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Acute-alcohol effects on the Experiential Discounting Task (EDT) and a question-based measure of delay discounting

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Abstract

Alcohol is widely believed to increase impulsive behavior. However, this has been difficult to demonstrate for impulsive choice using existing measures of delay discounting. We hypothesized a new real-time discounting task would be more sensitive to acute effects of alcohol. Measures included were a (a) question-based measure of delay discounting, the (b) Experiential Discounting Task (EDT), the (c) Balloon Analogue Risk Task (BART), the (d) Stop Task, and the (e) Go/No-Go Task. A three-session, double-blind, placebo-controlled, within-subjects design was used. Placebo, 0.4, or 0.8 g/kg alcohol doses were administered in a counterbalanced order over the three testing sessions. Twenty four (13 females) healthy social drinkers between the ages of 21 and 35 participated. Alcohol increased impulsive responding only on the EDT and the Stop Task. On the EDT, participants performed more impulsively after the 0.8 g/kg dose compared to placebo, whereas on the Stop Task, both the 0.4 and 0.8 g/kg doses increased impulsive responding. Alcohol had no significant effects on the other measures. The EDT was more sensitive to the acute effects of alcohol than previously used discounting tasks. Procedural differences between the EDT and question-based measures are discussed in the context of these divergent findings.
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1. Introduction

Behaviors considered "impulsive" may result from a variety of underlying processes. Principal-component analyses with different laboratory measures of impulsivity suggest these behaviors can be categorized into at least two independent dimensions. For example, Reynolds et al. (2006) reported a component analysis including measures of delay discounting, risk taking and behavioral inhibition. Two distinct components emerged: "impulsive disinhibition" (measures of behavioral inhibition) and "impulsive decision-making" (a measure of delay discounting and of risk taking). For the current study, effects of acute-alcohol doses were determined on measures subsumed under these two behavioral dimensions.

Previous laboratory examinations of alcohol effects on measures of behavioral inhibition and delay discounting have shown that alcohol disrupts inhibition (de Wit et al., 2000) but has no effect on delay discounting (Ortner et al., 2003; Richards et al., 1999). One conclusion that could be drawn from these findings is that alcohol has differential effects on the two components of impulsivity described above. However, some have suggested (McDonald et al., 2003; Reynolds and Schiffbauer, 2004) the measures used to assess delay discounting may lack sensitivity to acute state changes, such as those to be expected from alcohol consumption. The delay-discounting tasks used by Ortner et al. (2003) and Richards et al. (1999) to determine alcohol effects were hypothetical, question-based measures that did not expose participants to choice consequences during testing. By contrast, the Experiential Discounting Task (EDT; Reynolds and Schiffbauer, 2004) is a real-time

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discounting measure in which participants experience choice consequences (e.g., delays, monetary rewards, etc.) while completing the task, making it potentially more sensitive to the effects of a drug. Although the EDT is mainly a delay-discounting measure, it should be noted it has additional features that differ from other commonly used measures. Most notably, the EDT includes a probability component in the delayed-choice component, and it does not include inter-trial intervals. Arguably, however, these aspects of this measure may better simulate real-life situations where persons face choices with immediate versus delayed outcomes (see Reynolds, in press). Despite these unique features of the EDT, there is evidence this measure is comparable to question-based measures of delay discounting. For example, the EDT, like other measures of delay discounting (e.g., Mitchell, 1999; Reynolds et al., 2004), differentiates smokers and nonsmokers; and in a study that included both the EDT and a more commonly used question-based measure of delay discounting, performance on the two measures was positively correlated (Reynolds, in press). In the present study we included both question-based and EDT measures to compare sensitivity to acute-alcohol effects.

The present study also included a measure of risk taking, the Balloon Analogue Risk Task (BART; Lejuez et al., 2002). Risk taking involves an individual choosing event options (positive or negative) that occur with measurable probabilities over other comparatively certain options (see Knight, 1921). The BART differentiates those reporting more risky behaviors compared to others reporting fewer such behaviors, and also cigarette smokers and nonsmokers (Lejuez et al., 2002, 2003). The BART differs from the EDT in several important ways (see Methods section), but perhaps most notably the BART assesses risky choice and involves no systematic evaluation of choices relative to delayed outcomes, as does the EDT. Acute doses of alcohol are commonly believed to increase risk behaviors, including risky sex (e.g., Halpern-Felsher et al., 1996), aggression (e.g., Galanter, 1997), and behaviors resulting in increases in accidental injury (e.g., Cherpitel, 1999; Pless et al., 1995; Stallones and Xiang, 2003). However, laboratory observations of alcohol-induced risk taking have been less consistent. For example, Roehrs et al. (2004) found no effect of alcohol (0.5 g/kg) on the Stop-Light Task, a laboratory assessment of risk behavior, and Meier et al. (1996) found no effect of alcohol (0.1 to 1.5 g/kg) on a gambling task. On the other hand, Sayette et al. (2004) reported that alcohol (0.82 g/kg) increased risk taking on a group decision-making task, and Lane et al. (2004) found that alcohol (0.4 and 0.8 g/kg) increased risk taking on a choice procedure involving gains and losses. Such inconsistent laboratory findings may reflect a complex relation between alcohol intoxication and risk taking and/or the influence of variations in the different measures used to assess risk taking.

