

Acute alcohol effects on impulsivity: associations with drinking and driving behavior

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ABSTRACT

Aims Although drink drivers exhibit higher levels of trait impulsivity, no studies have tested the hypothesis that drink drivers experience increased impulsivity while intoxicated. We tested this hypothesis for two impulsivity constructs: delay discounting and behavioral inhibition. **Design** A within-subjects study comparing performance of drink drivers and non-drink drivers on behavioral measures of impulsivity in alcohol and no-beverage sessions. **Setting** A laboratory setting at the University of Missouri. **Participants** Twenty-nine young adults who were at least moderate drinkers were recruited from the local community and the University of Missouri. **Measurements** Impulsivity was assessed using the Two Choice Impulsivity Paradigm (TCIP) and the Stop-Signal Task. Participants also completed self-report measures of binge drinking and trait impulsivity. **Findings** In the no-beverage session, TCIP impulsive choices did not differ between drinking and driving groups ($P = 0.93$). In the alcohol session, drink drivers made more TCIP impulsive choices on both the ascending ($P < 0.01$) and descending limb ($P < 0.01$) of the blood alcohol concentration curve than their peers who did not drink and drive. Drinking and driving groups did not differ on the Stop-Signal Task. Supplementary analyses indicated that effects for the TCIP were not explained by individual differences in trait impulsivity. **Conclusions** Individuals who report having three or more drinks before driving show greater impulsivity when under the influence of alcohol than those who do not report heavy drinking before driving.

Keywords Alcohol, delay discounting, drinking and driving, impulsivity.

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INTRODUCTION

Driving after drinking alcohol is a common cause of traffic fatalities [1], particularly for young adults [2]. Impulsive individuals are more likely to use alcohol [3] and engage in alcohol-related problem behaviors, including drinking and driving [4]. While impulsivity can influence alcohol use, there is also evidence that the acute effects of alcohol can increase impulsivity [5–7]. The current study tested the hypothesis that individuals who drive after drinking experience greater impulsivity while intoxicated. This hypothesis was tested for two measures of impulsivity, behavioral inhibition and delay discounting.

Behavioral inhibition indexes the ability to inhibit a dominant or prepotent response in accordance with changes in stimuli or goals [8]. Alcohol has been shown

to impair inhibition [9], but not the implementation of responses [10]. Alcohol's effect on inhibitory control is associated with *ad libitum* drinking [11] and binge drinking [7]. This suggests that heightened sensitivity to alcohol's effect on inhibition can contribute to impulsive decisions following alcohol consumption.

Delay discounting is indicated by the tendency to decrease the value of an outcome as a function of a delay in receiving it. In humans, measures of delay discounting offer choices between rewards, typically monetary: either a smaller reward with no delay or a larger reward after a delay. Impulsive decision-making is indicated by a tendency to select the smaller reward in lieu of waiting for the larger reward. Studies have demonstrated correlations between delay discounting performance and questionnaire measures of impulsivity [12], although not consistently [13].

Delay discounting is associated with alcohol-related behaviors [14,15], including drinking and driving [16]. Results are mixed as to whether the acute effects of alcohol increase discounting [17,18]. Reynolds [19] has argued that real-time task methods of assessing delay discounting [8,9] are more sensitive to alcohol's effects than paper-and-pencil measures.

Individual differences in intoxicated impulsivity may play an important role in drinking and driving. Although some decisions about drinking and driving are made prior to drinking (e.g. selecting a designated driver), the decision to drive while intoxicated by alcohol is frequently made while intoxicated by alcohol. We focused on behavioral inhibition and delay discounting as they assess response tendencies in the face of countervailing information (i.e. inhibitory stimuli and reward contingencies, respectively). Similarly, the decision to drive while intoxicated is made despite significant counterindications and despite reward/punishment contingencies clearly weighted towards alternatives.

