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ALCOHOL-INDUCED IMPAIRMENT OF SIMULATED DRIVING PERFORMANCE AND BEHAVIORAL IMPULSIVITY IN DUI OFFENDERS

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ALCOHOL-INDUCED IMPAIRMENT OF SIMULATED DRIVING PERFORMANCE
AND BEHAVIORAL IMPULSIVITY IN DUI OFFENDERS

DISSERTATION

A dissertation submitted in partial fulfillment of the
requirements for the degree of Doctor of Philosophy in the
College of Arts and Sciences
at the University of Kentucky

By
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2018

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ABSTRACT OF DISSERTATION

ALCOHOL-INDUCED IMPAIRMENT OF SIMULATED DRIVING PERFORMANCE AND BEHAVIORAL IMPULSIVITY IN DUI OFFENDERS

Licensed drivers arrested for driving under the influence (DUI) of alcohol have increased rates of vehicle crashes, moving violations, traffic tickets, and contribute to an estimated 120 million occurrences of impaired driving per year (Evans, 2004; Jewett et al., 2015). Survey research on DUI offenders indicates traits of impulsivity (e.g., sensation seeking). Together, these pieces of evidence suggest that DUI offenders display patterns of impulsive action and risk-taking while driving. However, to-date DUI offenders are rarely studied in a laboratory setting, and not much is known about how they respond to a dose of alcohol. The present study examined the degree to which DUI offenders display an increased sensitivity to the acute impairing effects of alcohol on mechanisms of behavioral impulsivity, skill and risk-based driving simulations, and subjective evaluations of driving fitness and perceived intoxication following alcohol consumption. A sample of 20 DUI offenders were compared to a demographically-matched sample of 20 control drivers. All participants attended two dose sessions in which they received either a 0.65 g/kg dose of alcohol or a placebo dose, counterbalanced, on separate days. Results indicated that alcohol affected all of the behavioral outcome measures. More specifically, alcohol increased impulsive choice responses and decreased response inhibition on the behavioral impulsivity tasks. Alcohol also increased risky driving behaviors and decreased driving-related skills. Furthermore,

alcohol generally decreased participants' self-reported willingness and ability to drive a motor vehicle, and increased levels of intoxication and BAC estimations relative to placebo. With regard to group differences, DUI offenders showed an increased sensitivity to the disrupting effects of alcohol on impulsive choices, such that DUI offenders showed a significantly greater preference for impulsive choices under alcohol relative to placebo than controls. Taken together, these findings provide some of the first pieces of evidence that compared to controls, DUI offenders display an increased tendency for impulsive decisions under alcohol, which likely contributes to risky decisions to drive after drinking, despite clear evidence for their behavioral impairment. These findings could have important implications for understanding the mechanisms underlying maladaptive behaviors in this high-risk population, and sheds light on possible targets for intervention to reduce DUI recidivism.

Keywords: *Alcohol, driving, impulsivity, DUI, traffic safety, behavior*

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05/29/2018

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General introduction to driving under the influence of alcohol

The combination of alcohol consumption and the operation of a motor vehicle produce an estimated 120 million occurrences of impaired driving per year, or a rate of 505 episodes per 1,000 population annually (Jewett, et al., 2015). In 2010, it was reported that alcohol was a factor in over 250,000 traffic injuries and one-third of all traffic fatalities (NHTSA, 2012). Recent reports indicate the number of deaths resulting from alcohol-related traffic crashes has remained stable over the past several years (NHTSA, 2017). Last year this number equaled 9,967 motor vehicle fatalities (or approximately 1 death per hour) in the United States in which alcohol was a contributing factor (NHTSA, 2017). In the United States, a “per se” law determines the legal blood alcohol concentration (BAC) for which a driver can legally operate a motor vehicle. The current legal limit in all 50 states is 80 mg/100 mL (0.08%). Driving under the influence of alcohol (DUI) is a criminal offense defined as driving with a BAC in excess of 0.08% (Insurance Institute for Highway Safety, 2013). Data indicate that individuals arrested for DUI contribute a disproportionate amount toward the considerable public health costs associated with traffic accidents and fatalities (e.g., Cavaiola and Wuth, 2002; NHTSA, 2012, 2015). Within these statistics, it is recognized that not all DUI offenders are the same. Recidivist offenders, or DUI offenders with more than one prior arrest for DUI, are of particular importance as they commit more frequent episodes of drinking and driving, more moving traffic violations and risky driving behaviors, and tend to drink and drive at much higher BACs than people without a DUI history or those with only one prior offense (Cavaiola and Wuth, 2002; NHTSA, 2015).

DUI prevention and treatment efforts

A major public health focus has been to reduce the incidence of DUI in efforts to decrease the number of alcohol-related traffic injuries and fatalities, and improve traffic safety and public health outcomes. In order to accomplish this, government agencies have primarily focused on prevention strategies and treatment efforts aimed at preventing drinking and driving before it occurs, and reducing DUI recidivism by treating underlying issues within the individual in hopes they will forgo future drinking and driving behavior following an initial DUI arrest.

With regard to prevention efforts, most strategies tend to focus on general deterrence of DUI before the drinking episode begins. A few common strategies employed by government agencies, such as the Department of Transportation, focus on prevention of DUI by increasing public awareness of the issue through radio and television commercials, roadside billboards, public displays of motor vehicles involved in DUI crashes, and increased visibility of roadside DUI checkpoints (Cavaiola and Wuth, 2002; NHTSA, 2014). In addition, well-known advocacy groups such as Mothers Against Drunk Driving (MADD) and Students Against Destructive Decisions (SADD) have actively advocated for prevention efforts aimed at reducing alcohol-impaired driving (Cavaiola and Wuth, 2002). While initial data on the effectiveness of these prevention strategies was mixed, reports have shown they have been at least somewhat effective in reducing the number of alcohol-related crashes (e.g., Fell et al., 2003). However, despite modest successes of prevention strategies at reducing drinking and driving over the past decade, idle rates of alcohol-related traffic crashes and fatalities over the same timeframe has led agencies to look to other prevention methods to reduce alcohol-related traffic

injuries and fatalities. One recent strategy, proposed by The National Transportation Safety Board (NTSB) suggested reducing the current legal driving limit in the United States from 0.08% to 0.05% (NTSB, 2013). The United States is currently one of few major industrialized countries with a legal driving limit above 0.05%. Current legal driving limits for comparable countries around the world tend to range from 0.0% to 0.05%, including Australia, much of Canada, and the vast majority of Europe (NHTSA, 2015). As a result of adopting lower BAC limits, these countries have seen significant reductions in alcohol-related traffic crashes (NHTSA, 2015). The NTSB points to this evidence to indicate that reducing the legal limit will have a deterrent effect, preventing more individuals from drinking and driving, and thus contribute toward reducing the number of alcohol-related motor vehicle crashes in the United States. Such proposals have been met with considerable resistance from the Alcohol Beverage Industry (NTSB, 2105).

Treatment strategies aimed at reducing DUI recidivism generally rely on punishments following a DUI arrest to deter future drinking and driving behavior. The punishment for receiving a DUI varies by state and can include, but is not limited to, any combination of the following: fines, license suspension, mandatory alcohol education classes, mandatory drug and alcohol treatment programs, jail time, and the less frequently used ignition interlock systems in offenders' vehicles (Cavaiola and Wuth, 2002). In the case of severe offenders (i.e., BAC well above the legal limit at time of arrest) and recidivist offenders, treatment plans may be developed to focus on issues surrounding risky alcohol use. While prevention efforts have produced modest success in reducing DUI, treatment programs designed to reduce recidivism rates have shown limited efficacy

(Cavaiola and Wuth, 2002; NHTSA, 2016). One recognized issue regarding existing treatment modalities is that education-based and treatment programs mandated to both first-time and recidivist offenders often lack well-defined goals and desired outcomes, and lack an individual focus (Fitzpatrick, 1992; Frawley, 1988). Moreover, many programs, such as Alcoholics Anonymous, centrally focus on problems with alcohol as a treatment outcome (Alcoholics Anonymous, 1984), though research indicates that many DUI offenders do not have problems with alcohol usage (Wuth, 1987). Indeed, Fillmore and Kelso (1987) suggest a mere 20% of DUI offenders show alcohol-related problems similar to alcoholics.

Thus, despite considerable economic resources dedicated to prevention and treatment efforts aimed at reducing drinking and driving behaviors, driving under the influence of alcohol is one of the most frequently committed crimes (Federal Bureau of Investigation, 2006). The limited efficacy of existing programs has prompted research in recent years to focus on examining characteristics of individuals who have been arrested for DUI in efforts to improve existing prevention and treatment programs and reduce the incidence of DUI recidivism.

Characteristics of DUI Offenders

The overwhelming majority of existing research on DUI offenders has been conducted using surveys and personality inventories. Some basic statistics indicate that one in every 127 licensed drivers is arrested for DUI and over one-third of DUI offenders will re-offend within three years from an initial DUI arrest (Nochajski and Stasiewicz, 2006). In 2010, the NHTSA reported the DUI driver to be predominantly male and between the ages of 21 and 45 (NHTSA, 2012). Males offend at an approximate 3:1 ratio

compared to females (McCutcheon et al., 2011). DUI offenders above the age of 35 show increased rates of alcohol abuse (Cavaiola et al., 2003) while younger offenders do not typically meet DSM-IV diagnostic criteria for alcohol abuse or dependence (Lapham et al., 2004). The recidivist DUI offender, in particular, shows increased levels of various maladaptive and pathological traits, such as drinking to cope with negative feelings or emotions, antisocial personality traits, depressiveness, and anxiety that are often comorbid with alcohol abuse and/or dependence (Ball et al., 2000; Cavaiola et al., 2007; Miller and Fillmore, 2015).

Personality inventories of DUI offenders have identified traits implicated in risky drinking and driving behavior. Broadly speaking, the use of the five-factor model (Costa and McCrae, 1992) has correlated the neuroticism and extraversion personality dimensions with moving traffic offenses, road accidents, and aggressive driving behaviors (Dahlen and White, 2006; Lajunen and Parker, 2001; Matthews et al., 1991). Within these broad factors, decades of survey research links DUI offenders to traits of impulsivity and other related personality attributes within the impulsivity domain, such as sensation seeking (Chalmers et al., 1993; Ryb et al., 2006). Impulsivity can be defined as having a lack of control over the thoughts and behaviors within oneself (Barratt, 1994) and includes dimensions such as acting without thinking, sensation seeking, susceptibility to boredom, and inhibitory control (Buss and Plomin, 1975). Multiple studies have linked self-reported impulsivity with impaired driving, reduced perceptions of one's surroundings while in control of a motor vehicle, accidents, and drunk driving (e.g., Hansen, 1988; Stanford et al., 1996). Studies have also shown sensation seeking contributes to multiple facets of risky driving behavior such as drunk driving and

speeding (Arnett et al., 1997; Burns and Wilde, 1995). In addition to higher levels of impulsivity and sensation seeking, DUI offenders also possess a lowered risk perception (Chalmers et al., 1993), all of which may make them more likely to engage in risky driving behaviors. Indeed, analysis of driving records indicate that DUI offenders are involved in more accidents and commit more moving traffic violations (e.g., swerving or speeding) than individuals without a history of DUI (Bishop, 2011; McMillen, Pang, Wells-Parker, & Anderson, 1992). Such increased rates of traffic accidents and violations could reflect tendencies to act impulsively or take risks while driving.