Using variations on the Stop Task, several studies have demonstrated moderate doses of alcohol reduce behavioral inhibition (e.g., Abroms et al., 2003; de Wit et al., 2000; Easdon and Vogel-Sprott, 2000; Fillmore and Blackburn, 2002). A Stop-Signal Task (Logan et al., 1997) was included in the current study to provide both a manipulation check of acute-alcohol effects on impulsive behavior and to provide further data on robustness of previously observed alcohol effects.

Participants also performed the Go/No-Go Task (Newman et al., 1985) on which they were required to respond or withhold responding to a visual stimulus. This task has not been used extensively in alcohol research, although Ortner et al. (2003) found that a 0.7 g/kg alcohol dose did not change Go/No-Go performance.

The goal of the current study was to examine dose-dependent effects of alcohol (i.e., placebo, 0.4, and 0.8 g/kg) on these five measures of impulsive behavior. We hypothesized alcohol would increase discounting on the EDT but not on a question-based discounting task. We also hypothesized that alcohol would impair behavioral inhibition on the Stop Task but not the Go/No-Go Task, consistent with previous findings using the Go/No-Go Task (Ortner et al., 2003). Because of inconsistent findings across the alcohol-related risk-taking literature, we did not have a specific hypothesis for alcohol effects on BART performance.

2. Methods

2.1. Participants

Healthy male ($n=11$) and female ($n=13$) social drinkers between the ages of 21 and 35 years participated in this study. Respondents who reported consuming at least 3 drinks per week were eligible. Participants were recruited by means of posters, advertisements in newspapers, and word-of-mouth referrals from the University of Chicago and surrounding area. Following a brief telephone interview, prospective participants attended an in-person clinical assessment, including a psychiatric interview and physical examination that involved an electrocardiogram. Potential participants were excluded if they met criteria for any major Axis I DSM-IV diagnosis, had less than a high school education, had a body-mass index outside the range 19–26 kg/m^2, and smoked more than five tobacco cigarettes per day.

Before participating in the study, participants attended an orientation session where they provided written informed consent, were familiarized with the experimental procedures, and completed personality questionnaires. The consent form stated that the study was an investigation of the effects of commonly used drugs on mood and performance. For blinding purposes, participants were advised that they might receive any of several classes of drugs, and their associated side effects were listed. Participants were instructed to abstain from use of alcohol and other drugs except for their normal amounts of caffeine and nicotine for 24 h before and 6 h after each session. Their compliance was verified by testing breath-alcohol levels (BAL) and urine samples for D-amphetamine, cocaine, phencyclidine and opiates. Participants were instructed not to eat for 2 h before each session. Female participants provided urine samples for pregnancy testing before each session. No prospective participants failed drug-use screenings or tested positive for pregnancy.

2.2. Design

This study utilized a three-session, double-blind, placebo-controlled, within-subjects design. Placebo, 0.4, or 0.8 g/kg alcohol was administered via counterbalanced order on the three testing sessions. Testing sessions lasted about 2 h and occurred sometime between the hours of 1 and 5 PM. Sessions were scheduled a minimum of 48 h apart. Following 0.4 and 0.8 g/kg dosing sessions, participants were required to remain at the laboratory until breath-alcohol levels had reached an acceptably low level, i.e., BALs < 0.02 g/dl.

2.3. Procedure

This experimental protocol was approved by the University of Chicago Hospital's Institutional Review Committee for the use of human participants. Participants were tested individually in comfortably furnished rooms with a television/VCR, magazines, and a computer for administering questionnaires and tasks. When no dependent measures were being obtained, participants were allowed to watch television, movies, or read, but they were not allowed to work or study.