In the current study, we tested whether alcohol's effect on impulsivity, operationalized as decreased behavioral inhibition and increased delay discounting, differed between those who engage in drinking and driving and those who do not. Although previous work has demonstrated that drink drivers exhibit higher levels of trait impulsivity, extant studies have not tested the role of acute alcohol intoxication on this association. We compared drink drivers' and non-drink drivers' performance on measures of delay discounting and behavioral inhibition after a moderate dose of alcohol and in a no-beverage session.

As binge drinkers are more likely to drive while intoxicated [20], we controlled for binge drinking in all study analyses. Drink drivers also exhibit higher levels of trait impulsivity [4]. They may therefore exhibit increased intoxicated impulsivity due in part to higher levels of trait impulsivity. Supplementary analyses examined whether trait impulsivity explained differences in task performance between drink drivers and non-drink drivers.

METHODS

Participants

Participants were recruited from the University of Missouri (MU) and the city of Columbia, Missouri. An e-mail advertisement was sent to MU students, and fliers were posted on campus and at local community businesses. The resulting sample ($n = 29$, 45% women) was largely Caucasian (80%), with a mean age of 21.87 years [standard deviation (SD) = 0.82].

Potential participants completed a telephone screen to determine eligibility for the study. Participants were

required to report consuming approximately five or more drinks on a single occasion in the past 6 months. Participants were excluded if they were currently taking medication for which the use of alcohol is contraindicated, had a significant medical or psychiatric illness, were pregnant, had a body mass index greater than 31 or had ever intentionally abstained from alcohol due to either a formal diagnosis or concern about having an alcohol use disorder.

Measures

Demographic information

A self-report questionnaire was used to collect demographic information, including age, gender, race and education.

Alcohol use

Participants' typical and past-month drinking habits were assessed. Participants reported their past-month frequency and quantity of alcohol use, past-month frequency of binge drinking (five or more drinks at one time) and whether they experienced any of eight alcohol-related problems (e.g. hangover, blackouts, problem with friends/family).

Drinking and driving behavior

Participants were asked to indicate the number of times in the past year they had driven after having specific numbers of drinks in a 2-hour period. Participants were classified as drink drivers if they endorsed driving after three drinks in 2 hours in the past year.

Delay discounting

The Two Choice Impulsivity Paradigm (TCIP [21]) is a computerized impulsive decision-making task designed to assess tolerance for delayed rewards. Participants chose between two shapes that appeared simultaneously on the monitor. One shape led to a short delay and small reward (5 seconds, 5 cents), whereas the other resulted in a longer delay and larger reward (15 seconds, 15 cents). The delay-reward contingencies were fixed, with all contingencies remaining the same throughout the task. Participants completed 28 trials, and impulsive responding is indicated by a count of smaller-sooner (impulsive) choices (possible range = 0–28). Participants were rewarded with a monetary sum equal to the amount earned during the task (i.e. \$1.40–4.20 per session). Due to a computer problem, data from one participant's TCIP in the no-beverage session were lost.

An impulsive pattern of responding on the TCIP (i.e. more smaller-sooner choices) has been found in samples

with a range of psychiatric conditions characterized by impulsive symptoms (e.g. aggression, disruptive behaviors, substance use) [22,23]. TCIP performance has also been associated with self-reported impulsivity [24].

Behavioral inhibition

The Stop-Signal Task [25] is designed to construct a prepotent categorization response that participants are later asked to inhibit. In the first block, green left and right arrows were presented and participants were asked to respond as quickly as possible by pressing the corresponding button on the keyboard. In the subsequent block, green left and right arrows were again presented, but occasionally an arrow turned red. Participants were instructed to try *not* to respond when that happened, but to still respond as quickly as possible. Participants were instructed that it would not help to slow down and if their percentage of correct stops was not approximately 50% (range 40–60%) they would have to complete an extra block of trials. The Stop-Signal reaction time (SSRT) is the estimated time at which the stopping process finishes. Larger SSRT values indicate that more time is needed to stop a prepotent response, and therefore suggest higher impulsivity. Two participants did not complete the Stop-Signal in the no-beverage session.