While research has established the DUI offender as having high levels of self-reported impulsivity, a major problem lies in the fact that impulsivity is a broad construct. The specific components underlying impulsivity in DUI offenders have not been well studied in a laboratory setting. Increased trait levels of impulsivity in the DUI offender might be reflective of deficits of self-regulatory mechanisms leading these individuals to continually engage in high-risk drinking and driving behaviors. In order to fully understand the DUI offender, research needs to focus specifically on understanding how increased trait impulsivity is reflected behaviorally to determine how possible deficits in these areas might contribute to DUI and its recidivism. The ability to delay immediate rewards and behavioral inhibition of prepotent responses are two such domains that have received considerable laboratory research attention in recent years and might be especially relevant to DUI offenders. For example, DUI offenders may suffer from impaired inhibitory mechanisms and lack the ability to forgo instant gratification in favor of safer options leading to the risky drinking and driving behaviors seen in this population. For example, in this scenario, the DUI offender with greater levels of

disinhibition and an inability to delay reward might drink and drive at the end of the night instead of waiting for a ride home.

Theory guiding this dissertation

The general theory guiding this dissertation stems from the traits of impulsivity that characterize DUI offenders. More specifically, given that DUI offenders self-report higher levels of trait impulsivity than non-offenders, this dissertation focused on examining how this trait impulsivity is displayed behaviorally to determine the mechanisms that contribute toward DUI offenders' continual engagement in risky drinking and driving behaviors. The purpose of this dissertation was to identify whether DUI offenders possess deficits of two key aspects of behavioral regulation: Increased preference for immediate reward, and poor inhibitory control of pre-potent, instigated action. Impulsive responding can be defined as the inability to delay immediate reward or satisfaction in favor of delayed, and often more advantageous options (Bickel and Marsch, 2001) whereas inhibitory control can be defined as the ability to suppress or inhibit dominant responses (Fillmore, 2003). These two aspects of behavioral impulsivity might be indicative of specific maladaptive behaviors seen in this high-risk population. The breakdown of trait impulsivity into its behavioral constituents allows for the examination of simple mechanisms of behavior easily observable in the laboratory, that change in different scenarios, such as in response to a drug. In order to accomplish this, these two distinct domains of behavioral impulsivity that research has implicated in risky drinking and driving behaviors were assessed to determine if DUI offenders differ from non-offenders on key aspects of behavioral regulation.

Deficits of self-regulation might also directly contribute to risky decisions to drive after drinking and subsequent risky driving behavior once driving has begun. Thus, in addition to thoroughly examining two important mechanisms of behavioral impulsivity, self-appraisals of driving fitness (e.g., willingness and self-reported ability) and multiple facets of driving behavior will be assessed to determine if deficits of behavioral regulation lead DUI offenders to more readily drive after drinking and display riskier driving behaviors while driving. As such, the theoretical framework of this dissertation allowed for not only the identification of important deficits of behavioral regulation in a high-risk population (i.e., DUI offenders), but also examination of important mechanisms by which such deficits produce continual maladaptive and risky choice behaviors.

Laboratory assessment of inability to delay reward

The past decade has led to advancements in tasks used to measure specific behavioral components of impulsivity. One important component of behavioral impulsivity that is relevant to drinking and driving behavior is an individual's preference for immediate reward (i.e., impulsive responding). This preference for impulsive responding is generally defined as the inability to delay immediate rewards in favor of delayed rewards (Bickel and Marsch, 2001). Historically, these impulsive decisions are typically measured using pen and paper questionnaires which ask participants whether they would prefer a hypothetical smaller amount of money now, or some hypothetical larger sum of money at a future point in time (e.g., Bickel and Marsch, 2001; Johnson and Bickel, 2002). For example, participants might be asked if they would prefer \$5 now or \$100 in one week. An individual who shows impulsive responding would show a greater preference for immediate or short-delay rewards over larger rewards on a longer

delay. More recently, experiential discounting models have been developed to assess an individual's propensity for impulsive responding in real time. In experiential models, participants must physically experience each delay, such that if they were tasked with choosing between options with 5 sec. and 60 sec. delays, they would be required to endure the respective delay attached to each response option prior to receiving any reward (Dougherty et al., 2000; Reynolds et al., 2006). The experiential nature of these tasks in which participants must endure delays in real time prior to receiving rewards has led some researchers to suggest that experiential models have improved validity over hypothetical models and should be considered the gold standard for future impulsive responding research (Reynolds and Schiffbauer, 2004).

Laboratory work using traditional hypothetical discounting methods have produced somewhat equivocal findings with regard to tasks' sensitivity to alcohol or other drugs. However, there is at least some evidence that alcohol increases discounting on the tasks, leading participants to display a greater preference for immediate rewards over delayed rewards when under a dose of alcohol, compared with placebo (e.g., Reynolds, Richards, and de Wit, 2006). With regard to experiential discounting tasks, given that these tasks are still somewhat new to laboratory research, only a few studies have reported on the sensitivity of the tasks to various drugs of abuse. These studies have found the tasks to be sensitive to the effects of alcohol (Reynolds, Richards, & de Wit, 2006), nicotine (Reynolds, 2006), and other psychoactive drugs (e.g., methylphenidate) used to treat psychiatric illnesses (Shiels et al., 2009).

This behavioral component of impulsivity is relevant to the DUI offender as the inability to delay immediate rewards is likely related to individuals' decisions to drive

after drinking. An individual who shows a preference for immediate rewards may be more likely to get behind the wheel after drinking instead of waiting for a taxi home, for example. Thus, in this scenario, impulsive responding may be a mechanism by which DUI offenders show a propensity to drive after an episode of drinking, and continue to do so, even after an initial arrest for DUI. While it appears no studies to-date have examined this mechanism in DUI offenders, there is some evidence that individuals who self-report drinking and driving (but no history of DUI) display greater levels of impulsive responding than those who do not self-report drinking and driving (McCarthy et al., 2012).

Laboratory assessment of behavioral inhibition

Inhibitory control is another aspect of behavioral impulsivity that can be defined as the ability to suppress dominant responses (Fillmore et al., 2008; Fillmore and Vogel-Sprott, 2000) or the ability to inhibit inappropriate responses (Fillmore, 2003). This might be especially relevant to DUI offenders as impairment of inhibitory control may contribute to the disinhibited behaviors in this population that are often characterized by impulsive action and risk-taking. Inhibitory control has been measured in a laboratory setting for many years using go/no-go models (Weafer and Fillmore, 2016; Fillmore, 2003). One variant of this procedure is the cued go/no-go model in which participants are told to respond as quickly as possible to go targets by pressing a key on a keyboard, while withholding responses to no-go targets. In this task, cues preceding the target provide information about the likelihood of a go or no-go target that will follow and have a high probability of signaling the correct target, such that horizontally-oriented cues most often signal a go-target, whereas vertically-oriented cues most often signal a no-go target (e.g.,

Fillmore, 2003). This methodology creates a pre-potency to respond when participants are presented with a go cue. However, on a minority of trials, the respective cue signals the incorrect target. Of particular interest are the trials in which a go cue signals a no-go target. During these trials participants must inhibit any response as the go cue will produce a no-go target. Failure to inhibit responses to these trials are referred to as inhibitory failures. The task measures reaction time to go targets and the proportion of inhibitory failures to no-go targets preceded by go cues. Poor inhibitory control is signified by a greater percentage of inhibitory failures (Fillmore, 2003).

Laboratory work using cued go/no-go and stop signal models have shown that populations similarly characterized by increased trait levels of impulsivity (e.g., individuals with ADHD) possess reliable deficits of inhibitory control. A number of studies have shown that adults and children with ADHD, who are characterized by impulsive, maladaptive actions, possess significant deficits of inhibitory control compared with healthy control participants (e.g., Barkley, 1997a, b; Logan and Cowan, 1984; Schachar et al., 2000). With regard to the effect of alcohol on inhibitory control, research has well documented the ability of alcohol to increase impulsive actions by impairing basic inhibitory mechanisms necessary to inhibit behavior (Fillmore et al., 2008; Fillmore and Vogel-Sprott, 2000; Marcuzinski and Fillmore, 2003; Fillmore, 2003). A study by Weafer and Fillmore (2012) found that alcohol impaired inhibitory control indicated by an increase in failures to inhibit responses to go cues preceding no-go targets. Moreover, the magnitude of impairment followed in a dose-dependent fashion following placebo, 0.45 g/kg, and 0.65 g/kg alcohol, such that the level of impairment increased with each increasing dose. Testing in this study, under each dose, occurred 35

minutes post beverage consumption as BAC was rising rapidly (Weafer and Fillmore, 2012). Other studies have led to similar conclusions in finding that alcohol increased inhibitory failures on cued go/no-tasks following 0.65 g/kg alcohol compared to placebo on the ascending limb of the BAC curve (Fillmore et al., 2005; Fillmore and Weafer, 2004). Fillmore et al. (2005) also found that increased impairment of inhibitory control persisted from the ascending to the descending limbs, which provides evidence that alcohol-induced disinhibition is present even after drinking has ceased. These findings are especially relevant to the DUI offender as they indicate that not only do other populations characterized by impulsivity (ADHD) possess baseline deficits of inhibitory control, but that inhibitory mechanisms are significantly impaired by alcohol, and these impairments persist as BACs decline. Thus, DUI offenders might be particularly at-risk for impulsive, maladaptive behaviors, and these behaviors might be exacerbated under the influence of alcohol.