Upon arrival for each session, a urine sample was obtained for drug and pregnancy screening, and BAL was checked. Participants completed pre-dose subjective-effects questionnaires (described in detail below), and vital signs were recorded. Then, they ingested five small beverages of equal volumes (the exact volumes calibrated to participant body weight) over a 5 min interval, with 1 min to consume each beverage. Each beverage contained alcohol (0.4 and 0.8 g/kg) or placebo under double-blind conditions. Fifteen minutes after the final beverage, participants completed further subjective-effects questionnaires, and vital signs and BAL were recorded. The impulsivity tasks were administered between 15 and 105 min following consumption of the final beverage. See more detailed descriptions of these tasks below. All tasks were completed via computer, and task order was counterbalanced. BAL was measured immediately after the participant completed each task. Because the tasks required different lengths of time to complete, the intervals between BAL assessments during the task-completion phase were unequal. After completing all of the tasks (~105 min after beverage ingestion), participants again completed the subjective-effects questionnaires, and vital signs were taken. Participants received all money earned from the behavioral tasks in cash at the end of each session. After completing all three sessions, participants attended a separate debriefing session and were paid for their participation.

2.4. Drugs

Alcohol (Everclear© 190 proof, 0.4 and 0.8 g/kg doses) was mixed with non-pulp orange juice. Beverage volume was determined for the 0.8 g/kg dose at a 13% alcohol-to-juice concentration. The other doses (placebo and 0.4 g/kg) were administered in the same volume. Doses for female participants were reduced to 90% of male doses to equate BALs across genders (Hindmarch et al., 1991). Placebo doses were masked by placing 1 ml of 190 proof alcohol around the rim of each cup.

2.5. Dependent measures

2.5.1. Experiential Discounting Task (EDT; Reynolds and Schiffbauer, 2004)

The EDT is a computerized delay-discounting measure developed to be sensitive to state changes in discounting and to model naturalistic choice contexts associated with delayed and immediate outcomes and addictive activities (see Reynolds, in press, for more conceptual description of the EDT). Completing a session with the EDT involved multiple blocks of choices, one for each delay assessed. During each block of trials a participant made choices between a standard amount ($0.30) that was delayed (0, 15, 30, or 60 s) and probabilistic (35% chance of receiving) and an adjusting amount of money that was delivered immediately and was certain. The probability of receiving the standard amount was consistent across all choice blocks; however, the delay to possibly receiving the standard was different for each block but did not change during a block. Because only delay was systematically varied, and because of a data-transformation procedure intended to reduce individual differences in discounting resulting from the standard being probabilistic (see Section 2.8. Primary data analyses), the EDT is considered a measure of delay discounting and not of risk taking.

Each choice block then began with the *Choice Phase*, which was signaled by two light-bulb images "illuminating." When the lights were illuminated, the participant could mouse-click on either bulb to choose that option. The left bulb represented the delayed *standard option*. Following a response to the standard option, the participant was required to wait to see if the probabilistic $0.30 would be delivered. If the money was delivered, a bank button became illuminated in the lower left corner of the computer screen to signal the *Consummatory Phase*. To finish the choice trial, the participant clicked on the illuminated bank button to move the money to a "Total Amount" bank area, which kept a running total on money earned for that block of choices. Following each response to the bank button the actual money in coins (pennies, nickels, dimes, and quarters) was delivered from a coin dispenser. Participants were required to put all accumulated money from the coin dispenser in a glass located on the table next to the computer. Once the $0.30 had been moved to the Total-Amount area, the light bulbs illuminated again to signal the next choice. If the standard option was not delivered the bank button did not illuminate after the delay had elapsed, and the light bulbs illuminated again to signal the next choice trial.

The right light bulb represented the immediate *adjusting option*. When the adjusting option was chosen, the bank button illuminated immediately, and the participant could move the adjusting amount (the amount always displayed under the light bulb) to the Total-Amount area. Again, the money was delivered from the coin dispenser. The adjusting amount was not probabilistic. Once the adjusting-option money was in the bank, the light bulbs illuminated again to signal the start of the

next choice trial. Participants were required to complete a forced trial following four consecutive responses to either choice option. To signal a forced trial, only the light bulb of the non-chosen option illuminated, and only that option could be responded to. Forced trials ensured regular exposure to choice consequences associated with both options.

Once a number of choice trials had been completed (a minimum of 16 choices per choice block) and an indifference point determined (see below), an *Inter-Block Interval* began, during which the participant did not make choices but had to wait for a textbox to appear that signaled the end of the choice block. The Inter-Block Interval was included to ensure a block of choices could not be ended more quickly by any specific choice sequence.

