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Acute Effects of Alcohol on Inhibitory Control and Simulated Driving in DUI Offenders

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Abstract

Introduction—The public health costs associated with alcohol-related traffic accidents have prompted considerable research aimed at identifying characteristics of individuals who drive under the influence (DUI) in order to improve treatment and prevention strategies. Survey studies consistently show that DUI offenders self-report higher levels of impulsivity compared to their nonoffending counterparts. However, little is known about how individuals with a DUI history respond under alcohol. Inhibitory control is a behavioral component of impulsivity thought to underlie risky drinking and driving behaviors.

Method—The present study examined the degree to which DUI drivers display deficits of inhibitory control in response to alcohol and the degree to which alcohol impaired their simulated driving performance. It was hypothesized that DUI offenders would display an increased sensitivity to the acute impairing effects of alcohol on simulated driving performance. Young adult drivers with a history of DUI and a demographically-comparable group of drivers with no history of DUI (controls) were tested following a 0.65 g/kg dose of alcohol and a placebo. Inhibitory control was measured using a cued go/no-go task. Drivers then completed a driving simulation task that yielded multiple indicators of driving performance, such as within-lane deviation, steering rate, centerline crossings and road edge excursions, and drive speed.

Results—Results showed that although DUI offenders self-reported greater levels of impulsivity than did controls, no group differences were observed in the degree to which alcohol impaired inhibitory control and driving performance. The findings point to the need to identify other aspects of behavioral dysfunction underlying the self-reported impulsivity among DUI offenders, and to better understand the specific driving situations that might pose greater risk to DUI offenders.

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Conflict of interest
All authors declare that they have no conflicts of interest.

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Keywords

Simulated driving; alcohol; DUI; impulsivity; inhibitory control

INTRODUCTION

Alcohol-related traffic fatalities and injury continue to be a major public health problem. The National Transportation Safety Board (NTSB, 2013) reported that in 2011, approximately 173,000 traffic injures in the United States were alcohol-related, and alcohol was a factor in one-third of all traffic fatalities. The public health costs associated with alcohol-related traffic accidents have prompted considerable research aimed at identifying characteristics of individuals who drive under the influence (DUI) in efforts to improve treatment and prevention strategies. The vast majority of this research has relied on analyses of driving records, surveys, and personality inventories. Driving records show that DUI offenders commit more moving violations, such as speeding, and are involved in more accidents compared with the general population (Bishop, 2011; Donovan, Marlatt, & Salzberg 1983; McMillen, Pang, Wells-Parker, & Anderson, 1992). Survey studies of DUI drivers have used self-report inventories to assess levels of impulsivity among DUI offenders (Chalmers, Olenick, & Stein, 1993; Hubicka, Kallman, Hiltunen, & Bergman, 2010; Ryb, Dischinger, Kufera, & Read, 2006). Broadly defined, impulsivity refers to a pattern of under-controlled behavior in which the individual is unable to delay gratification and acts without forethought or consideration of potential consequences. Such studies have reliably observed greater self-reported impulsivity among DUI offenders compared with demographically-matched control cases (e.g., Chalmers et al., 1993).

Together, these lines of evidence suggest that DUI drivers can be characterized by patterns of impulsive action and that such impulsivity could contribute to their poor driving behavior. Indeed, the idea that impulsivity could impair driving performance was raised decades ago by Wallgren and Barry (1970) who theorized that alcohol can disrupt driving performance via two distinct behavioral effects of the drug: impaired motor coordination and increased disinhibition. Motor impairing effects of alcohol can reduce driver precision, resulting in greater within-lane swerving and line crossings. The disinhibiting effects of alcohol can compromise driving performance by increasing reckless behaviors, such as speeding, excessive lane changing, and a disregard of traffic signals.

Although it has been established that risky drivers and DUI offenders self-report greater impulsivity, such self-reports provide limited insight into the specific behavioral and cognitive mechanisms that contribute to risky driving behavior and DUI. As such, it is necessary to understand the basic behavioral mechanisms that underlie impulsivity. Several theories in cognitive neuroscience postulate that the control of behavior is governed by distinct inhibitory and activational systems (Fowles, 1987; Gray, 1976; Logan & Cowan, 1984), and a key feature of impulsivity appears to be a lack of inhibitory control over prepotent, inappropriate actions (Fillmore, 2003; Fillmore & Vogel-Sprott, 2000). Thus, considerable research has focused on the ability to inhibit inappropriate action.

Inhibitory control has been measured in laboratory settings using go/no-go models (Fillmore, 2003) where subjects are instructed to respond quickly to go targets, but must inhibit responses to no-go targets. Poor inhibitory control on these tasks is indicated by more inhibitory failures on trials which no-go targets were presented. Laboratory research using these measures provides evidence implicating the role of poor inhibitory control in impulsivity. For example, studies show that groups characterized by impulsivity, such as those with ADHD or drug abusers, display poorer inhibitory control than healthy control groups (Roberts, Fillmore, & Milich, 2011; Barkley, 1997). Also, studies in behavioral pharmacology show that drugs such as alcohol, known for promoting impulsive actions, appear to do so by selectively reducing the drinker's ability to inhibit responses (Marczinski & Fillmore, 2003; Fillmore & Weafer, 2004).