Laboratory assessment of driving behavior

Driving performance is typically measured in a laboratory setting using driving simulators designed to assess specific aspects of driving behavior. Laboratory studies of simulated driving performance clearly demonstrate that alcohol impairs several aspects of driving performance that are critical to the safe operation of a motor vehicle. These studies tend to focus on driving behaviors that can be characterized as either skill-based or risk-taking behaviors. In terms of drivers' skill, research indicates that alcohol reliably impairs the ability to maintain stable position of the vehicle in the drivers' lane, slows braking time, and reduces the ability to detect potential hazards on the roadway (for reviews see Martin, Solbeck, Mayers, Langille, Buczek, & Pelletier, 2013; Ogden &

Moskowitz, 2004). With regard to risky driving behaviors, studies typically focus on measuring aspects of driving that could be considered high-risk, such as tailgating or otherwise placing the driver's vehicle close to other objects on the roadway. The few studies that have examined risky driving following alcohol have provided evidence that alcohol increases risk-taking, leading drivers to decrease their safety margins under alcohol (e.g., Laude and Fillmore, 2015; Van Dyke and Fillmore, 2017). In addition, other models of risky driving indicate that drivers opt for riskier lane options when given the choice between safer and riskier driving lanes (e.g., Burian et al., 2012). With regard to the disruptive effect of alcohol on driving performance, research indicates that alcohol impairs skill-based behaviors and increases risk-taking under moderate doses of alcohol that produce BACs at or below the current legal limit of 0.08%

Relationship between behavioral impulsivity and driving behavior

Studies have also linked measures of trait impulsivity to driving behavior. For example, one study showed that drivers who reported high levels of sensation-seeking displayed riskier driving behaviors than drivers who reported low levels of sensation-seeking (Schwebel, Severson, Ball, & Rizzo, 2006). Such a relationship might be especially evident when the driver is intoxicated. In the DUI offender, a population characterized by impulsive action and risk-taking, impairment of self-regulatory mechanisms following alcohol likely impacts decision-making processes and risky driving behaviors while behind the wheel. Indeed, it is also important to consider how these factors relate to driving behaviors. A previous study of alcohol effects on simulated driving performance in our laboratory showed this on an individual level, such that drivers whose impulse control was most impaired by alcohol also tended to display the

poorest driving performance under the drug (Fillmore, Blackburn, & Harrison, 2008).

This study tested 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. Results of the study indicated that compared with placebo, alcohol impaired simulated driving performance and performance on the cued go/no-go task. Moreover, the study indicated that driving behavior was closely related to inhibitory control, in that under alcohol poor inhibitory control was associated with increased impairment indicated by multiple measures of driving performance, such as increased deviation of lane position, line crossings, increased steering rate, and a faster average driving speed. Similar results have been found when examining the relationship between inhibitory control and driving scenarios designed to assess risky driving behaviors. A recent study from our laboratory examined healthy adult drinkers following 0.65 kg/kg and a placebo and found that sober levels of inhibitory control, measured by a cued go/no-go task, were significantly related to risk-taking behaviors, such that drivers who displayed the poorest inhibitory control displayed the greatest levels of risky driving, evidenced by a decrease in drivers' time-to-collision (Laude and Fillmore, 2015).

This research has also been extended to other populations considered to be at-risk drivers such as adults with attention deficit-hyperactivity disorder (ADHD). Individuals with ADHD are also characterized by heightened impulsivity (Weafer et al., 2008). Laboratory studies using cued go/no-go models have examined inhibitory control in adults with ADHD (Weafer et al., 2011; Roberts et al., 2011). Results have shown an increase in sensitivity to the disrupting effects of alcohol on inhibitory control evidenced by an increase in the proportion failures to inhibit responses to go cues that preceded no-

go targets. Results also indicated that, compared to control drivers with no history of ADHD, drivers with ADHD displayed poorer overall driving performance under alcohol. Taken together, these findings indicate that individuals with traits of impulsivity show deficits of inhibitory mechanisms under alcohol, and these deficits likely contribute to increased impairments in driving performance under the drug.

The relationship between impulsivity and driving behaviors might be especially relevant to driving in situations of response conflict (Fillmore et al., 2008). Response conflict refers to the simultaneous occurrence of any two competing response tendencies, such as approach and avoidance (Kanfer & Karoly, 1972). In the case of driving, opposing tendencies can be simultaneously activated when drivers are rewarded and punished for displaying a specific driving behavior, such as speeding. There may be a strong instigation to speed in order to arrive at a destination on time. Conflicting with this tendency is the incentive to avoid speeding and risky driving behaviors as these behaviors could result in traffic citations or personal injury. Drivers with high levels of impulsivity might be more likely to display reckless driving under such conflict as they would respond to the potential rewards for speeding while failing to consider the potential negative consequences that would otherwise temper the impulse to speed.

Response conflict can also heighten reactions to alcohol. Studies show that the disinhibiting effects of alcohol can be exacerbated by response conflict (Conger, 1956; Curtain & Fairchild, 2003; Fillmore & Vogel-Sprott, 2000). With respect to driving, alcohol might be most likely to produce reckless driving behavior when the driver is operating the vehicle in a situation of response conflict. Indeed, we have shown in the laboratory that the impairing effects of alcohol on simulated driving performance are

increased in situations of response conflict where speeding resulted in monetary rewards but also led to conflicting monetary losses (Fillmore et al., 2008).

Taken together, these findings implicate impulsivity as a risk factor for risky/reckless driving, and possibly greater disruptive effects of alcohol on driving performance. Given that such impulsive tendencies are commonly ascribed to DUI offenders, it is likely these individuals would engage in risky driving behaviors in driving simulations in the laboratory. Moreover, such impulsivity among DUI offenders could increase their sensitivity to the disruptive effects of alcohol on driving performance, especially in situations of response conflict. However, the application of these techniques to DUI offenders has not been systematically examined in a laboratory setting.

Perceived intoxication and decisions to drive

Another important variable to consider when examining the relationship between impulsivity and driving behavior are factors that contribute to decisions to drive after drinking. Decisions to drive after drinking are based on both environmental factors and interoceptive cues within the individual. One important cue that has been examined in research studies throughout the years is perceived intoxication (Beirness, 1987). Self-evaluations of intoxication are made based on subjective and behavioral changes after drinking such as sedation and slurred speech and these evaluations are what the drinker may base important decisions on such as their willingness and ability to drive a vehicle (Marczinski and Fillmore, 2009). In the laboratory, self-reported levels of subjective intoxication are often measured using rating scales (e.g., 100 mm visual analogue). In completing these scales, participants place a tick mark along the continuum that includes anchors of “none at all” to “very much”. The overarching design of existing studies

requires participants to evaluate their intoxication following acute doses of alcohol using Likert-type rating scales. Overall, research has shown that people are often inaccurate at estimating levels of intoxication. Early studies required participants to estimate BACs at different time points and found that participants often underestimated their BAC (Oguzursoff and Vogel-Sprott, 1976). A study conducted by Beirness (1987) assessed intoxication by asking participants to evaluate their perceived ability to drive a vehicle following alcohol. Results indicated that perceived ability to drive legally (i.e., below 80 mg/100 ml) became less accurate as BAC increased in response to a dose of alcohol. Other laboratory studies have shown that participants often underestimate their BAC and amounts of alcohol consumed (Marczinski et al., 2007).

With regard to populations characterized by impulsivity, there is some evidence of increased self-reported willingness and ability to drive following a dose of alcohol. Indeed, a study from our laboratory found that not only were adults with ADHD significantly more impaired than healthy controls on measures of simulated driving performance, but they also self-reported a greater perceived ability to drive on Likert-type rating scales (Weafer et al., 2008). Thus, the results of the study suggest that an increased self-appraisal of one's driving ability under alcohol is important because it could contribute to the decision to drive after drinking. In terms of DUI offenders, our laboratory has shown that DUI offenders with only one previous arrest for DUI rated themselves as more willing and able to drive a motor vehicle across the declining limb of the BAC curve, despite no differences in perceived intoxication or BAC estimation (Van Dyke and Fillmore, 2014). Importantly, these findings lend support to the idea that drivers may inaccurately assess their level of intoxication and driving fitness and

therefore decide to drive after drinking despite being legally impaired. Such appraisals of ability while intoxicated appear to be poor indicators of observed ability to drive and are also important because an overestimation of driving skill could factor into the decision to drive after drinking.

Gaps in our knowledge

To date, the systematic examination of specific behavioral mechanisms of impulsivity, and assessment of risk-taking behaviors while driving have never been applied to the DUI offender to determine how impaired mechanisms of behavioral impulsivity or inaccurate self-appraisals of intoxication could affect decisions to drive and driving performance. In fact, rarely have DUI offenders been studied in a laboratory setting. Research continuously links the DUI offender to self-reported characteristics of impulsivity, but the extent to which DUI drivers (especially recidivist offenders) display deficits in inhibitory control or show impulsive responding is unknown. We also do not know if the DUI driver might be more sensitive to the disinhibiting effects of alcohol in that they might display increased disinhibition and poorer driving skill and/or greater risk-taking in response to acute doses of the drug. Thus, no information exists on how DUI offenders might display reckless driving behavior and how this behavior may be exacerbated high-risk situations.

Similarly, little research has examined self-reported intoxication levels in DUI offenders. It will be important to understand how DUI drivers appraise their driving fitness (e.g., willingness and ability) and perceived levels of intoxication. Studies of ADHD drivers (e.g., Weafer et al., 2011) suggest that those characterized by heightened impulsivity might over-estimate their driving performance, particularly in the intoxicated

state. It may be likely that DUI offenders also self-report less subjective intoxication and perceived impairment leading them to more readily drive under the influence of alcohol compared to individuals without a DUI offense. Understanding these subjective evaluations and potential differences between DUI offenders and controls could help us understand differences in factors that lead to decisions to drive following a drinking episode. Moreover, the possibility that self-evaluations of driving fitness and subjective intoxication are related to aspects of behavioral impulsivity or simulated driving performance and driver risk-taking is unknown.

Current study

The current study sought to understand how DUI offenders respond to a moderate dose of alcohol (target BAC = 0.08%) by determining how specific behavioral mechanisms of impulsivity and subjective evaluations of driving fitness are altered by the drug in a manner that could promote risk for DUI and risky driving behaviors once behind the wheel. Much of the only information known about how DUI offenders in a laboratory setting comes from previous work conducted in our laboratory (i.e., Van Dyke and Fillmore, 2014; Miller and Fillmore, 2015; Roberts and Fillmore, 2016). These studies have indicated DUI offenders do differ from non-offenders in aspects of impulsivity and other cognitive factors, suggesting they are at an increased risk for poor decision-making processes and maladaptive behaviors under the influence of alcohol. The current research aimed to extend upon previous findings by applying new methodologies with an increased emphasis on behavioral impulsivity and risky driving behaviors. A sample of DUI offenders was compared to a sample of non-offending control drivers. Each group was tested in two driving scenarios in response to a 0.65 g/kg

dose of alcohol and a placebo. Participants completed two tests of behavioral impulsivity (i.e., TCIP; cued go/no-go) to evaluate baseline behavioral impulsivity and the impairing effect of alcohol on these important mechanisms which are thought to contribute to decisions to drive after drinking. In addition, participants completed two distinct driving scenarios aimed to provide a wide spectrum of important driving behaviors, and those that might be degraded by alcohol. The first scenario emphasized driving precision and vigilance where drivers were tasked with navigating winding, rural roads while maintaining a speed limit and proper lane control. The second scenario emphasized risk-taking where drivers earned monetary rewards for weaving around traffic in order to finish the drive in the shortest time, and incurred monetary losses for crashing into other vehicles or off the road. In addition, similar to previous work in this area (i.e., Van Dyke and Fillmore, 2014), participants also rated their willingness and ability to drive, subjective intoxication, stimulation and sedation, and provide BAC estimations at regular intervals across the declining limb of the BAC curve, when decisions to drive are typically made.