The adjusting amount adjusted according to which option was chosen, and this allowed the determination of indifference points. Following a choice for the delayed standard, the adjusting amount *increased* for the next choice by a set percentage. Inversely, the immediate-adjusting amount *decreased* by a percentage following choices for that option. Participants made choices during each choice block until the immediate amount had been adjusted to a point of indifference, i.e., an equal number of choices for each option. The average adjusted monetary amount of the immediate option at the point of indifference was recorded as the indifference point for each choice block. At the end of the procedure, the participant received the total amount of money in cash accrued across all choice blocks. See Reynolds and Schiffbauer (2004) for a more detailed description of the EDT.

2.5.2. Question-based delay-discounting task (Richards et al., 1999)

This delay-discounting task provides an index of the relative value of immediate versus delayed rewards through questions presented on a computer screen. Participants were given choices between $10 available after some delay and a smaller amount available immediately (e.g., "would you rather have $10.00 in 30 days or $2.00 right now?"). The task uses an adjusting-amount procedure (see Richards et al., 1999, for an exhaustive description of this task) to derive indifference points, at which the delayed and immediate options are judged to be of equivalent subjective value. The indifference points obtained for each delay are plotted, and discount functions are derived through hyperbolic curve-fitting analyses, yielding a parameter "k." Higher values of *k* indicate greater impulsivity. At the end each session, one choice response was selected at random and honored (see Reynolds et al., 2003 for exact procedure).

2.5.3. Balloon Analogue Risk Task (BART; Lejuez et al., 2002)

This task measures a subjects' tendency to respond for rewards while the risk of losses increases. Participants are required to "pump up" a series of 30 balloons on a computer screen by pressing a response key. In the version of the task used here, each pump added $0.1, 0.5, or 0.25 to a cumulating total for the trial. Participants could stop pumping at any time and bank their accumulated money. However, as they continued to pump the balloon would occasionally "explode," resulting in the loss of money accumulated on that trial. Though the probability of an explosion was constant across pumps, a greater number of pumps increased the likelihood that an explosion would occur. Thus, more pumps on a trial were taken as an index of greater risk taking. At the end of each session, participants received a calculated average amount of money accumulated on non-exploding balloons. The outcome measure of interest from the BART was the average number of pumps made on trials when the balloon did not explode. A greater number of pumps indicate greater risk taking.

2.5.4. Stop-Signal Task (Logan et al., 1997)

The Stop-Signal Task is designed to assess ability to inhibit a pre-potent motor response. Participants are instructed to respond as quickly as possible when a certain letter (go signal) appears on a computer screen, and to inhibit their responses when a tone is heard (stop signal). The tone is randomly presented 25% of the time and at different delays following the letter presentation. The delays to the stop signal are adjusted until the participant inhibits responses on approximately 50% of trials. At this 50% criterion a stop reaction time (SRT) can be calculated by subtracting the final mean stop signal delay at which the tone is presented from the mean go reaction time (GRT) on non-stop trials. The primary dependent measures obtained from the Stop-Signal Task are the stop (SRT) and go (GRT) reaction times, measured in milliseconds.

2.5.5. Go/No-GoTask (Newman et al., 1985)

The Go/No-Go Task is a learning task designed to assess participants' ability to inhibit inappropriate responses. It consists of repeated presentations of 8 two-digit numbers, of which 4 are designated "correct" and 4 "incorrect." Participants were required to respond to correct numbers and to withhold responses to incorrect numbers. A different list of numbers was used for each session and the participants had to learn by experience during the test session which of the four numbers were correct and which of the numbers were incorrect. They were rewarded for correct responses (+$0.10) and penalized for incorrect responses (−$0.10). Errors of omission (withholding a response when a "correct" stimulus is presented) and errors of commission/false alarms (responding to an "incorrect" stimulus) were recorded, and participants received money they earned at the end of each session.

2.6. Measures of subjective effects

2.6.1. Drug-Effects Questionnaire (DEQ; Johanson and Uhlenhuth, 1980)

The DEQ consists of four questions concerning drug effects. On a 100 mm line participants indicate the extent to which they feel the drug, how high they feel, if they like the drug, and if they want more of the drug. The 100 mm line has "not at all" on the extreme left end and "extremely" on the extreme right.