Larger SSRT values have been associated with several disorders characterized by poor behavioral inhibition (ADHD [26], substance use disorders [27,28]). SSRT is also correlated with self-reported levels of impulsivity [29].

Self-report impulsivity

The UPPS-P scale [30,31] is a 59-item inventory designed to assess five impulsive personality traits: negative urgency, (lack of) perseverance, (lack of) premeditation, sensation seeking and positive urgency. The five scales are shown to have good convergent and discriminant validity, and to have distinct external correlates [32].

Procedure

Participants completed two testing sessions approximately 1–2 weeks apart. Participants were required to abstain from alcohol and drug use for 24 hours prior to their sessions. Procedures were approved by the University of Missouri Institutional Review Board, and written informed consent was obtained at the start of each session.

Alcohol sessions began at 1:00 p.m. and lasted approximately 5 hours. Participants were asked to eat a light lunch prior to coming to the laboratory. Women were given a urine pregnancy test and excluded if they

tested positive. Participants' breath alcohol concentration (BrAC [33]) was assessed prior to beverage consumption and in 15-minute intervals following consumption (i.e. 15, 30, 45, 60, 75, 90 and 105 minutes). Short practice blocks for each study task were also administered prior to beverage consumption.

Participants received a dose of alcohol calculated to produce a peak BrAC of approximately 0.075–0.080 mg% (0.72 g/kg for men, 0.65 g/kg for women) [34]. The alcoholic beverages were made using 50% alcohol (vodka) in 20% solution with non-caffeinated soda. Beverages were divided into three equal doses and consumed at a rate of 5 minutes per dose. After a 15-minute absorption period, BrAC assessments began. Each task was administered twice, on the ascending and descending limb of the blood alcohol curve. Task order was matched by BrAC on each limb such that one task was administered 15 and 90 minutes post-consumption and the other at 30 and 75 minutes. Task order was counterbalanced across participants and matched within participants across sessions.

To minimize risk, study protocol followed procedures outlined in the Recommended Council Guidelines on Ethyl Alcohol Administration in Human Experimentation [35]. Participants were required to remain in the laboratory until their BrAC fell below 0.02 mg% and their behavior returned to normal. Participants signed an affidavit stating that they would not drive a car or operate other machinery for 3 hours after leaving the laboratory. Participants travelled home by taxi (provided by the study) or with a friend. They were compensated at a rate of \$12 per hour and could earn an additional amount of money (up to \$15) for their performance on study tasks and a bonus (\$15) for completing both study sessions.

No-beverage sessions began at 11:00 a.m. and lasted approximately 2 hours. Procedures were similar to those for the alcohol session, but truncated to include only one administration of each study task. Participants completed a baseline BrAC assessment and practice tasks identical to those administered in the alcohol session.

RESULTS

Descriptive statistics

Forty-five per cent of the sample reported driving after three drinks in 2 hours in the past year. Drink drivers reported greater past-month frequency of drinking ($t(27) = 5.05$, $P < 0.01$) and binge drinking ($t(27) = 2.47$, $P < 0.05$) than non-drink drivers. Drink drivers also reported higher levels of positive ($t(27) = 2.29$, $P < 0.05$) and negative ($t(27) = 2.89$, $P < 0.01$) urgency. BrAC obtained during the alcohol session did not differ between drinking and driving groups.

Delay discounting

We tested whether drink drivers exhibited greater delay discounting than non-drink drivers, and whether this difference varied across no-beverage and alcohol sessions. A $3 \times 2 \times 2$ mixed factorial analysis of covariance (ANCOVA) was conducted examining TCIP immediate choices with session (no-beverage, ascending limb, descending limb) as the within-subjects factor, drinking and driving group and gender as between-subjects factors and past-month binge drinking as a covariate. All study analyses were conducted initially with session order as a factor. No main effects or interactions were observed for session order, and the pattern of results did not change for any study analyses. Results reported do not include session order.