Hypotheses

Research continually links the DUI offender to self-reported levels of impulsivity (e.g., Chalmers et al., 1993). Therefore, it was hypothesized that, compared with non-offenders, DUI offenders will perform more poorly on the behavioral tests of impulsivity, evidenced by impulsive responding and increased disinhibition, both sober and in response to alcohol. However, it was expected that the greatest group differences might be seen in levels of impulsive responding, as this facet of impulsivity might be closest to the drinking and driving behavior seen in DUI offenders. With regard to simulated

driving performance and risk-taking while driving, research has also shown that DUI offenders commit more moving traffic violations and receive more traffic citations (e.g., Lajunen, 2001). Thus, it was hypothesized that, compared with non-offenders, DUI offenders will display poorer driving skills on multiple measures of driving performance (e.g., lane position, steering rate, line crossings) and exhibit greater risk-taking behaviors (e.g., decreased time to collision) while sober and in response to alcohol.

With regard to self-perceptions of impairment and decisions to drive under alcohol, DUI offenders might also differ from control drivers. Previous research from preliminary studies and studies examining other at-risk populations (i.e., adults with ADHD) found increased levels self-reported driving ability and less perceived intoxication among first-time DUI offenders (Van Dyke and Fillmore, 2014) and adults with ADHD (Weafer et al., 2011). Therefore, it was hypothesized that DUI offenders will self-report an increased driving fitness (i.e., ability and willingness) and less subjective intoxication and BAC estimation throughout the declining limb of the BAC curve, when decisions to drive are often made. Similarly, it was hypothesized that DUI offenders will report the highest levels of driving fitness, higher levels of stimulation, lower levels of sedation, and report the lowest levels of subjective intoxication and BAC estimation while intoxicated, compared with control drivers. Lastly, it was predicted that increased impulsive responding under alcohol will predict risky driving behaviors in DUI offenders, but not in control drivers.

Methods

Recruitment and screening

Forty adults between the ages of 21 and 34 participated in the study. Volunteers consisted of 20 DUI offenders and 20 controls with no prior DUI arrests. Each group was comprised of 15 male and 5 female subjects. This ratio was chosen based on recent estimates indicating the ratio of male to female DUI offenders is 3:1 in the United States (e.g., U.S. DOT, 2015). Online postings and fliers placed around the greater Lexington community advertised for the recruitment of individuals for studies on the effects of alcohol on behavioral and mental performance. Some of the advertisements directly targeted individuals arrested for DUI. All DUI offenders were required to have at least one alcohol-related DUI conviction in the past five years, whereas control subjects had no prior DUI convictions or license revocations. All DUI convictions were verified by State District Court Record Reporting Systems (e.g., Courtnet[®]). Interested individuals called the laboratory and completed a telephone screening during which information on demographics, drinking habits, drug use, and physical and mental health was gathered. Individuals reporting history of psychiatric disorder, CNS injury, or head trauma were excluded from participation. All volunteers were current consumers of alcohol, but individuals were excluded if their current alcohol use met criteria for a severe alcohol use disorder on the *Structured Clinical Interview for DSM-V (SCID-V)*. Individuals consuming fewer than two standard drinks per month were also excluded from participation. All volunteers were required to have held a valid driver's license for at least the past three years and drive on a weekly basis. The use of any psychoactive prescription medication and recent use of amphetamines (including methylphenidate), barbiturates,

benzodiazepines, cocaine, opiates, and tetrahydrocannabinol (THC) was assessed by means of urine analysis. Any volunteer testing positive for the presence of any of these drugs (except THC) during the sessions was excluded from participation. In the event a participant tested positive for THC, the participants were asked to self-report the last time of marijuana use. If the time of last use was greater than 24 hours prior to the session, the session continued as normal. If participants reported using marijuana in the past 24 hours, attempts were made to reschedule the session to a later date. No female volunteers who were pregnant or breast-feeding participated in the research, as determined by self-report and urine human chorionic gonadotrophin levels. The University of Kentucky Medical Institutional Review Board approved the study. All study volunteers provided informed consent prior to participation and received a base payment of \$115 (before task-specific monetary bonuses) for their participation.

Apparatus and materials

Measures of drinking/driving experience and alcohol-related risk

Driving History and Experience Questionnaire – DHEQ (Harrison & Fillmore, 2005). This self-report questionnaire gathered information on driving history and behaviors. The questionnaire included measures of driving experience such as length of time holding a driver's license and number of days and miles driven per week. The questionnaire also gathered information about participants' driving behaviors, such as license revocations, presence and number of DUI citations and punishments, traffic accidents, traffic tickets, typical driving environment (rural, urban, and interstate), and the type of vehicle transmission (manual, automatic, or both).

Drinking and driving questionnaire (McCarthy, Niculete, Treloar, Morris, & Bartholow, 2012). This self-report questionnaire gathered information on drinking and driving history. Included in the questionnaire are measures of frequency of drinking and driving, quantity of alcohol consumed before driving, and the most alcohol ever consumed before driving. The questionnaire also asks participants how many times in the past year they have driven following 1, 3, and 5 drinks in a 2-hour period. Lastly, the questionnaire asked individuals to report on the probability of getting caught drinking and driving on a 5-point Likert scale ranging from “extremely low” to “extremely high”.

Measures used to screen for alcohol abuse

Drug Abuse Screening Test – DAST (Skinner, 1982). This 28-item self-report questionnaire was used to screen for drug abuse problems. Participants were asked to respond yes/no to each statement (e.g., “Do you try to limit your drug use to certain situations?”). Total scores provided a measure of problems related to drug use. A score of six or more has been suggested as indicative of a drug use disorder (Skinner, 1982).

Short Michigan Alcohol Screening Test – S-MAST (Selzer et al., 1975). This 13-item self-report questionnaire was used as a screen for alcohol dependence. The questionnaire included items such as “Have you ever gotten into trouble at work because of drinking?” and participants were instructed to respond yes/no to each item.

Alcohol Use Disorder Identification Test – AUDIT (Babor et al., 1989). This 10-item self-report questionnaire was used as a further screen for traditional alcohol dependence symptoms and consequences of harmful drinking. For the majority of the questions (e.g., “How often during the last year have you had a feeling of guilt or remorse after drinking?”) participants responded on a 5-point Likert scale ranging from never to

daily or almost daily. The questionnaire also measured quantity and frequency of drinking with anchors of 1 or 2 drinks to 10 or more drinks and never to 4 or more times a week, respectively. Lastly, participants responded to questions regarding injury while drinking and concern from family members on a 3-point Likert scale ranging from no to yes, and during the last year (Babor et al., 1992). Higher total scores indicated greater problems with alcohol. Use of the AUDIT has been well-validated for use in a variety of populations such as college students and drug users (Fleming et al., 1991; Skipsey et al., 1997).

Measures of self-reported drinking habits

Timeline Follow-back (TLFB; Sobell and Sobell, 1992). The TLFB assessed daily patterns of alcohol consumption over the past 3 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 3 months were measured including the total number of drinking days, total number of drinks consumed, number of binge drinking episodes, defined by a drinking day in which the participant drank to or in excess of a 0.08% BrAC, and the number of self-reported drunk days. Participants also indicated days in which they drove a motor vehicle following consumption of any amount of alcohol.

Self-report measures associated with alcohol-related problems

It is well-known that DUI offenders self-report increased levels of impulsivity (e.g. Chalmers et al., 1993). More recent research has indicated that DUI offenders might endorse different motives for drinking than non-offenders (Miller and Fillmore, 2015). That study also indicated that DUI offenders reported greater temptations with alcohol as

measured by the CEP scale of the TRI. As such, the following questionnaires were included in the current study to assess risk for alcohol-related problems.

Drinking Motives Questionnaire – DMQ-R (Cooper, 1994). This 20-item self-report questionnaire assessed individuals' motives to drink alcohol. Participants were asked to evaluate, of all their previous drinking episodes, how often they drank for each of the 20 statements (e.g., "To forget your worries") on a 5-point Likert scale ranging from almost never/never to almost always/always. Responses were categorized into one of four factors (i.e., social, coping, enhancement, and conformity) with higher scores indicating greater motives for each subscale. Drinking to experience positive social reward and drinking to relieve negative affect are characteristic of the social and coping subscales, respectively. Enhancement is defined as drinking to experience positive mood, while conformity can be defined as drinking to avoid social costs, such as teasing from a peer group (Cooper, 1994). The questionnaire has established predictive and discriminant validity in adult samples (Cooper et al., 1988; Cutter & O'Farrel, 1984). This questionnaire was included to determine if motivations to drink differed between DUI offenders and controls.

Temptation and Restraint Inventory – TRI (Collins & Lapp, 1992). This 15-item self-report questionnaire quantitatively measured drinking restraint by assessing an individual's temptations with alcohol and their ability to restrain from drinking (Collins and Lapp, 1992). Participants responded to each statement (e.g., "Do thoughts about drinking intrude into your daily activities?") on a 9-point Likert scale ranging from none to a great deal. Responses were categorized into two factors related to restraint. The cognitive and behavioral control (CBC) factor represents restriction or

successful/inhibitory regulation of drinking behavior. The cognitive and emotional preoccupation (CEP) factor represents temptation or unsuccessful/disinhibited regulation of drinking behavior (Collins and Lapp, 1992). The TRI has successfully predicted weekly alcohol consumption in moderate adult drinkers (Collins and Lapp, 1992; Collins et al., 2000) and may more effectively predict problems with alcohol than alcohol expectancies (Connor et al., 2000). The questionnaire was used to determine if DUI offenders and controls differ in terms of thoughts and behaviors associated with alcohol use.

Barratt Impulsiveness Scale – BIS-11 (Patton et al., 1995). This 30-item self-report questionnaire was 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).