With regard to driving, some work in our laboratory also has shown that deficient inhibitory control can contribute to reckless driving in a driving simulator. Drivers with poor inhibitory control, as measured by the go/no-go task, are more likely to speed, run red lights, and display poorer driving precision (Fillmore & Harrison, 2008; Fillmore et al., 2008). Poor inhibitory control might also result in increased sensitivity to the impairing effects of alcohol on driving performance. We have shown that reckless drivers and drivers with poor inhibitory control show the greatest sensitivity to the disruptive effects of alcohol on their driving performance (Fillmore, Blackburn, & Harrison, 2008; Harrison & Fillmore, 2005; Weafer, Camarillo, Fillmore, Milich, & Marczinski, 2008). In one study we tested 14 healthy adult drinkers between the ages of 21 and 30 in a cued go/no-go task following 0.65 g/kg alcohol and a placebo (Fillmore et al., 2008). Results showed that driving performance under alcohol was related to the drivers' inhibitory control. Drivers who displayed poorer inhibitory control under alcohol showed greater impairment in their driving as indicated by increased deviation of lane position, centerline and road edge crossings, and increased steering rate. Thus, there is preliminary evidence that deficient inhibitory control can contribute to heightened sensitivity to the impairing effects of alcohol on driving performance, albeit the evidence was based on a rather small sample size of 14 subjects.

Taken together, these recent findings implicate deficient inhibitory control in risky driving behavior, underscoring the need to examine this deficit in high-risk drivers, such as DUI offenders. Despite numerous studies showing that DUI offenders self-report traits of impulsivity, the specific underlying cognitive deficits, such as poor inhibitory control, have not been systematically studied in the laboratory. Nor has research examined how poor inhibitory control might contribute to poor driving performance in this population, particularly under the influence of alcohol.

The purpose of the present study was to examine the effects of alcohol on simulated driving performance and inhibitory control in a group of DUI offenders. DUI offenders were compared to "control" drivers with no DUI history. Laboratory tasks examined inhibitory control (i.e., go/no-go task) and simulated driving performance following 0.65 g/kg alcohol that produces a peak blood alcohol concentration of approximately 80 mg/100 ml and following a placebo beverage. It was predicted that alcohol would impair inhibitory control and several aspects of driving performance, and that greater impairment of inhibitory control would predict poorer driving performance, particularly under alcohol. With regard to DUI offenders, it was predicted that compared with controls, DUI offenders would self-report greater impulsivity, and that they would display poorer inhibitory control and poorer driving performance, particularly in response to alcohol.

METHODS

Participants

Forty adults between 21 and 34 years of age participated in this study. Twenty subjects (4 women and 16 men) had a history of DUI offense and 20 subjects (6 women and 14 men) were non-offending controls with no history of DUI offense. DUI offenders were required to have at least one DUI offense in the past five years. DUI convictions were verified by State District Court Record Reporting Systems (e.g., Kentucky Courts Records Online©, Courtnet©). Subjects were recruited by newspaper, web listings, and community bulletins that invited individuals to participate in studies on the behavioral effects of alcohol. Some posted advertisements specifically targeting adults with previous DUI offenses. Volunteers completed a comprehensive driving history questionnaire that included measures of driving experience (e.g., years driving, weekly distance driven), as well as reports of license revocations, traffic violations, and DUI offenses. Volunteers also provided a detailed medical history and history of prescription and recreational drug use. Volunteers had be at least 21 years of age and hold a valid driver’s license for at least 5 years and drive at least once per week. Volunteers who self-reported head trauma, psychiatric disorder, or substance abuse disorder were excluded from participation. All subjects were current consumers of alcohol. However, volunteers were excluded if their current alcohol use met dependence/ withdrawal criteria as determined by the substance use disorder module of the *Structured Clinical Interview for DSM-IV (SCID-IV*). No female volunteers who were pregnant or breast-feeding participated in the research, as determined by self-report and urine human chorionic gonadotrophin levels. No participant reported the use of any psychoactive prescription medication. Recent use of amphetamines (including methylphenidate), barbiturates, benzodiazepines, cocaine, opiates, and tetrahydrocannabinol (THC) was assessed by means of urine analysis. Any volunteer who tested positive for the presence of any of these drugs was excluded from participation. The University of Kentucky Medical Institutional Review Board approved the study, and participants received $110 for their participation.

Apparatus and Materials

Cued go/no-go task—Inhibitory control was measured using a computerized cued go/no-go model used in previous research (e.g., Fillmore & Weafer, 2004) and was operated by E-Prime experiment generation software (Schneider, Eschman, & Zuccolotto, 2002). A trial began with a fixation point (+) for 800 ms, followed by a blank screen for 500 ms. A rectangular-shaped cue was then displayed for one of four randomly occurring stimulus onset asynchronies (SOAs = 100, 200, 400, and 800 ms) before a go or no-go signal appeared for 1000 ms. If the rectangle turned green (the go signal) subjects were to make a computer key press as quickly as possible and if the rectangle turned blue (the no-go signal) they were to inhibit any response. A test consisted of 250 trials with 700 ms inter-trial intervals and required 15 minutes to complete. The orientation of the rectangular cue signaled the probability that a go or no-go signal would appear. A vertically-oriented rectangle (height = 7.5 cm, width = 2.5 cm) turned green on 80% of the trials and turned blue on 20% of the trials. A horizontally-oriented rectangle (height = 2.5 cm, width = 7.5 cm) turned green on 20% of the trials and turned blue on 80% of the trials. Therefore, vertical and horizontal-oriented rectangles operated as go and no-go cues, respectively. The measure of interest was the proportion (p) of inhibition failures to no-go signals in the go cue condition. Greater p-inhibition failures indicate poorer inhibitory control (i.e., disinhibition). Presentation of the go cue increases response preparation (i.e., produces a response prepotency), making it more difficult to inhibit a response when the no-signal unexpectedly appears. The disinhibiting effects of alcohol are most evident in this cue condition (Fillmore, 2003).