2.6.2. Addiction Research Center Inventory (ARCI; Haertzen and Hickey, 1987)

The ARCI is a standardized questionnaire consisting of 53 true/false statements. The ARCI was specifically designed to measure subjective effects of certain classes of abused

Table 1
Participant demographics and drug-use summaries ($N=24$)

Age (mean, SD years)	25.6±4.06
Weight (mean, SD lb)	150.2±25.8
Sex (male/female)	11/13
Race (Cauc/Black/Asian/Unknown)	16/3/5/0
Education	
High school/partial college	0/4
College degree/adv degree	10/5
Full time student	5
Current drug use (mean±SD)	
Alcohol (drinks/week)	6.6±3.52
Caffeine (drinks/week)	10.23±7.37
Cigarettes (cigarettes/week)	12.87±32.4
Marijuana (times/week)	0.19±0.46
Lifetime drug use	
Stimulants (*n*; ever used)	5
Tranquilizers (*n*; ever used)	1
Hallucinogens (*n*; ever used)	12
Opiates (*n*; ever used)	5
Marijuana	
Never (*n*)	5
Used 1–10 times (*n*)	6
Used 11–50 times (*n*)	9
Used 51–100 times (*n*)	1
Used>100 times (*n*)	3
Inhalants (*n*; ever used)	5

drugs. This version of the ARCI consists of six empirically derived scales, which measure drug-induced euphoria (Morphine–Benzedrine Group; MBG), stimulant-like effects (Amphetamine; A, and Benzedrine Group; BG), sedation (Pentobarbital–Chlorpromazine; PCAG), and dysphoria and somatic effects (Lysergic Acid; LSD).

2.6.3. Profile of Mood States (POMS; McNair et al., 1971)

The POMS consists of 72 adjectives commonly used to describe mood states. Participants indicate how they feel at that moment in relation to each of the adjectives using a five-point scale ranging from "not at all" [0] to "extremely" [4]. The POMS consists of 8 scales: friendliness, anxiety, depression, fatigue, anger, elation, confusion, vigor and two derived scales arousal, and positive mood (Johanson and Uhlenhuth, 1980).

2.7. Personality questionnaire

2.7.1. Barratt Impulsiveness Scale-11 (BIS-11; Patton et al., 1995)

The BIS-11 assesses impulsivity as a personality trait. The questionnaire consists of 30 statements to which participants respond by choosing one of the following responses: rarely/never, occasionally, often, and almost always. In addition to a total score, each subject receives scores on six scales: attention, motor impulsivity, self control, cognitive complexity, perseverance, and cognitive instability.

2.8. Primary data analyses

The EDT raw indifference-point data were transformed to reduce inter-individual variability resulting from the standard option being probabilistic. Each participant completed a choice block with no delay to receiving the standard (0 s delay). Inter-individual variability in indifference values for these 0 s delay blocks was presumably due to individual-difference effects of probability. For all participants, the indifference values for these blocks were converted to a value of 1 by dividing the number by itself. This transformation was extended to the indifference values of the remaining choice blocks by dividing those values by the indifference value of the 0 s delay block. These transformed indifference points were plotted and used to determine *k*-values.

Statistical analyses were conducted using SPSS® version 12. For analyses of vital signs, BALs, and subjective measures, two-way repeated-measures analyses of variance (ANOVAs; factors of drug dose and time) were used. The *k*-values derived from indifference points (transformed for the EDT) for the delay-discounting tasks were normalized using a log-10 transformation, as in previous research with these types of measures (e.g., Richards et al., 1999). For analyses of drug effects and gender on task performance, two-way (dose and gender) repeated-measures ANOVAs were used for each measure. Matched-samples *t*-tests were used for post hoc analyses when significant main effects or interactions were identified. Independent-samples *t*-tests were used to test for gender difference on the behavioral tasks using only the placebo-session data. Also, using placebo-session data, Spearman rank-order correlation coefficients were used for exploring patterns of co-variation between the different measures of impulsivity, and point-biserial correlations were used to explore relations between the behavioral measures and the BIS-11. The significance criterion for all of the statistical analyses was $p<0.05$.

3. Results

3.1. Participants

Participant demographic and drug-use history data are summarized in Table 1. Most participants were in their early 20s and had a college education.

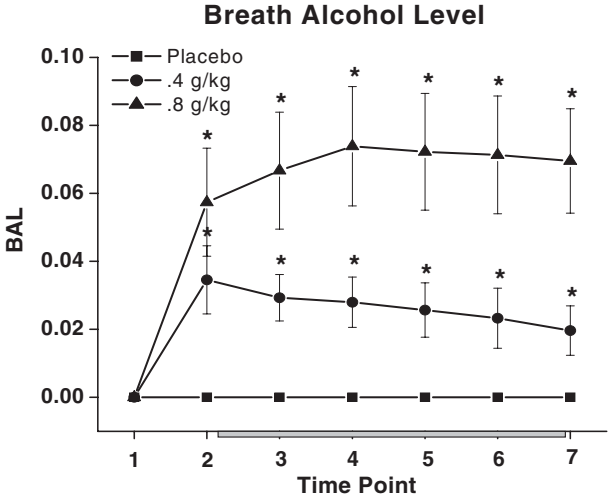

Fig. 1. Mean (±SEM) breath alcohol levels across the seven consecutive measurement time points for placebo, 0.4 and 0.8 g/kg conditions. The shaded region along the *x*-axis shows when the impulsivity tasks were performed. Asterisks indicate significant difference from placebo.