Two-choice impulsivity paradigm. A two-choice impulsivity paradigm (TCIP; Dougherty et al., 1999) was used to assess participants’ ability to delay responding for immediate rewards in favor of delayed rewards. Participants responded to one of two images (i.e., circle or square) on a computer screen by clicking on the image of their choice using the computer’s mouse. The circle was associated with a short time delay (i.e., 5 seconds) and the square was paired with the long time delay (i.e., 15 seconds). After making a response, participants experienced the respective time delay in real time

before preceding to the next trial. After the delay, the reward (i.e., \$0.05 or \$0.15) appeared on the screen and was added to the participant's "bank", which kept a running total of task earnings and was visible on the computer screen at all times during the task. Impulsive choices were indicated by a greater number of responses to the short-delay reward compared with the long-delay reward. The measure of interest was the proportion of total responses to the short-delay reward (i.e., impulsive responding) relative to the long-delay reward (i.e., non-impulsive responding) across 50 test trials. The TCIP required approximately 12 minutes to complete.

Cued go/no-go task. A cued go/no-go reaction time task was used to measure participants' response inhibition to no-go targets and their reaction time to go targets (e.g., Fillmore and Weafer, 2004). The task required finger presses on a keyboard, and measured the ability to inhibit prepotent behavioral response of executing a key press. Cues provided preliminary information regarding the type of target stimulus (i.e., go or no-go) that was likely to follow, and the cues had a high probability of signaling the correct target. Participants were instructed to press the forward slash (/) key on the keyboard as soon as a go (green) target appeared and to suppress the response when a no-go (blue) target was presented. The go cue conditions were of particular interest. Go cues generate response prepotency which speeds response time to go targets. However, subjects must overcome this response prepotency to inhibit the response if a no-go target is subsequently displayed. Response inhibition was measured by the proportion of no-go targets in which subjects failed to inhibit a response (p-inhibition failures) during the test. Poor inhibitory control was indicated by a higher proportion of inhibition failures (i.e., greater p-inhibition failure score). A test required approximately 15 minutes to complete.

Simulated driving task (STISIM Drive, Systems Technology Inc., Hawthorne, CA). A computerized driving simulator was used to measure driving performance. In a small room, participants sat in front of a 19-inch computer display which presented the driving simulation at a 60-degree horizontal field of view. The simulation placed the participant in the driver seat of the vehicle which was controlled by steering wheel movements and manipulations of the accelerator and brake pedals. At all times, the participant had full view of the road surroundings and instrument panel, which included an analog speedometer. Buildings, animals, and trees in addition to other cars, which required no passing or slowing on the part of the participant, were present in each drive scenario. 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. The program provides several output measurements of driving performance (i.e., the standard deviation of lane position, steering rate, line crossings, and average speed).

Skill-based drive test. This 15-minute simulated driving course consisted of 80,000 feet or approximately 15 miles conducted on a rural, two-lane highway with overcast skies, with few buildings designed to mimic what a driver might encounter driving through the rural countryside. Drivers were instructed to accelerate to and adhere to the 55-mph speed limit while remaining in the center of the driven lane for the entire duration of the drive. The drive scenario included both straight and winding roads, requiring vigilance on the part of the driver to maintain the center of the lane and the required speed throughout. The drive task has been successfully used in numerous previous studies in our laboratory (e.g., Harrison et al., 2007; Marczinski and Fillmore,

2009), including studies examining DUI offenders (e.g., Roberts and Fillmore, 2016; Van Dyke and Fillmore, 2014), and has shown to be sensitive to the impairing effects of alcohol.

The primary measure of driving skill on the skill-based drive test is the within-lane standard deviation of the driver's vehicle (i.e., SDLP). This variable is determined by the standard deviation of the driver's mean vehicular position within the lane, measured in feet. 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 SDLP score for a test was obtained by averaging deviation measures sampled at each foot of the driving test. The drive test also provided measures of average drive speed (mph), steering rate, lane exceedances, and accident frequency.

Risk-based drive test. This simulated driving scenario was designed to test risky driving behavior and required participants to drive 21,100 feet on a busy 4-lane road in a metropolitan setting. There was no posted speed limit. Each direction of traffic is comprised of two lanes. The driver was free to navigate among other vehicles traveling in the same direction as their vehicle (i.e., two lanes of traffic). Other vehicles were presented at various speeds and intervals in both lanes such that the driver had to change lanes to overtake vehicles to maintain speed. To instigate the potential for risk-taking, drivers earned monetary reinforcement for quickly completing the drive test: \$5 for completion in 3-4 min, \$4 for 4-5 min, \$3 for 5-6 min, \$2 for 6-7 min, \$1 for 7-8 min, and \$0.50 for over 8 min. Drivers were penalized \$0.50 for each crash. This response conflict scenario was designed to mimic everyday driving behaviors in which drivers are

rewarded by arriving at their destination on time at the cost of potential traffic citations (e.g., speeding), and has been successfully used in other research in our laboratory (e.g., Fillmore et al., 2008; Laude and Fillmore, 2015; Van Dyke and Fillmore, 2014).

The primary measure of driver risk-taking is time-to-collision (TTC). This is a time-related safety margin measure (Taieb-Maimon and Shinar, 2001), determined by the bumper-to-bumper distance between two vehicles, divided by the closing speed of the vehicles (Zhang and Kaber, 2013). As such, it is thought to have utility as an index of driver risk-taking. TTC is operationally defined as the time that remains until collision occurs if both the lead and the driven vehicle continue on the same course (Zhang et al., 2006). A single TTC score for each participant was obtained by averaging the TTC value of the five riskiest instances in which a driven car approaches a lead car throughout the drive, sampled at each foot of the driving test. This value was chosen to provide a range of risk-taking behavior rather than a single risky instance, which may be equal to zero in the event of a vehicle crash. Riskier driving was indicated by smaller TTC values (in seconds). The drive test provided measures of other variables including average drive speed (mph) and accident frequency.

Perceived driver fitness scale. Participants self-evaluated their driving fitness (i.e., willingness and ability to drive a motor vehicle), perceived level of intoxication, and subjective stimulation and sedation on 100 mm visual-analogue scales ranging from 0 “not at all” to 100 “very much.” Participants were also tasked with estimating their current BAC on a scale ranging from 0 to 160 mg/100 ml with a provided midpoint of the current legal driving limit (i.e., 80 mg/100 ml). Peak levels of each criterion variable were assessed by determining the highest reported value of each variable for each

participant, among several administrations of the perceived driver fitness scale. These scales have been used in other alcohol studies of driving and are sensitive to the effects of the drug (e.g., Harrison and Fillmore, 2005; Harrison, Marczinski & Fillmore, 2007; Van Dyke and Fillmore, 2015).

Procedure

Qualifying participants attended three sessions, an initial familiarization session followed by two dose sessions. The sessions were separated by a minimum of 24 hours and all of the sessions were completed within two weeks from the first day of participation.

Pre-checks

Testing occurred in the Human Behavioral Pharmacology Laboratory in the University of Kentucky's Department of Psychology. All testing started between the hours of 10:00 a.m. and 6:00 p.m. Participants were instructed to fast for 4 hours and abstain from alcohol and other mind-altering substances for at least 24 hours prior to each session. At the start of each session, a breath sample was collected to verify a zero BrAC (Intoxilyzer, Model 400, CMI Inc., Owensboro, KY). Upon arrival to each dose session, urine samples were collected to test for the presence of drug metabolites (amphetamine, barbiturates, benzodiazepines, cocaine, opiates, and tetrahydrocannabinol) in all participants (On Trak TesTsticks, Roche Diagnostics Corporation, Indianapolis, IN). All females were tested for pregnancy by urine analysis (Mainline Confirms HGL, Mainline Technology, Ann Arbor, MI).

Familiarization session

During the familiarization session, participants became acquainted with laboratory procedures and background information (i.e., questionnaires) on each participant was gathered. During this session participants also completed practice versions of the TCIP, cued go/no-go task, and each driving scenario.

Dose sessions

Drivers were tested under 0.65 g/kg alcohol and a placebo on separate days and the dose order was counterbalanced across subjects. The 0.65 g/kg alcohol dose was expected to produce a peak BAC of 80 mg/100 ml approximately 70 minutes after administration, as is typical of this dosing procedure in our laboratory (e.g., Fillmore et al., 2008; Van Dyke and Fillmore 2014). Alcohol doses were calculated based on body weight and consisted of one part absolute alcohol to three parts carbonated mixer divided equally between two drinks in a single blind design. Placebo doses consisted of four parts carbonated mix in order to match the volume of the 0.65 g/kg dose. A small amount (i.e., 3 ml) of alcohol was floated on the surface of the placebo beverages and each glass sprayed with an alcohol mist to provide a strong alcohol scent as the drink was consumed. Research has shown that participants report this type of beverage administration contains alcohol (e.g., Fillmore & Vogel-Sprott, 1998). Participants were required to consume both beverages in six minutes during each dose session.

Testing began 20 minutes post-beverage consumption and each task was separated by a small (i.e., 5 min) rest interval (see Table 1 for timeline at end of current section). Timing and test order was identical across each dose session. To ensure comparable BrACs across participants during each task, task order was fixed for each

participant. At 20 minutes post-beverage, participants completed the skill-based drive test. The cued go/no-go task was completed 40 minutes post-beverage. At 60 minutes post beverage participants completed the risk-based drive test. At 70 minutes post-beverage, participants completed the TCIP. Thus, all testing was complete at approximately 85-90 min post-beverage consumption. Immediately afterwards, participants were moved to another room where they were allowed to relax at leisure within the laboratory. During this time, they were given a hot meal and allowed to watch a movie or television for the remainder of the session. The perceived driver fitness scale was first administered immediately following the risk-based drive test (i.e., 70 min post-beverage), TCIP (i.e., ~85 min post-beverage), and again every 45 minutes thereafter. Thus, this scale was administered a total of six times at 70 min, 85 min, 130 min, 175 min, 220 min, and 265 min from the onset of drinking. BrAC samples were gathered immediately prior to the onset of testing, at the completion of each task, and across the declining limb to coincide with each administration of the perceived driver fitness scale. Thus, the timing of BrAC samples was 20 min, 40 min, 60 min, 70 min, 85 min, 130 min, 175 min, 220 min, and 265 min. At 265 min from the onset of drinking, most participants were below the 20 mg/100 ml release criteria and were allowed to leave. If not, participants remained in the lab until their BrAC fell below 20 mg/100 ml. Upon completion of the final session, participants were paid and debriefed. Transportation home by taxi was provided after the sessions.

Table 1. Dose session task timeline

Behavioral task timeline of dose sessions (onset of testing)

Skill-based drive test	20 min.
Cued go/no-go task	40 min.
Risky drive test	60 min.
Two-choice impulsivity paradigm	70 min.