Simulated driving task—A computerized driving simulation task was used to measure driving performance (STISIM Drive, Systems Technology Inc., Hawthorne, CA). In a small test room, participants sat in front of the 48 cm computer display that presented the driving simulation. The driver was placed in the cab of the vehicle, providing a view of the roadway and dashboard instruments. Drivers controlled the vehicle by moving a steering wheel and manipulating accelerator and brake pedals. The drive test was a daylight driving scenario that required participants to drive 9.5 km on a busy street in a metropolitan setting while obeying all traffic laws. Participants had to drive through 20 intersections equipped with traffic lights. At five of the intersections, the traffic light was red and required the driver to stop until the light turned green. At all other intersections, the light was either green or turned yellow as the vehicle approached and did not require the driver to stop. Order of the traffic lights was random. Other vehicles were presented on the roadway at random intervals but did not require passing or braking on the part of the driver. Crashes, either into another vehicle or off the road, resulted in the presentation and sound of a shattered windshield. The program then reset the driver in the center of the right lane at the point of the crash. Because impulsive/reckless behavior is most likely observed when there is instigation to display such actions, drivers were provided with monetary incentives that encouraged speeding. Drivers were rewarded for finishing in the shortest time and penalized for failing to obey traffic laws (i.e., stop at red lights). Participants earned $5 for completing the drive in less than 5 minutes, $4 for finishing in 6–7 minutes, $3 for 7–8 minutes, $2 for 8–9 minutes, $1 for 9–10 minutes, and 50 cents if the driver finished in greater than 10 minutes. Drivers were penalized 50 cents for failing to stop at each red light. The drive test required between 5 and 10 minutes to complete, depending on the speed of the driver.

Timeline Follow-Back (Sobell & Sobell, 1992)—The Timeline Follow-back (TLFB) assesses daily patterns of alcohol consumption over the past three months. The measure is structured with prompts to facilitate participants' recall of past drinking episodes to provide a more accurate retrospective account of alcohol use during that time period. Multiple aspects of alcohol consumption over the past three months are measured including the total number of drinking days and total number of drinks consumed.

Barratt Impulsiveness Scale – BIS-11 (Patton et al., 1995)—This 30-item self-report questionnaire is designed to measure the personality dimension of impulsivity.

Impulsivity is thought to contribute to the risk of behavioral disinhibition under alcohol (Fillmore, 2007; Finn, Kessler, & Hussong, 1994). Participants rated 30 different statements (e.g., “I do things without thinking”) in terms of how typical each statement is for them on a 4-point Likert-type scale ranging from Rarely/Never to Almost Always/Always. Higher total scores indicate higher levels of self-reported impulsiveness (score range 30–120).

Perceived intoxication—Participants self-evaluated their perceived level of intoxication on a 100 mm visual-analogue scale that ranged from 0 “not at all” to 100 “very much.” These scales have been used in other alcohol studies of driving and are sensitive to the effects of the drug (e.g., Harrison & Fillmore, 2005; Harrison, Marczinski, & Fillmore, 2007).

Blood alcohol concentrations (BACs)—BACs were determined from breath samples measured by an Intoxilyzer, Model 400 (CMI Inc., Owensboro, KY).

Procedure

The study was conducted in the Behavioral Pharmacology Laboratory of the Department of Psychology at the University of Kentucky and all volunteers provided informed consent. Subjects were informed that the purpose of the study was to examine the effects of alcohol on driving performance and other cognitive and behavioral tasks. Subjects were tested individually and completed an initial familiarization session to become acquainted with laboratory procedures, practice the simulated driving and go/no-go tasks, and gather background information.

Subjects were then required to attend two separate test sessions in which they received one of two doses of alcohol: 0.0 g/kg (placebo) and 0.65 g/kg. They were required to abstain from alcohol for 24 hours and fast for 4 hours prior to each session. Each dose was administered on a separate test session, and dose order was counterbalanced across subjects and groups. Sessions were separated by a minimum of one day and a maximum of one week and test sessions were conducted between 10 a.m. and 6 p.m. The alcohol dose was calculated based on body weight and administered as absolute alcohol mixed with three parts carbonated soda. Subjects consumed the dose in six minutes. The dose produces an average peak BAC of 80 mg/100 ml approximately 60–70 minutes after consumption. The placebo dose (0.0 g/kg) consisted of a volume of carbonated mix that matched the total volume of the 0.65 g/kg alcohol drink. A small amount (i.e., 3 ml) of alcohol was floated on the top of the beverage and each glass was sprayed with an alcohol mist that provided a strong alcoholic scent as the beverage was consumed.

Behavioral testing began 40 minutes after beverage consumption during each session. Participants first completed the cued go/no-go task which began 40 minutes after beverage administration and required 15 minutes to complete. Sixty minutes post-administration participants completed the drive test, which required between 5–10 minutes. Subjects reported their levels of perceived intoxication at 70 minutes post-administration. Thus, all testing occurred during the late ascension and peak portion of the BAC curve. Subjects’ BACs were measured at 40, 60, and 70 minutes post-administration. Breath samples were also taken at these times during the placebo session, ostensibly to measure BACs. Once testing was finished, subjects remained at leisure in the lounge until their BACs fell to 20 mg/100 ml or below. Transportation home was provided after the sessions.