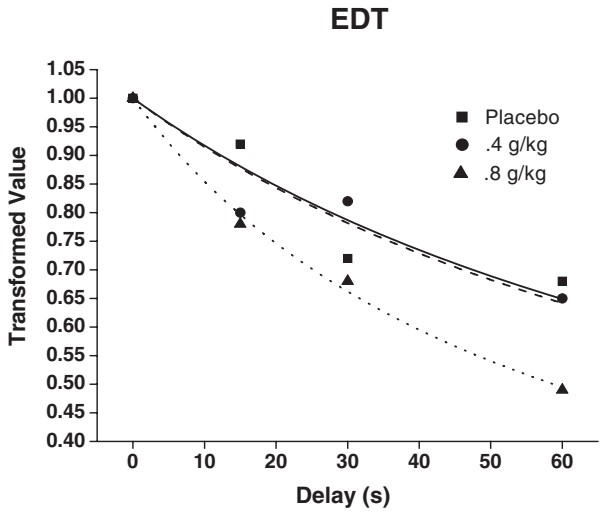

Fig. 2. Median indifference values and best fitting hyperbolic discount functions for the EDT. There was greater discounting on the EDT during the 0.8 g/kg dose session compared to placebo.

3.2. Vital signs and subjective effects

Compared to placebo, alcohol increased BALs determined from breath samples taken after completion of each behavioral task (Fig. 1). Alcohol (0.8 g/kg) increased heart rate at 15 min compared to placebo, and both the 0.4 and 0.8 g/kg doses increased heart rates at 105 min. Heart rate mean and standard-deviation values (SD) for the placebo session at pre-beverage, 15 min, and 105 min were 70.56 (9.88), 72 (10.9), and 66.17 (8.80), respectively. For the 0.4 g/kg session, these values were 70.5 (13.39), 70.75 (11.87), and 71.25 (11.55); and for the 0.8 g/kg session 70.52 (11.57), 75 (10.25), and 73.13 (11.21), respectively. Alcohol did not significantly affect systolic or diastolic blood pressure.

Alcohol increased subjective effects on the DEQ "feel drug" and "feel high" scales, but had no effect on the "like drug" or "want drug" scales compared to placebo. Post hoc analyses showed that participants reported feeling the drug more at 15 min for both the 0.4 and 0.8 g/kg doses compared to placebo. Alcohol increased ratings of "feel drug" at 15 (0.4 and 0.8 g/kg) and 105 min (0.8 g/kg only).

Alcohol increased ARCI scores for stimulant-like effects (A scale), marijuana-like effects (M scale), euphoria and somatic effects (MBG scale), and sedation (PCAG scale). On the ARCI A and M scales, alcohol (0.8 g/kg only) significantly increased ratings at both 15 and 105 min. Finally, alcohol (0.4 g/kg) increased ratings of sedation 15 min, whereas alcohol (0.8 g/kg) increased sedation ratings only at 105 min. Alcohol (0.8 g/kg) also increased POMS friendliness scores at 15 min.

There were no significant gender differences in BAL, vital signs, or subjective effects of alcohol.

3.3. Behavioral-task measures of impulsivity

There was an overall effect of alcohol dose on discounting with the EDT, F (2, 34)=4.04, p=0.027. Follow-up analyses showed this effect was between the placebo and 0.8 g/kg conditions, t(18)=2.48, p=0.023, two-tail test. Fig. 2 depicts median indifference values of each dosing session for the EDT. As previously reported (Reynolds and Schiffbauer, 2004) some EDT data could not be used for analyses. EDT data from five participants for the placebo session, three for 0.4 g/kg session, and one for 0.8 g/kg session were not considered because k-values could not be determined due to low R^2-values.

Alcohol had no effect on discounting as assessed by the question-based measure (see Table 2). For the question-based measure, data from two participants for the placebo session, six for 0.4 g/kg session, and three for 0.8 g/kg session were not considered for analyses because of low R^2-values.

Barring extremely low R^2-values, which were eliminated, the R^2-values did not differ significantly across dosing conditions for either the EDT or question-based measure; however, R^2-values were on average higher for the question-based measure than for the EDT (see Table 2). Using a paired-sample t-test, these mean R^2-values did differ significantly, t(60)=3.20, p=0.002, two-tail test.