Proposed analyses

The general statistical approach for the behavioral tests (i.e., tests of impulsivity, driving tests) to examine group differences in behavior involved 2 group (DUI offenders vs. non-offenders) X 2 dose (0.0 g/kg vs. 0.65 g/kg) mixed-model analyses of variance (ANOVAs). Subjective evaluations (i.e., perceived driver fitness scale) were analyzed by 2 group (DUI offenders vs. non-offenders) X 6 time (70, 90, 135, 180, 225, 270 min) mixed-model analyses of variance (ANOVAs). In each case, omnibus ANOVAs looked for main effects of group and/or dose and group by dose interactions. In addition, two-sample t tests compared maximum levels of each perceived driver fitness scale criterion variable. A limited number of planned comparison t tests were conducted to examine group differences in demographics and background characteristics. Lastly, exploratory correlational analyses examined relationships between behavioral tests of impulsivity, simulated driving performance, and key demographic variables (e.g., drinking habits and trait impulsivity).

Results

Demographics, driving history, recent drinking habits, and drug use

Table 2 lists the demographic and other background characteristics of drivers in the DUI and control groups. The racial makeup of the DUI group was 90% Caucasian and 10% African-American. In the control group, 85% of the participants self-reported Caucasian and reported 15% African-American. Driving experience was determined based on years of licensed driving, number of driving days per week, total weekly miles driven, number of traffic tickets, and number of vehicle crashes in which the participant was the driver of the vehicle. Comparisons between DUI and control drivers using post-hoc, two-sample t tests showed no group differences on any measure of driving experience ($ps > .24$; $ds: .18 - .38$). The means for each group in terms of driving experience are reported in Table 2.

Table 2. Demographics and driving history

	Controls		DUI Offenders		<i>t</i>	<i>p</i>
	M	(SD)	M	(SD)		
Age	24.20	(3.56)	25.75	(4.28)	1.25	0.22
Time Since DUI	0	0	21.00	(13.01)	-	-
Drive years	8.30	(3.63)	9.04	(4.55)	0.57	0.57
Drive freq.	5.29	(1.77)	5.81	(2.07)	0.86	0.40
Drive distance	26.57	(41.71)	17.71	(13.30)	0.90	0.37
Traffic tickets	1.25	(1.73)	1.71	(1.58)	0.87	0.39
Crashes	1.13	(2.02)	1.84	(1.72)	1.20	0.24

Table 2. Comparison of DUI offenders to controls on background characteristics. Age = years; Time since DUI = number of months since most recent DUI; Drive years = total years of licensed driving; Drive freq. = number of driving days per week; Drive distance = miles driven per day; Traffic tickets = total number of traffic citations; Crashes = total number of vehicle crashes in which the participant was the driver of the vehicle.

Table 3 reports the means for each group in terms of drinking history and other questionnaires assessing risky alcohol and other drug use (i.e., S-MAST, AUDIT, and

DAST). With regard to drinking habits assessed by the TLFB, DUI offenders consumed a greater number of drinks than controls, $t(38) = 2.99, p = .005, d = .95$. DUI offenders also reported a greater number of binge drinking episodes, $t(38) = 2.49, p = .017, d = .79$, and a greater number of self-reported drunk days, $t(38) = 2.79, p = .008, d = .88$. There was no difference between DUI offenders and controls on the total number of drinking days, $t(38) = 0.81, p = .43, d = .25$.

In terms of other drug use, 10 participants in the DUI group ($M = 12.1$ days, $SD = 3.77$) and four control participants ($M = 5.25$ days, $SD = 8.45$) reported using cannabis in the past month. Eight participants in the DUI group and three participants in the control group tested positive for THC at testing. However, all participants self-reported not using cannabis for at least 24 hours prior to the study sessions. No other drug use was reported in the past month. In terms of problems associated with the use of alcohol and other drugs, DUI offenders reported higher S-MAST scores compared to control participants, $t(38) = 3.95, p < .001, d = 1.25$. DUI offenders also scored higher on the AUDIT, $t(38) = 2.88, p = .01, d = .91$. With regard to DAST scores, while the groups were not statistically different, DUI offenders were trending toward higher DAST scores, $t(38) = 1.93, p = .06, d = .61$.

Table 3. Drinking history and other drug use questionnaires

	Controls		DUI Offenders		<i>t</i>	<i>p</i>
	M	(SD)	M	(SD)		
Total drinks	92.99	(48.34)	178.26	(118.08)	2.99	.005*
Total days	24.48	(12.96)	27.95	(14.31)	0.81	0.43
Binge days	6.41	(7.13)	13.37	(10.25)	2.49	0.02*
Drunk days	7.99	(6.78)	14.56	(8.06)	2.78	.008*
S-MAST	0.70	(1.34)	7.10	(7.12)	3.95	<.001*
AUDIT	7.10	(3.11)	10.55	(4.36)	2.88	.006*
DAST	1.60	(1.64)	3.70	(4.59)	1.93	0.06

Table 3. Total drinks = TLFB total drinks consumed in the past 3 months; Total days = TLFB total drinking days in the past 3 months; Binge days = days in which BAC exceeded 80 mg/100 ml on TLFB; Drunk days = TLFB self-reported drunk days; S-MAST = total score; AUDIT = total score; DAST = total score. * denotes significant group difference at $p < .05$.

Drinking and driving history

Drinking and driving behaviors were assessed via self-report questionnaires. DUI offenders reported a greater number of lifetime drinking and driving episodes than controls, $t(38) = 2.17, p = .04, d = .61$. On the TLFB, DUI offenders and controls did not differ on the number of days in which they reported driving after consuming alcohol, $t(38) = 1.03, p = .31, d = .33$, or the number of days in which participants reported drinking and driving on binge drinking days, $t(38) = 0.65, p = .52, d = .21$. The groups also did not differ on self-reported driving in the past year following one, three, or five drinks in a two-hour period (all $ps > 0.18$; $ds: .10 - .41$). In addition, the groups did not differ in terms of their assessment of the probability of being caught drinking and driving, $t(38) = 1.46, p = .15, d = .46$. The means for each group are reported in Table 4.

Table 4. Drinking and driving history

	Controls		DUI Offenders		<i>t</i>	<i>p</i>
	M	(SD)	M	(SD)		
TLFB						
Drink drive	5.80	(7.05)	3.62	(6.34)	1.03	0.31
DD binge	0.50	(1.35)	0.28	(0.63)	0.65	0.52
Lifetime freq.	1.68	(0.90)	2.24	(0.93)	2.17	0.04*
Past Year						
1 drink	20.15	(44.68)	6.75	(13.86)	1.28	0.21
3 drinks	8.35	(22.78)	4.35	(7.32)	0.75	0.46
5 drinks	0.90	(1.68)	1.10	(2.29)	0.32	0.76
Prob. caught	3.35	(1.09)	2.75	(1.48)	1.46	0.15

Table 4. Drink drive = number of drinking days on the TLFB in which participants also drove a vehicle after consuming alcohol; DD binge = number of binge drinking days on the TLFB in which participants drove a vehicle after consuming alcohol; Lifetime freq. = 4-point Likert scale assessing lifetime drinking and driving frequency with higher numbers indicating greater frequency; Past year = how many times in the past year participants drove after having 1, 3, or 5 drinks in the past 2 hours; Prob. caught = 5-point Likert scale assessing probability of being caught with higher numbers indicating greater probability. * denotes significant group difference at $p < .05$.

Drinking motives

Table 5 lists the group means on participants' motivation to drink as measured by the DMQ. DUI participants reported significantly fewer social, $t(38) = 2.90, p = .006, d = .92$, and conformity, $t(38) = 3.33, p = .002, d = 1.05$, motivations for drinking than controls. There were no group differences on the coping or enhancement subscales (all $ps > .07$; $ds: .54 - .60$).

Table 5. Drinking motives questionnaire

	Controls		DUI Offenders		<i>t</i>	<i>p</i>
	M	(SD)	M	(SD)		
Social	11.33	(7.47)	5.76	(4.22)	2.90	.006*
Coping	5.99	(4.69)	3.71	(3.78)	1.69	0.10
Enhancement	8.91	(6.42)	5.38	(5.36)	1.89	0.07
Conformity	5.17	(3.74)	2.16	(1.53)	3.33	.002*

Table 5. Mean scores on the DMQ subscales. * denotes significant group difference at $p < .05$.

Temptation and restraint from alcohol

With regard to the cognitive preoccupations with alcohol and attempts to control drinking from the TRI, DUI offenders reported significantly greater attempts to control drinking behavior (CBC), $t(38) = 2.63$, $p = .012$, $d = .83$, and greater cognitive preoccupations with alcohol (CEP), $t(38) = 3.14$, $p = .003$, $d = .99$, than control participants. The means for each group are reported in Table 6.

Table 6. Temptation and restraint

	Controls		DUI Offenders		<i>t</i>	<i>p</i>
	M	(SD)	M	(SD)		
CBC	11.10	(6.28)	18.05	(10.01)	2.63	.012*
CEP	17.00	(6.24)	25.65	(10.63)	3.14	.003*

Table 6. Mean scores from the TRI subscales. CBC = cognitive and behavioral control; CEP = cognitive and emotional preoccupation.

Self-reported impulsivity

In terms of self-reported impulsivity, DUI offenders and controls did not differ on total impulsivity scores or any subscale, as measured by the BIS (all $ps > .30$; $ds: .06 - .32$). Table 7 lists the means for each group.

Table 7. Self-reported impulsivity

	Controls		DUI Offenders		<i>t</i>	<i>p</i>
	M	(SD)	M	(SD)		
BIS total	62.65	(9.10)	62.85	(6.83)	0.08	0.94
Attention	10.35	(2.30)	10.55	(2.26)	0.28	0.78
Motor	14.80	(2.84)	14.00	(2.20)	1.00	0.33
Self-control	11.80	(3.79)	12.00	(3.43)	0.18	0.86
Cognitive Comp.	10.50	(2.12)	10.85	(2.54)	0.47	0.64
Perseverance	8.55	(1.76)	9.10	(2.08)	0.91	0.37
Cognitive Instab.	6.65	(2.03)	6.35	(1.50)	0.53	0.60

Table 7. BIS total = Barratt Impulsiveness Scale (BIS-11) total score and mean scores from the BIS subscales.

Breath alcohol concentrations (BrACs)

BrACs under alcohol were examined by a 2 (Group) X 10 (Time) ANOVA. A main effect of time owing to the rise and fall of BrACs during the course of testing was found, $F(9, 342) = 177.76, p < .001, \eta_p^2 = 0.82$. As BrACs did not differ between DUI offenders and controls at any time point, Figure 1 plots the BrACs averaged across the entire sample. The figure reveals that BrACs increased through the ascending limb toward the peak and decreased steadily across the declining limb. No main effects ($p = .12; \eta_p^2 = .06$) or interactions involving group or time were found ($p = .26; \eta_p^2 = .03$). No detectable BrACs were observed in the placebo condition.