Criterion Measures

Cued go/no-go task: Failures of response inhibition—Drivers' inhibitory control was measured by the proportion of no-go targets in which the driver failed to inhibit a response during the test on the cued go/no-go task. Because go cues generate response prepotency and make inhibition difficult, the measure of interest was the proportion (p) of inhibition failure score in the go cue condition. Greater p- inhibition failures indicated poorer inhibitory control (i.e., disinhibition).

Simulated drive task—Four measures of driving performance were obtained during the driving test. The measures were intended to provide a profile of the driving behaviors typically impaired as a result of alcohol intoxication and were chosen on the basis of their established sensitivity to the disruptive effects of alcohol as demonstrated in previous research (Harrison & Fillmore, 2005).

Deviation of lane position—Within-lane deviation was determined by the lane position standard deviation (LPSD) of the driver's mean vehicular position within the lane measured in meters. The within-lane deviation measure is an indicator of the degree of adjustment by the driver to maintain a desired position within the lane. Greater within-lane deviation indicates poorer driving performance. A single lane position standard deviation (LPSD) score for a test was obtained by averaging deviation measures sampled at each meter of the driving test.

Steering rate—This is a measure of the rate with which the driver turns the steering wheel in order to maintain the vehicle's position on the road. Sober drivers typically maintain their position on the road by executing continuous, smooth steering wheel movements. Alcohol-impaired drivers can be slow to make adjustments to their road position requiring them to execute quick, abrupt manipulations to the steering wheel. These late corrections are reflected by an increased steering rate value. Steering rate was measured in terms of the degree change in the steering wheel per second. A single steering rate score for a test was obtained based on the average degree/sec change over the test.

Centerline and road edge crossings—A line crossing occurred when the vehicle moved outside the lane, either crossing over the centerline into oncoming traffic or the road edge line onto the shoulder of the road. The total number of line crossings was recorded for each test.

Speed—Drive speed was measured in terms of kilometers per hour (kph) and speed was measured as the average kph of the vehicle during the test.

Data analyses

The performance measures on each task and the measure of subjective intoxication were each analyzed individually by a 2 Group (DUI vs. control) × 2 Dose (0.0 g/kg vs. 0.65 g/kg) mixed-design analysis of variance (ANOVA). Bivariate correlations examined the relationship of drivers' impulsivity and their inhibitory control to their driving performance.

RESULTS

Demographics, driving history, and drug use

Table 1 lists the demographic and other background characteristics of drivers in the DUI and control groups. The racial makeup of the DUI group was 75% Caucasian, 20% African-American, and 5% Hispanic. In the control group, 80% of the participants reported Caucasian, 10% African-American, 5% Asian, and 5% other. Driving experience was determined based on years of licensed driving, number of driving days per week, and total weekly kilometers driven. Comparisons between DUI and control drivers using t tests showed no significant group differences on any measure of driving experience (ps > .25).

With regard to drinking habits, DUI offenders did not differ from controls on the total number of drinks consumed in the past 3 months, $t(38) = 1.11$, $p = .28$. Similarly, there was no difference between DUI offenders and controls on the total number of drinking days in the past 3 months, $t(38) = 0.46$, $p = .65$. In terms of other drug use, four subjects in the DUI group and five control subjects reported using cannabis an average of 2 days in the past month. However, no subject tested positive for THC at testing. No other drug use was reported in the past month. Analysis of BIS total scores indicated that DUI offenders self-reported higher levels of impulsivity compared to controls, $t(38) = 3.06$, $p = .004$.

Blood Alcohol Concentrations

BACs following the 0.65 g/kg alcohol dose were examined by a 2 (group) × 3 (time) mixed-design analysis of variance (ANOVA). A main effect of time owing to the rise of BACs during the course of testing was found, $F(2, 76) = 21.55$, $p < .001$, $\eta_p^2 = 0.36$. No main effects or interactions involving group or time were found (ps > .08). Because BACs did not differ between DUI offenders and controls, readings at each time point were averaged across the entire sample. The mean BACs (mg/100 ml) at each time were as follows: 40 minutes ($M = 61.00$, $SD = 16.24$); 60 minutes ($M = 64.35$, $SD = 16.10$); and 70 minutes ($M = 72.58$, $SD = 17.30$). No detectable BACs were observed in the placebo condition.

Cued go/no-go task

A 2 (group) × 2 (dose) ANOVA of drivers' proportion of inhibitory failures revealed a significant main effect of dose, $F(1, 38) = 6.15$, $p = .018$, $\eta_p^2 = 0.14$. Figure 1 plots the average p-inhibition failures for each group following placebo and alcohol. The figure shows that inhibition failures increased under alcohol compared with placebo, and this increase was similar for DUI offenders and controls. The figure also shows that DUI offenders tended to make more inhibition failures overall compared with controls. However, this difference failed to attain statistical significance as no main effect of group or interaction was obtained (ps > .11).