Alcohol did not affect GRT on the Stop-Signal Task, but it increased SRTs, F (2, 34)=7.26, p=0.002. Follow-up analyses on the SRTs showed significant differences between placebo and 0.4 g/kg conditions, t(18)=2.82, p=0.001, two-tail test, and placebo and 0.8 g/kg conditions, t(19)=4.19, p=0.000, two-tail test. In both cases, SRTs were longer during the alcohol conditions compared to placebo. The SRTs for the two alcohol conditions did not differ significantly.

Alcohol did not affect performance on the BART or the Go/No-Go Task.

3.4. Gender differences and correlations for the behavioral tasks

Placebo-session data were used to compare behavioral-task performance between male and female participants when there was no alcohol effect. There were no significant main effects of gender on task performance for any of these measures. Also, considering data from placebo and drug sessions, there were no

Table 2
Median k-values (SD) and mean R^2-values (SD) for the EDT and question-based discounting measures by dose condition

	EDT			Question-based measure		
	PL	0.4 g/kg	0.8 g/kg	PL	0.4 g/kg	0.8 g/kg
k-values	0.008 (0.0006)	0.009 (0.0011)	0.019 (0.0003)	0.021 (0.259)	0.031 (0.183)	0.025 (0.395)
R^2-values	0.721 (0.293)	0.728 (0.261)	0.714 (0.197)	0.833 (0.188)	0.853 (0.193)	0.814 (0.206)

dose by gender interaction effects on any of the measures of impulsive behavior. There also were no gender differences on ratings of impulsivity using the BIS-11.

Placebo-session data also were used to explore inter-task correlations and correlations between the different behavioral measures and scores on the BIS-11. Notably, none of the behavioral measures were significantly correlated. Total scores on the BIS-11 also were not correlated with any of the behavioral measures. However, the question-based measure of delay discounting was positively correlated with the *Self Control* subscale, $r(21)=0.47$, $p=0.021$, two-tailed test. Participants who discounted most on the question-based discounting measure also reported the least self control on the BIS-11 subscale.

4. Discussion

In this study we examined the effects of acute doses of alcohol on several measures of impulsive behavior, including the EDT, a new measure of discounting designed specifically to be sensitive to state changes in impulsive behavior. As predicted, alcohol (0.8 g/kg) increased impulsive responding on this task, relative to placebo and a lower dose of alcohol (0.4 g/kg). In contrast, alcohol did not increase discounting on a question-based discounting measure, in which delays and rewards were not experienced during the testing session.

As we have suggested elsewhere (see Reynolds, in press; Reynolds and Schiffbauer, 2004), there are key differences between the EDT and hypothetical measures that may have led to the observed differential effects of alcohol. For example, there is the real-time quality of the EDT compared to the question-based measure. Participants performing the EDT experienced actual delays and monetary rewards while making choices, in the drug and non-drug states. Experiencing these choice consequences may increase sensitivity of this task to acute changes in discounting. For example, the concept of delay aversion might illustrate the importance of real-time delays. It has been hypothesized (e.g., Sonuga-Barke et al., 1992) that participants find waiting for rewards aversive and that this aversion to waiting results in a preference for an immediate alternative. From this delay-aversion perspective, it is possible alcohol at the highest dose used in this study generally increases delay aversion, which would reduce the value of delayed rewards and lead to greater discounting. The EDT, because it includes real delays, may be more sensitive to the effects of delay aversion than the question-based discounting task, which does not require the participant to experience delays. Compared to the EDT the question-based task requires respondents to predict or imagine the aversiveness of waiting. It could well be these predicted or imagined delays are not affected by any level of intoxication resulting from alcohol. Related to the EDT, it should be noted that because there was no dose-dependent effect of alcohol (no alcohol effect at the 0.4 g/kg dose), the observed change in EDT performance may only occur at higher levels of intoxication.

Another possible reason for the observed effect of alcohol on the EDT and not the question-based measure involves the probabilistic component of the EDT, which is not present in the question-based measure. However, if this probabilistic quality of the EDT were responsible for the observed alcohol effects we should also have found an alcohol effect on the BART, as it too includes probabilistic rewards. That is, the lack of alcohol effects on the BART in the current study provides some evidence that observed effects on the EDT were not solely the result of its probability component; however, it should also be noted there were other differences between these tasks (e.g., lack of discrete choice trials for the BART compared to the EDT) that may have resulted in the differential alcohol effects.