Figure 1. Breath alcohol concentrations

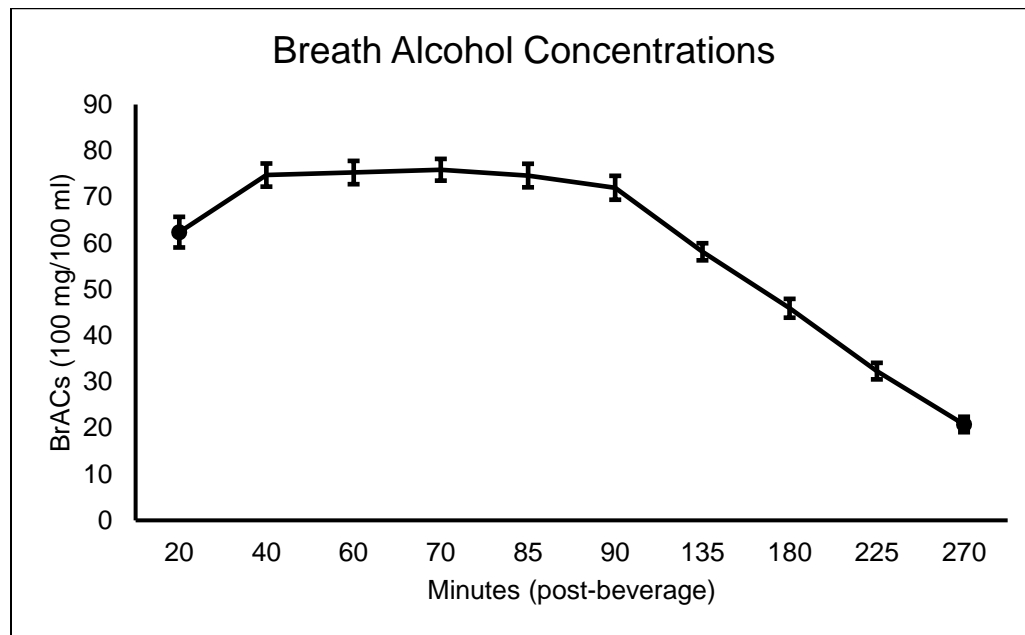


Figure 1. BrACs following 0.65 g/kg alcohol averaged across the entire sample. Error bars indicate standard error of the mean.

Two-choice Impulsivity Paradigm (TCIP)

A 2 (group; DUI vs. Control) X 2 (dose; 0.0 g/kg vs. 0.65 g/kg) mixed-design ANOVA examined participants' tendency toward impulsive choices, calculated by the percentage of trials in which participants chose the short-delay/reward relative to the total number of trials. The analysis revealed a significant group X dose interaction, $F(1, 38) = 4.53, p = .040, \eta_p^2 = .11$. No significant main effects of group, $F(1, 38) = 1.77, p = .191, \eta_p^2 = .04$, or dose, $F(1, 38) = 1.30, p = .261, \eta_p^2 = .03$, were found. These effects are plotted in Figure 2. The figure indicates that for control participants, impulsive choices were unaffected by alcohol as their preference for immediate rewards remained stable following placebo and alcohol. However, for DUI participants, the figure indicates that impulsive choices increased under alcohol, relative to placebo. Post-hoc two-sample t tests indicated that the group difference in impulsive choice under alcohol was marginally

significant, $t(38) = 1.97, p = .056, d = .62$. The group comparison under placebo was not significant, $t(38) = 0.19, p = .853, d = .06$.

Figure 2. Impulsive choices on the TCIP

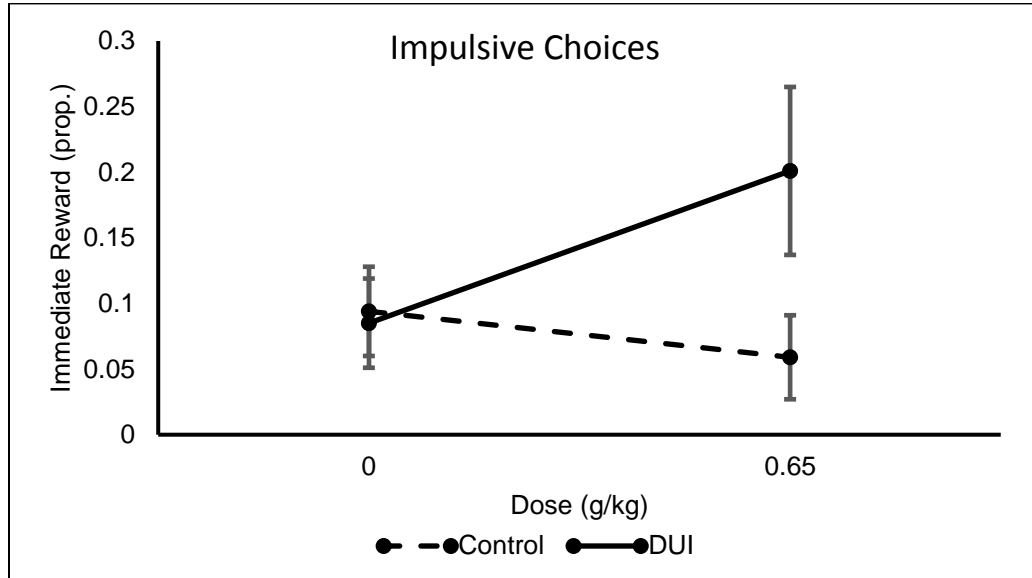


Figure 2. Impulsive responding under 0.65 g/kg alcohol and placebo for DUI and control participants. Impulsive choice scores calculated by the proportion of impulsive trials over the total number of trials. Higher values indicate a greater preference for impulsive choices. Error bars indicate standard error of the mean.

Cued go/no-go task

A 2 (group) X 2 (dose) mixed-design ANOVA of drivers' proportion of inhibitory failures on the cued go/no-go task revealed a significant main effect of dose, $F(1, 38) = 8.35, p = .006, \eta_p^2 = .18$. The left panel of Figure 3 plots the average proportion of 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 participants and controls. The figure also shows that control participants tended to make more inhibition failures overall compared with DUI participants. However, this difference was not significant as no main effect of group ($p = .33; \eta_p^2 = .02$) or interaction was found ($p = .95; \eta_p^2 = .00$). A 2 (group) X 2 (dose) ANOVA of

reaction time to go cues found no significant main effects of dose or group, or an interaction (all $ps > .24$; η_p^2 : .01 - .04). The right panel of Figure 3 plots the average reaction time to go cues for each group following placebo and alcohol.

Figure 3. Cued go/no-go task

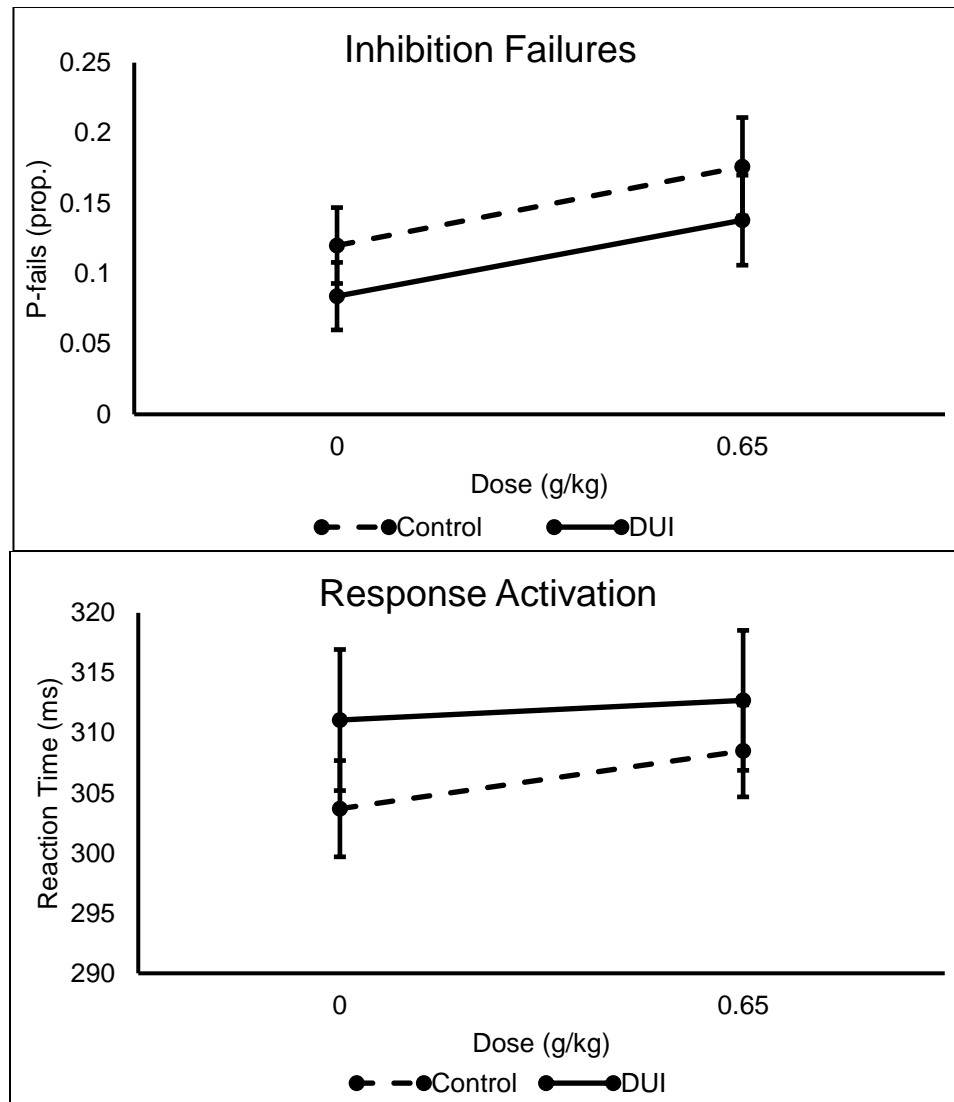


Figure 3. Top panel = mean number of inhibitory failures (p-inhibition failures) on the cued go/no-go task following placebo and 0.65 g/kg alcohol for DUI and control participants. Bottom panel = mean reaction time to go cues on the cued go/no-go task following placebo and 0.65 g/kg alcohol for DUI and control participants. Error bars indicate standard error of the mean.