Simulated Driving Performance

Figure 2 plots each of the four measures of simulated driving performance for each group following placebo and alcohol. A 2 (group) × 2 (dose) ANOVA of lane position standard deviation scores revealed a significant main effect of dose, $F(1, 38) = 29.79$, $p < .001$, $\eta_p^2 = 0.44$. The mean LPSD scores for each group following placebo and alcohol are shown in Figure 1a. The figure shows that LPSD increased following alcohol compared with placebo indicating less driving precision under the drug. No significant main effect of group or interaction was found (*p*s > .60). Figure 1b plots the mean steering rate scores for each group following placebo and alcohol. A 2 (group) × 2 (dose) ANOVA indicated a significant main effect of dose, $F(1, 38) = 4.14$, $p = .049$, $\eta_p^2 = 0.10$. The figure shows an increase in steering rate under alcohol compared to placebo. No significant main effect of group or interaction was found (*p*s > .75). Figure 1c plots the mean number of line crossings. A 2 (group) × 2 (dose) ANOVA revealed a significant main effect of dose, $F(1, 38) = 15.49$, $p < .001$, $\eta_p^2 = 0.29$. The total number of centerline and road edge crossings increased under alcohol compared to placebo. No significant main effect of group or interaction was found (*p*s > .28). Mean speed is shown in Figure 1d. A 2 (group) × 2 (dose) ANOVA a main effect of dose, $F(1, 38) = 4.14$, $p = .049$, $\eta_p^2 = 0.10$. The average drive speed of the sample increased under alcohol compared to placebo. No significant main effect of group or interaction was found (*p*s > .29).

Subjective Intoxication

A 2 (group) × 2 (dose) ANOVA of subjective intoxication revealed a main effect of dose, $F(1, 38) = 147.83$, $p < .001$, $\eta_p^2 = 0.80$. The means for each group are shown in Figure 3. The figure indicates the sample reported a higher level of intoxication under alcohol compared with placebo. No significant main effect of group or interaction was found (*p*s > . 68).

Correlations of driving measures with self-reported impulsivity and inhibitory control

In order to determine if individual differences in drivers' self-reported impulsivity and their inhibitory control, as measured by the cued go/no-go task, were related to driving performance, bivariate correlational analyses were conducted. Correlations were conducted separately for each group, and for the sample as a whole. Results indicated that impulsivity scores were not significantly correlated with any measure of driving performance while sober or under in either group, or in the sample as a whole alcohol (ps > .60). Results also indicated that inhibitory control on the cued go/no-go task was not related to any driving performance measure in the sober state or under in either group or in the entire sample alcohol (ps > .76).

DISCUSSION

The present study examined the acute impairing effects of alcohol on the simulated driving performance and the inhibitory control of a group of DUI offenders and a comparison control group of drivers with no DUI history. The dose of alcohol produced an average peak BAC of 73 mg/100 ml and impaired multiple aspects of driving performance during a test of simulated driving in the laboratory. Compared with placebo, drivers' performance under alcohol was characterized by faster and more abrupt steering maneuvers, increased deviation of the vehicle within and outside of the lane, and a greater average speed. However, the degree to which alcohol impaired driving performance did not differ between the two groups. With regard to impulsivity, DUI offenders reported greater levels of impulsivity compared with controls. As predicted, alcohol impaired drivers' inhibitory control as evident by increased frequency of inhibition failures to no-go targets under alcohol compared with placebo. Although DUI offenders displayed more inhibitory failures than controls following placebo and alcohol, suggesting poorer inhibitory control, this group difference was not statistically significant.

Given that DUI offenders typically report greater impulsivity compared with controls, it was expected that DUI offenders would display poorer inhibitory control as well. Although it is unclear why no significant group differences were found, one reason might have to do with the multifaceted nature of impulsivity. Our study examined poor inhibitory control as one specific aspect of impulsivity in drivers. To that end, the cued go/no-go task was employed to measure inhibitory control as the ability to momentarily suppress a prepotent (i.e., instigated) behavioral response to a visual signal. However, in addition to a reduced ability to inhibit such prepotent responses, impulsivity also involves heightened approach tendencies towards rewarding and appetitive stimuli, often observed as a failure to delay gratification (Christiansen, Cole, Goudie, & Field, 2012). The impulsive behaviors typically reported by DUI offenders on self-report inventories could primarily reflect this latter behavioral tendency. That is, their impulsivity might reflect difficulty delaying immediate rewards, despite potential negative consequences in the long-term. Indeed, some recent research lends credence to the notion that a failure to delay reward underlies the impulsivity of such individuals, particularly in the intoxicated state. McCarthy, Niculete, Treloar, Morris, and Bartholow (2012) examined the effects of alcohol on impulsive behavior of drivers who reported drinking and driving in the past year. They found that, under alcohol, these drivers readily discounted rewards that were delayed, showing a preference for immediate reward. Thus, it might be that those who drink and drive are more sensitive to the impairing effects of alcohol on the ability to delay reward, but not on the ability to inhibit pre-potent action. Deciding to drive after drinking yields the immediate reward of convenience for the drinker, to travel home, to the next bar, or elsewhere. Thus a failure to delay or forgo such immediate reward could play a role in the decision to drive after drinking. Such a possibility points to the need to deconstruct the complex construct of impulsivity among DUI offenders to better understand how specific aspects of impulsivity are acutely affected by alcohol and possibly contribute to risky decisions to drive and risky driving behaviors (Fillmore, 2012).