Other differences between the two discounting measures may be responsible for the different findings. For example, the EDT combines delay and probability, which may be more sensitive to alcohol effects than just delay alone. Similarly, while the BART includes probabilistic rewards, it does not combine delay and probability, which may be necessary for the observed effects. In addition, it was possible to make choices more frequently with the EDT when choosing the immediate adjusting option. More frequent choices would both increase local rate of reward and increase stimulation. As with delay aversion, participants may have become intolerant of, or frustrated with, long periods with nothing to do (i.e., sitting through delays for probabilistic rewards) while intoxicated and could to some extent avoid this lack of stimulation or frustration by making more responses for the adjusting option (see Bornovalova et al. (2005) for related review). Ultimately, however, findings from the current study do not provide any definitive data to specify which of the procedural differences, or combination of differences, between the EDT and question-based measure led to the observed different alcohol effects.

A secondary objective of this study was to explore the effects of alcohol on various measures of impulsive behavior subsumed under two broad dimensions: impulsive disinhibition and impulsive decision-making (e.g., Reynolds et al., 2006). We found that alcohol increased impulsive performance on both dimensions, a measure of behavioral inhibition (Stop-Signal Task) and a measure of discounting (EDT). On the other hand, alcohol did not affect performance on two other measures of these dimensions (i.e., Go/No-Go Task and BART). These findings suggest differential effects of alcohol on impulsivity at the level of individual measures but not at the level of broader dimensions of impulsive behavior. That is, the current findings do not support alcohol having differential effects on the different dimensions of impulsive behavior defined by Reynolds et al. (2006).

Alcohol impaired performance on the Stop-Signal Task but not the Go/No-Go Task. This pattern is consistent with previous reports that alcohol impaired performance on the Stop-Signal Task but not the Go/No-Go Task (e.g., de Wit et al., 2000; Ortner et al., 2003). It is unclear whether these inconsistent effects across measures reflect differential sensitivities of the tasks, or whether they reflect different underlying processes. For example, these two measures differ in that the Go/No-Go Task provides monetary incentives based on performance and requires respondents to remember go-response numbers. The Stop-Signal Task includes neither of these features. However, past findings using the Stop-Signal and Go/No-Go Tasks

indicate these measures sometimes do, and sometimes do not, co-vary. For example, acute doses of Δ^9-tetrahydrocannabinol increased SRTs on the Stop-Signal Task but had no effect on the Go/No-Go Task (McDonald et al., 2003), whereas D-amphetamine decreased both SRTs and errors of commission on the Stop-Signal and Go/No-Go Tasks, respectively (de Wit et al., 2002). In an analysis of co-variation among different tasks in the absence of any drugs, these two measures were positively correlated (Reynolds et al., 2006), suggesting they share some common underlying features.

Alcohol did not alter BART performance at any of the reward magnitudes. This finding is consistent with some past research showing similar doses of alcohol do not change risk taking (e.g., Roehrs et al., 2004), but this finding is inconsistent with other reports that alcohol does increase risk taking (e.g., Lane et al., 2004). The source of these inconsistent findings is not clear. Again, as with the EDT and question-based measures of discounting, it is possible measurement-procedure differences between the different behavioral tasks lead some to be more sensitive to alcohol effects than others. For example, the risk-taking task used by Lane et al. (2004) involved discrete choice trials between two options of different probabilities, whereas the BART less clearly involved choices between two options but instead involved the continuation or discontinuation of a behavior (i.e., inflating a balloon). Future research should explore these types of differences as possible reasons for the inconsistent reports.

The behavioral measures of impulsivity in the placebo condition were not correlated with each other, or with the BIS-11 total scores. This lack of association may reflect Type II error resulting from the relatively small number of participants. For example, previous studies involving larger samples have shown associations between the Stop-Signal and Go/No-Go Tasks (Reynolds et al., 2006) and between the EDT and a question-based discounting measure (Reynolds, in press), which were not present in the current analyses.

To conclude, alcohol increased impulsive behavior on the Stop-Signal Task and the EDT, while not increasing impulsivity on three other behavioral measures. This alcohol effect on the Stop-Signal Task is a replication of earlier findings. However, the effect on EDT performance is unique for human measures of discounting. More research is needed to better understand why this effect exists with the EDT and not question-based measures. As discussed, procedural differences in the timeframe of choice consequences may be important, but other differences exist between these measures that cannot at this time be ruled out as important factors leading to the observed differential effects. Related to delay discounting, identifying the specific procedural dissimilarities leading to differential effects may ultimately be important in more generally understanding acute-alcohol effects on this type of impulsive behavior.

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