Results indicated main effects of drinking and driving group ($F_{(1, 24)} = 6.98$, $P < 0.05$; partial $\eta^2 = 0.23$) and binge drinking ($F_{(1, 24)} = 8.30$, $P < 0.01$; partial $\eta^2 = 0.27$), but not gender ($F_{(1, 24)} = 2.22$, $P = 0.15$; partial $\eta^2 = 0.09$) on TCIP immediate choices. These main effects were qualified by a significant session \times drinking and driving group interaction ($F_{(2, 46)} = 4.29$, $P < 0.05$; partial $\eta^2 = 0.16$). The session \times binge drinking interaction was not significant ($F_{(2, 46)} = 0.69$, $P = 0.51$; partial $\eta^2 = 0.03$). Follow-up ANCOVAs for each session indicated that TCIP immediate choices did not differ by drinking and driving group during the no-beverage session [$F_{(1, 24)} = 0.01$, $P = 0.93$; partial $\eta^2 < 0.01$], but drink drivers made more impulsive choices on both the ascending ($F_{(1, 26)} = 8.60$, $P < .01$; partial $\eta^2 = 0.26$) and descending limb ($F_{(1, 26)} = 8.33$, $P < 0.01$; partial $\eta^2 = 0.25$) (see Fig. 1).

Behavioral inhibition

We next tested whether drink drivers exhibited greater behavioral disinhibition than non-drink drivers, and

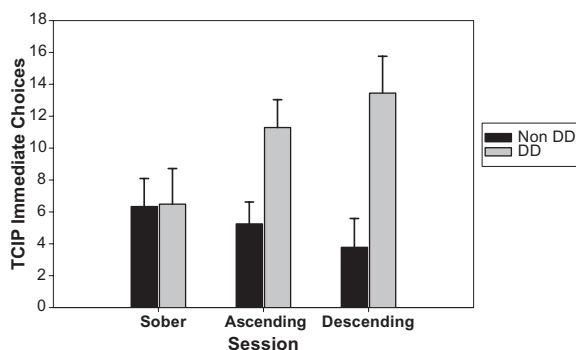


Figure 1 Delay discounting immediate choices by drinking and driving (DD) group across no-beverage and alcohol sessions. Error bars are based on the standard error of the mean; TCIP: Two Choice Impulsivity Paradigm

whether this difference varied across no-beverage and alcohol sessions. A parallel $3 \times 2 \times 2$ mixed factorial ANCOVA was conducted on SSRT. Results indicated a marginal main effect of session ($F_{(2, 44)} = 3.17$, $P = 0.05$; partial $\eta^2 = 0.12$), with alcohol sessions having higher SSRTs. This was qualified by a significant session \times gender interaction ($F_{(2, 44)} = 6.02$, $P < 0.01$; partial $\eta^2 = 0.22$), but no session \times drinking and driving group interaction ($F_{(2, 44)} = 2.04$, $P = 0.14$; partial $\eta^2 = 0.09$). Follow-up ANCOVAs by session indicated that SSRTs differed by gender during the no-beverage session ($F_{(1, 24)} = 9.15$, $P < 0.01$; partial $\eta^2 = 0.29$), with women having higher SSRTs. There were no significant gender differences on the ascending ($F_{(1, 24)} = 0.01$, $P = 0.97$; partial $\eta^2 < 0.01$) or descending limb ($F_{(1, 24)} = 2.55$, $P = 0.12$; partial $\eta^2 = 0.10$).