As mentioned in the introduction, the majority of behavioral research on DUI offenders has involved survey studies, and there have been limited laboratory assessments of specific cognitive and neuropsychological functioning in this population. Moreover, despite speculation and assumptions about the intoxicated driving behavior of DUI offenders, prior to this study no laboratory research had examined how DUI offenders actually respond to alcohol in terms of their driving performance. As such, our findings provide some important new information about the reactions to alcohol observed in DUI offenders. A common assumption among behavioral pharmacologists and forensic toxicologists is that DUI offenders are heavy drinkers and consequently they might display tolerance to the impairing effects of alcohol, such that their driving ability is only mildly disrupted by alcohol (for a review see Martin et al., 2013). In the present study we found no differences in the drinking habits between DUI offenders and controls, and thus one would not expect differences in tolerance between the two groups. However, in addition to a history of heavy alcohol consumption, tolerance can be acquired by performing a specific skill repeatedly under the influence of alcohol. Such functional tolerance is akin to state-dependent learning, and can be rapidly acquired as a function of repeated performance of an activity of under alcohol (for a review see, Vogel-Sprott, 1992). Laboratory demonstrations of functional tolerance to simple motor skills in animals (Leblanc, Gibbins, & Kalant, 1973) and humans (Vogel-Sprott, 1979) have led researchers to suggest that those who regularly drive after drinking should acquire functional tolerance, such that they display less impairment of driving skill in the intoxicated state (e.g., Martin et al., 2013). Therefore, in the present study, it would be expected that those with a history of DUI arrest should have a greater learning history of driving while intoxicated compared with those with no prior DUI arrest (i.e., controls). Nonetheless, our results showed that DUI offenders displayed levels of impairment under alcohol that were comparable to control drivers on all measures of driving performance. Thus, from these data, it seems that any history of drinking and driving among the DUI offenders did not result in any appreciable tolerance to the impairing effects of alcohol on their simulated driving performance in the laboratory. It is also important to recognize that any such functional tolerance could wane as the driver ceases to engage in driving while intoxicated, as might be expected following their DUI arrest. Thus it is difficult to draw any definitive conclusions about the role of functional tolerance in this population.

Another factor that is important to consider in the present study is the simulated driving test that emphasized aspects of driving behavior often considered to be non-demanding, reflecting largely automated skill. Driving researchers have long recognized that aspects of driving can be classified on the basis of representing either automatic or controlled modes of cognitive processing (e.g., Michon, 1985; Salvucci, 2006). Behaviors governed by automatic processes tend to be well learned actions that require little conscious effort and can be conducted in parallel with other activities. By contrast, controlled actions are effortful, demanding greater cognitive resources, and are often disrupted by a secondary activity (Shiffrin & Dumais, 1981). The driving test in the present study emphasized the ability to maintain lane position by executing minor steering adjustments that reflect automatic processes. Such automatic processes could be less vulnerable to impulsivity and poor inhibitory control on the part of the driver. By contrast, overtaking other vehicles and breaking suddenly to avoid unexpected obstructions are considered to entail controlled, conscious actions on the part of the driver (Michon, 1985). Such controlled, effortful driving skills could be adversely affected by poor impulse control and other aspects of impulsive behavior on the part of the driver. As such, the distinction between controlled and automatic processes in driving behavior would be important to consider in studies of DUI offenders and other at-risk drivers who are characterized by impulsivity.

It is also recognized that the DUI offender group was comprised primarily of first-time offenders, with only three DUI offenders having multiple DUI offenses (i.e., recidivist offenders). As a group, first-time offenders are likely to be fairly heterogeneous with respect to any underlying behavioral dysfunction that might contribute to risky driving behavior and DUI. For many drivers, a single DUI conviction might not indicate any underlying behavioral dysfunction, but rather reflect an isolated, unlucky event for an individual. By contrast the recidivist offender demonstrates a pattern of poor decision-making and risky driving behavior that is more likely to reflect some underlying and enduring behavioral or cognitive dysfunction. Indeed, among the few laboratory studies that examine neurocognitive functioning in DUI offenders, cognitive dysfunction is most often observed in DUI groups who are comprised solely of recidivist offenders (e.g., Glass, Chan, & Rentz, 2000; Ouimet et al., 2007). To the extent that recidivism reflects some behavioral dysregulation, it is possible that recidivist offenders could also display increased sensitivity to the disruptive effects of alcohol on impulse control and measures of driving performance. Such an intriguing possibility awaits to be examined.

In summary, the findings point to the need to identify specific aspects of behavioral dysfunction underlying the self-reported impulsivity among DUI offenders. Additional work is also needed to examine other types of driving situations commonly encountered outside the laboratory, including longer drives and those that are more demanding, requiring controlled, effortful actions on the part of the driver. The integration of such approaches allows longstanding but rarely tested hypotheses to be examined, such as the possibility that DUI drivers display aberrant reactions to alcohol that could compromise self-regulatory processes and contribute to their decisions to drive after drinking.

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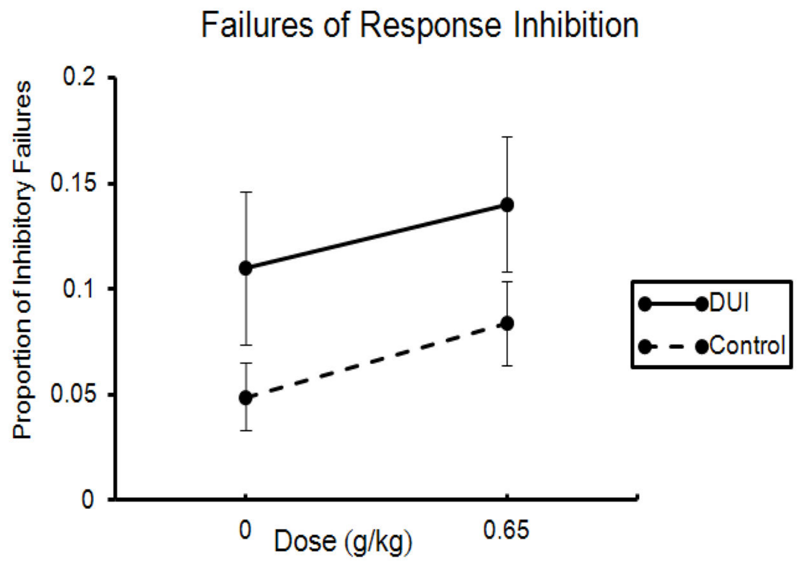

Figure 1.

