regular drink and alcohol + diet drink conditions, $p = .70$. There were no other significant effects in this

ANOVA, $p > .10$. The ANOVA for the stimulation ratings revealed no significant main effects or interaction, $p > .13$.

Results of the ANOVA for the feel the drink ratings revealed a significant main effect of Dose, $F(2,13) = 32.11$, $p < .001$, $\eta^2 = .832$. LSD tests for the Dose main effect revealed that feel ratings were significantly higher in the two alcohol conditions compared to the placebo condition, $p < .001$. However, there was no significant difference between the two alcohol conditions, $p = .93$. There were no other significant effects in this ANOVA, $p > .11$. Finally, the ANOVA for the like the drink ratings revealed no significant main effects or interactions, $p > .60$.

Discussion

This study examined the acute effects of alcohol when mixed with artificially sweetened (i.e., diet) and sugar sweetened (i.e., regular) soft drinks. The results revealed that BrACs were significantly higher when alcohol was mixed with the diet drink as compared to the same amount of alcohol consumed with the regular drink. Moreover, the greatest degree of behavioral impairment was observed in the diet alcohol condition. Mean RTs were significantly slower than the placebo condition when the alcohol + diet drink was administered. By contrast, there was no significant difference between the alcohol + regular drink and the placebo condition for mean RTs. While greater p-inhibition failures were observed for both alcohol conditions compared to placebo in the go cue condition, the same was not observed in the no-go cue condition. The p-inhibition failures for the no-go cue condition were significantly higher than placebo for the alcohol + diet condition. However, there was no significant difference between the alcohol + regular drink and placebo conditions for no-go cue p-inhibition failures.

Despite higher BrACs at all time points in the alcohol + diet drink condition compared to the alcohol + regular drink condition, participants appeared unaware of any BrAC differences. Subjective ratings of intoxication, impairment, fatigue, willingness to drive, sedation, and feeling the drink all revealed significant effects of the alcohol conditions compared to placebo. However, there were no significant differences between the two alcohol conditions for any of these subjective measures. It is notable that the peak BrAC was above the legal limit for driving in the U.S. (.08 g/210 L) in the alcohol + diet drink condition and below the legal limit for the alcohol + regular drink condition. Despite this difference, willingness to drive ratings were not significantly different for the two alcohol conditions.

As with any study, there are limitations. While it appears that gender played little role in the effects obtained in this laboratory study, the sample size in this study was relatively modest. Furthermore, it is likely that gender does play an important role in obtained BrACs and levels of impairment in natural drinking environments, since women are more likely to select artificially sweetened mixers (Fowler et al., 2008). In addition, we observed an 18% increase in BrAC with the diet mixers, whereas other research reported a more dramatic 56% increase, albeit at a lower BrAC level and using different mixers (Wu et al., 2006). Since we only tested one alcohol dose, the reliability of this BrAC difference, particularly at different BrAC levels requires careful examination. In this study, BrACs were obtained using a handheld breathalyzer machine so that multiple measurements could be obtained from participants with a low level of invasiveness. BrACs are often consistent with obtained blood alcohol concentrations, but discrepancies can occur (Schechtman & Shinar, 2011). Thus, these results should be replicated while measuring blood alcohol levels directly. At the very least, health educators and prevention practitioners who incorporate BrAC estimation charts as part of their prevention programs should be aware that their algorithms do not incorporate the type of mixer. A warning to participants of prevention programs that diet

mixers could elevate BrACs is advisable. Finally, it remains to be elucidated what this 18% increase in BrAC for the diet condition compared to the regular drink condition means for the health and well-being of alcohol users. In conclusion, the elevation in BrAC associated with diet mixers warrants greater consideration and consumers should be made aware of this phenomenon.

Acknowledgments

The project described was supported by grant R15AA019795 from the National Institute on Alcohol Abuse and Alcoholism and NIH grant P20GM103436 from the Kentucky Biomedical Research Infrastructure Network, all awarded to CA Marczinski. The content is solely the responsibility of the authors and does not necessarily represent the official view of the National Institute on Alcohol Abuse and Alcoholism or the National Institutes of Health.

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Figure 1.

Mean breath alcohol concentrations (BrACs) for the alcohol + diet drink and the alcohol + regular drink conditions. Standard errors are represented in the figure by the error bars attached to each symbol. Paired samples t-tests revealed that the mean BrAC was significantly higher for the alcohol + diet drink condition compared to the alcohol + regular drink condition for each time point, $p < .014$.

Table 1

Mean BrACs, cued go/no-go task performance, and subjective ratings for the three dose conditions.

Variable	Placebo		Alcohol + Regular Drink		Alcohol + Diet Drink	
	M	(SD)	M	(SD)	M	(SD)
BrAC (g/210 L)						
30 min.			.066	(.013)	.078	(.019)
40 min.			.077	(.015)	.091	(.022)
70 min.			.071	(.013)	.083	(.015)
80 min.			.070	(.012)	.079	(.015)
90 min.			.068	(.011)	.077	(.015)
120 min.			.057	(.009)	.064	(.013)
150 min.			.046	(.010)	.055	(.014)
180 min.			.037	(.010)	.044	(.013)
Cued go/no-go task performance						
Go cue mean RT (ms)	281.671	(35.454)	285.521	(45.396)	288.943	(42.550)
No-go cue mean RT (ms)	306.351	(32.574)	319.423	(40.546)	318.207	(34.063)
Go cue p-inhibition failures	.073	(.103)	.194	(.197)	.171	(.167)
No-go cue p-inhibition failures	.023	(.014)	.029	(.014)	.034	(.020)
Subjective ratings						
Intoxication	0.13	(0.29)	3.34	(1.14)	3.66	(1.41)
Impairment	2.06	(2.96)	49.88	(29.05)	55.88	(30.35)
Fatigue	17.13	(28.60)	42.69	(23.39)	49.25	(35.49)
Willingness to drive	98.75	(2.75)	31.88	(35.32)	29.69	(36.81)
Sedation	7.19	(9.41)	26.00	(14.36)	27.13	(18.64)
Stimulation	15.00	(18.01)	22.50	(14.39)	21.69	(12.22)
Feel	8.88	(18.55)	63.19	(21.74)	63.63	(21.78)
Like	39.37	(33.51)	48.06	(28.38)	47.94	(32.32)