Trait impulsivity

We then tested whether individual differences in trait impulsivity explained observed differences in task performance between drink drivers and non-drink drivers. Analyses were parallel to primary study analyses ($3 \times 2 \times 2$ mixed factorial ANCOVA), except that trait impulsivity was the covariate. Analyses were conducted separately for each of the five UPPS-P scales. Results for both the TCIP and Stop-Signal demonstrated no significant main effects or interactions for any of the UPPS-P factors. Further, for the TCIP, the session \times drinking and driving group interaction remained significant when each of the UPPS-P scales were included as a covariate ($F_{(2, 46)}$ ranged from 3.82 to 5.03, P s < 0.05 ; partial η^2 ranged from 0.14 to 0.19).

DISCUSSION

This study provides some of the first data on the association between intoxicated impulsivity and drinking and driving. We found support for the hypothesis that drink drivers experience greater delay discounting while intoxicated. Prior work has demonstrated that delay discounting is associated with substance use [15,19], suggesting that a preference for immediate rewards leads to use of a drug for its short-term benefits, despite later consequences. Our results provide evidence that the decision to drive after drinking may also be influenced by alcohol's effect on preference for immediate rewards. Importantly, drink drivers only exhibited this preference when intoxicated, and did not differ from non-drink drivers in the sober condition.

Prior studies have highlighted the importance of alcohol-induced impairment of inhibitory control in impulsive behaviors such as binge drinking [7] and aggression [36]. Some behavioral decisions made while

drinking are immediately actionable, such as whether to consume additional drinks, and may therefore be influenced by alcohol impairing the ability to terminate an ongoing behavior [9]. In contrast, the decision to drive after drinking typically does not involve stopping an ongoing behavior, but rather the decision to initiate a new behavior (driving). We argue that one element of this decision is the trade-off between short-term rewards (driving home, increased convenience [37]) and delayed, but larger rewards (reduced risk of accident or arrest). Our results suggest that, for individuals who drive after drinking, the acute effects of alcohol shift the balance of this trade-off in favor of short-term rewards.

There are several limitations to the current study. The relatively small and homogeneous sample limits the generalizability of our results. We did not observe significant differences in behavioral inhibition by session for drinking and driving groups. However, given the observed effect size for this interaction (partial $\eta^2 = 0.09$), this effect might be statistically significant in a larger sample. Further research is required to determine whether alcohol-induced impairment of behavioral inhibition differs for drink drivers.

We chose a no-beverage session, rather than placebo, as our comparison condition. Previous studies have demonstrated placebo compensatory effects for some components of impulsivity tasks [38]. In addition, while the within-subjects design of this study increased power, it can also reduce the believability of a placebo. We therefore believe a no-alcohol assessment of impulsivity is the appropriate comparison condition to establish the presence of the hypothesized effect. One direction for future research is to test whether the effects observed in the current study are due to alcohol pharmacology, alcohol expectancy or a combination.

Participants were assigned to drinking and driving groups based on self-report. This precluded examination of severity of drinking and driving, either in terms of frequency or quantity consumed. Those classified as drink drivers reported driving after consuming three drinks in 2 hours, which may not constitute legal intoxication for all participants. One important direction for future research is to test differences in intoxicated impulsivity as a function of severity and persistence of drinking driving. In addition, there are potential biases associated with self-report data of alcohol-related behaviors [39] and these biases may be influenced by impulsivity [40], which could inflate drink driving and impulsivity associations.

Another limitation is the use of single task measures for each impulsivity construct. This is particularly important for delay discounting. The TCIP is a relatively simple measure of delay discounting, which limited our ability to assess several important elements of this construct. We

selected the TCIP because real-time tasks may be more sensitive to acute alcohol effects [19]. An important direction for future research will be to extend these results to alternative measures of discounting [5].

A direction for future research is to test whether trait and behavioral measures of impulsivity are associated with different aspects of drinking and driving (e.g. frequency, driving at higher BrACs). It is also probable that there are complex interactions between alcohol-related risk behaviors. For example, binge drinkers are more likely to drive after drinking [41], and have also been found to differ in their perceived risk of drinking and driving [20]. How such judgements interact with tolerance for delayed rewards for drink drivers is an important unanswered question.

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