Mean number of inhibitory failures (p-inhibition failures) on the cued go/no-go task following 0.0 g/kg and 0.65 g/kg alcohol for DUI and control drivers. Error bars indicate standard error of the mean.

Figure 2a.

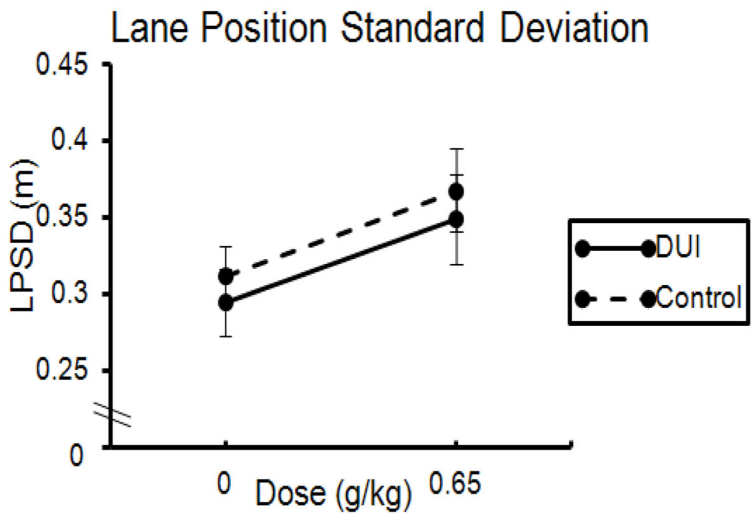

Figure 2b.

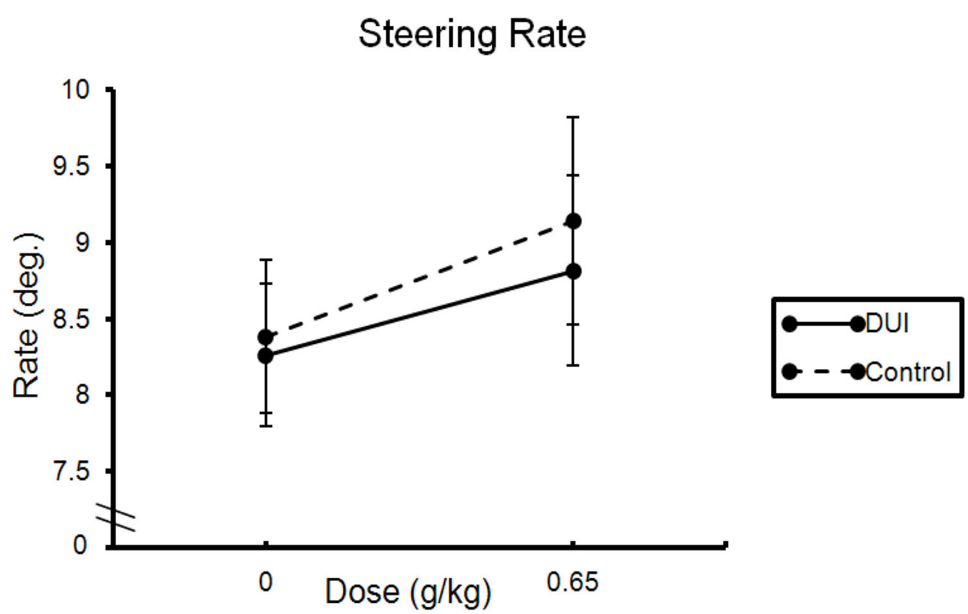

Figure 2c.

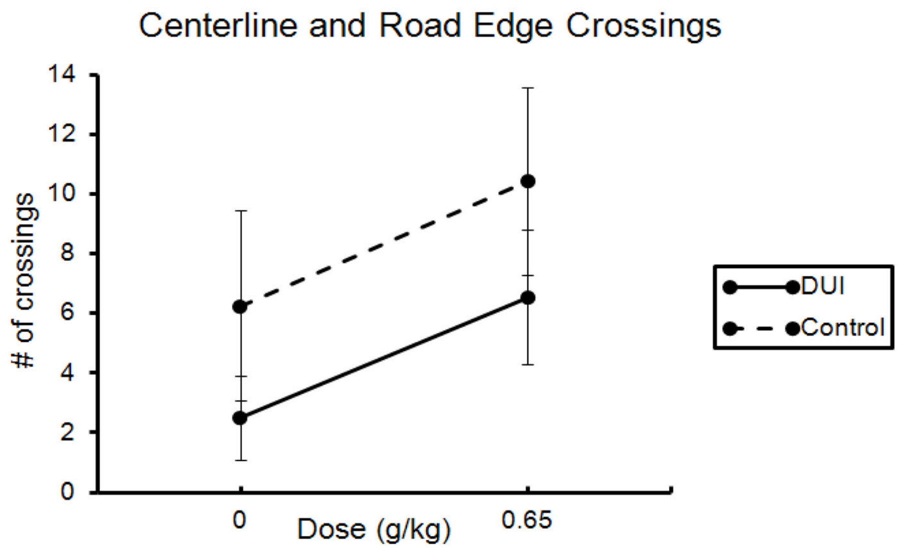

Figure 2d.

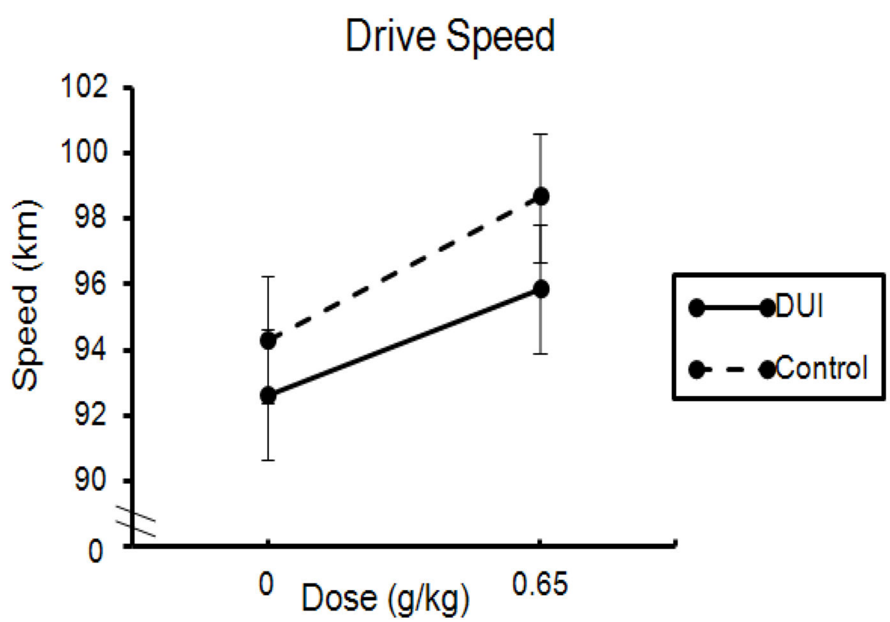

Figure 2.

Figure 2a. Mean deviation of lane position (meters) following 0.0 g/kg and 0.65 g/kg alcohol for DUI and control drivers. Error bars indicate standard error of the mean.

Figure 2b. Mean steering rate in deg/sec following 0.0 g/kg and 0.65 g/kg alcohol for DUI and control drivers. Error bars indicate standard error of the mean.

Figure 2c. Mean number of centerline and road edge crossings following 0.0 g/kg and 0.65 g/kg alcohol for DUI and control drivers. Error bars indicate standard error of the mean.

Figure 2d. Mean drive speed (kilometers per hour) following 0.0 g/kg and 0.65 g/kg alcohol for DUI and control drivers. Error bars indicate standard error of the mean.

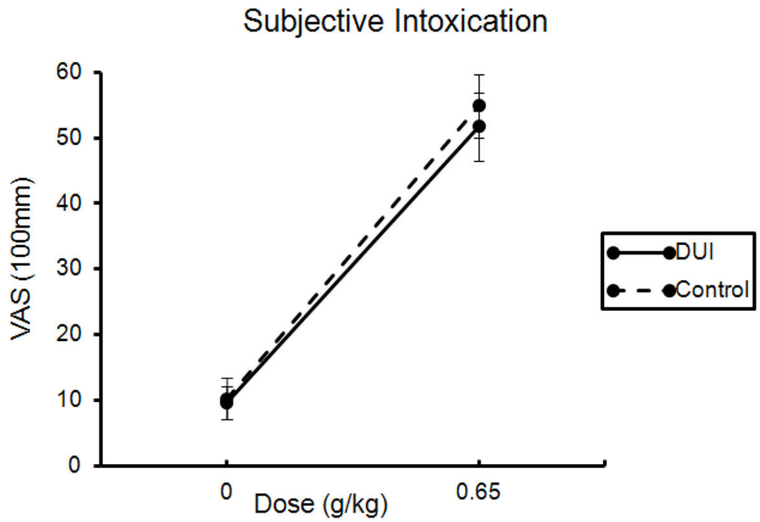

Figure 3.
Mean subjective rating of perceived intoxication ratings on 100-point visual analogue scales following 0.0 g/kg and 0.65 g/kg alcohol 70 min post-administration for DUI and control drivers. Error bars indicate standard error of the mean.

Table 1

Comparison of DUI offenders to controls on background characteristics.

	Controls		DUI Offenders			
	M	**(SD)**	**M**	**(SD)**	***t***	***P***
Age	24.6	(3.4)	25.95	(4.1)	1.09	0.28
Drive years	8.8	(3.3)	10.28	(4.6)	1.16	0.25
Drive freq.	5.7	(2.1)	6.03	(1.6)	0.56	0.58
Drive distance	211.0	(184.5)	144.2	(96.5)	1.91	0.07
Traffic tickets	2.2	(5.5)	1.8	(2.4)	0.26	0.80
Total drinks	122.0	(92.5)	158.98	(117.3)	1.11	0.28
Total days	28.4	(13.0)	31.05	(22.0)	0.46	0.65
Impulsivity	57.4	(8.0)	65.25	(8.3)	3.06	0.004

Age = years; Drive years = total years of licensed driving; Drive frequency = number of driving days per week; Drive distance = kilometers driven per week; Traffic tickets = total number of traffic citations; Total drinks = TLFB total drinks consumed in the past 3 months; Total days = TLFB total drinking days in the past 3 months; Impulsivity = Barratt Impulsiveness Scale (BIS-11) total score.