Simulated driving performance

Skill drive test. Figure 4 plots each criterion measures of driving performance on the skill-based drive test for each group following placebo and alcohol. A 2 (group) X 2 (dose) mixed-design ANOVA of the standard deviation of vehicle lane position (SDLP) scores revealed a significant main effect of dose, $F(1, 38) = 6.85, p = .013, \eta_p^2 = .15$. The mean SDLP scores for each group following placebo and alcohol are shown in the top-left panel of Figure 4. The figure shows that, for both groups, SDLP increased following alcohol compared with placebo, indicating less driving precision under the drug. No significant main effect of group ($p = .73; \eta_p^2 = .003$) or interaction was found ($p = .47; \eta_p^2 = .014$). The top-right panel plots the mean number of lane exceedances, indicated by any instance in which the driver's vehicle crossed outside the boundary of their driven lane, for each group following placebo and alcohol. A 2 (group) X 2 (dose) mixed-design ANOVA found a significant main effect of dose, $F(1, 38) = 7.36, p = .010, \eta_p^2 = .16$. The figure shows an increase in the number of lane exceedances under alcohol compared with placebo for both groups. No main effect of group ($p = .93; \eta_p^2 = .00$) or interaction was found ($p = .47; \eta_p^2 = .01$). The bottom-left panel plots the mean number of traffic crashes in which the driver crashed into another vehicle on the road, or off the road. A 2 (group) X 2 (dose) mixed-design ANOVA revealed a significant main effect of dose, $F(1, 38) = 5.10, p = .030, \eta_p^2 = .12$. The figure indicates that, while traffic crashes were infrequent, the number of crashes increased under alcohol compared with placebo. No significant main effect of group ($p = .79; \eta_p^2 = .002$) or interaction ($p = .36; \eta_p^2 = .02$) was found. A 2 (group) X 2 (dose) mixed-design ANOVA of drive speed found no significant main effects or interaction ($ps > .32; \eta_p^2: .01 - .02$). In sum, alcohol impaired multiple skill-

based aspects of driving behavior. However, DUI drivers and controls did not differ in overall driving performance or in the degree to which alcohol impaired their performance.

Figure 4. Skill-based drive test

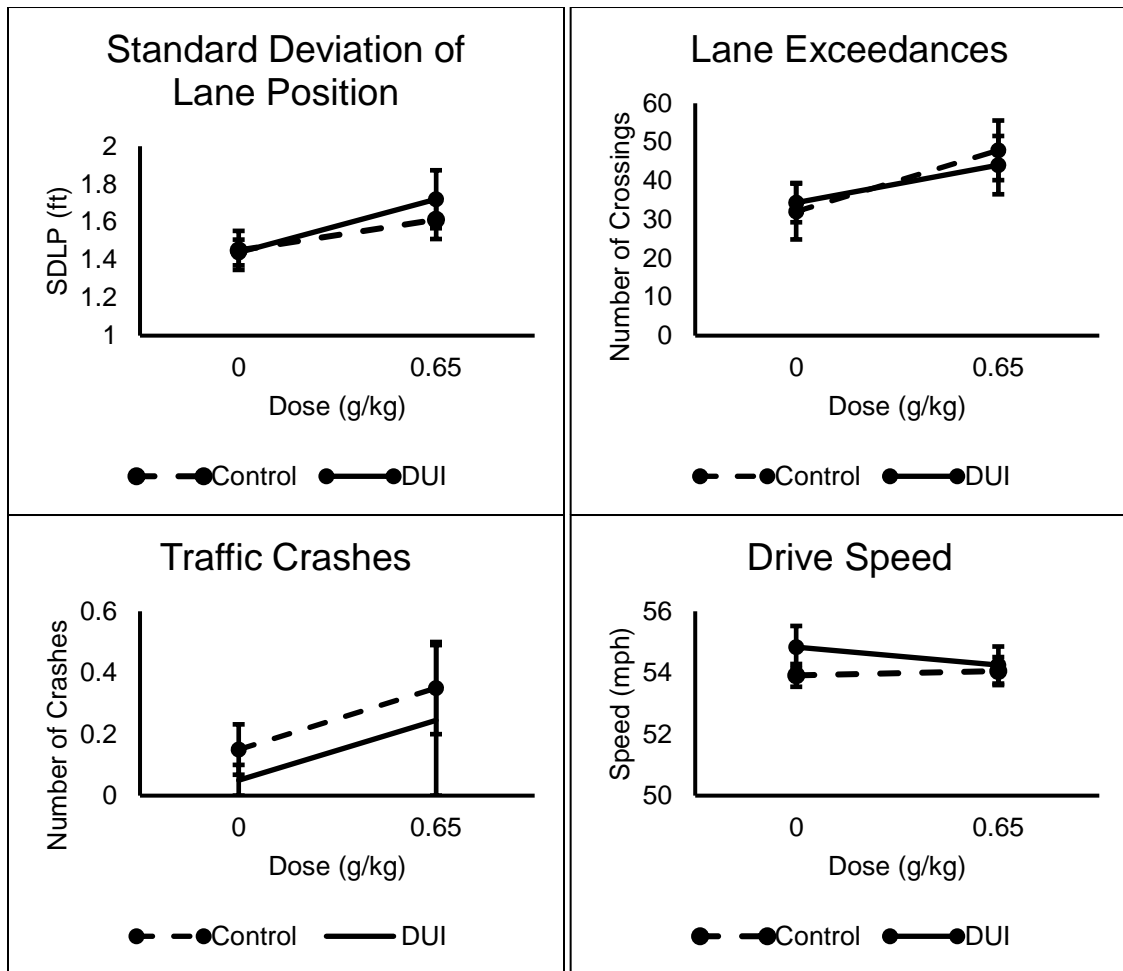


Figure 4. Top-left panel = standard deviation of the vehicle’s lane position following placebo and 0.65 g/kg alcohol for DUI and control drivers; Top-right panel = mean number of centerline and road edge crossings following placebo and 0.65 g/kg alcohol for DUI and control drivers; Bottom-left panel = mean number of vehicle crashes following placebo and 0.65 g/kg alcohol for DUI and control drivers; Bottom-right panel = mean drive speed following placebo and 0.65 g/kg alcohol for DUI and control drivers. Error bars indicate standard error of the mean.

Risky drive test

Figure 5 plots the mean time-to-collision (TTC) values under each dose. The figure indicates that alcohol increased risky driving by reducing drivers' TTC with both groups showing similar reductions in their TTC under alcohol compared with placebo. A 2 (group) X 2 (dose) mixed-design ANOVA of TTC values confirmed a significant main effect of dose on drivers' TTC, $F(1, 38) = 8.85, p = .005, \eta_p^2 = .18$, such that TTC decreased under alcohol, indicating riskier driving. No main effect of group ($p = .437; \eta_p^2 = .02$) or interaction ($p = .861; \eta_p^2 = .00$) was found.

With regard to the effect of alcohol on secondary risky driving outcome measures, 2 (group) X 2 (dose) mixed-design ANOVAs found a significant main effect of dose on drive speed, $F(1, 38) = 6.90, p = .012, \eta_p^2 = .15$, indicating faster drive speed under alcohol compared with placebo. However, no significant main effects or interactions on the number of vehicle crashes, or on monetary rewards earned as a function of time to completion and the number of crashes were found (all $ps > .19; \eta_p^2: .003 - .03$).

Figure 5. Risky driving test

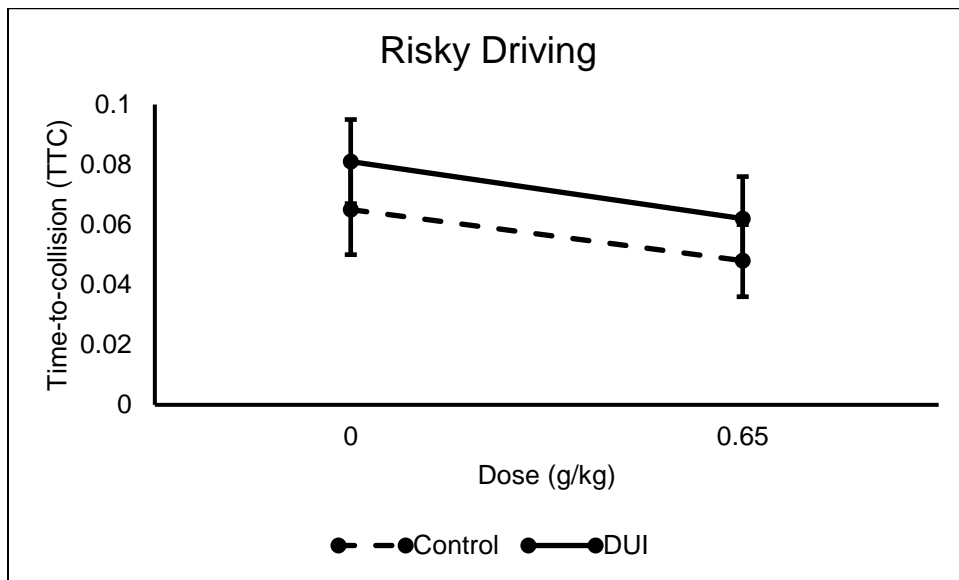


Figure 5. The mean time-to-collision values (TTC) from the risky driving scenario under placebo and 0.65 g/kg alcohol for DUI and control drivers. Error bars indicate standard error of the mean.

Perceived driver fitness scale

Perceived driver fitness scale outcome measures were analyzed by 2 (group) X 2 (dose) X 6 (time) mixed-design ANOVAs. A summary of the effects is shown in Table 8.

Table 8. Summarized Perceived Driver Fitness Scale effects

	Group (G)	Dose (D)	Time (T)	GxD	GxT	DxT	GxDxT
Willing Ability	ns.	***	***	ns.	ns.	**	*
Intox. BAC est.	ns.	***	***	ns.	*	***	*
Stimulation	ns.	***	***	ns.	***	ns.	ns.
Sedation	ns.	***	***	ns.	ns.	ns.	ns.

Table 8. * = ANOVA significant at $p < .05$; ** = significant at $p < .01$; *** = significant at $p < .001$; ns. = not significant.

Willingness and ability to drive

The ANOVA of self-reported willingness to drive a motor vehicle revealed a significant three-way interaction between group, dose, and time, $F(5, 190) = 2.32$, $p = .045$, $\eta_p^2 = .64$. This effect is shown in Figure 6. The figure indicates that ratings of willingness to drive differed as a function of dose and time, such that willingness to drive ratings were generally higher under placebo than under alcohol, and increased over time, across the declining limb of the BAC curve. Moreover, while the groups self-report similar willingness to drive ratings at each time-point under placebo, under alcohol, DUI participants tended to report a greater willingness to drive early in the time-course of the declining limb.

With regard to self-reported ability to drive a motor vehicle, the ANOVA revealed a significant dose by time interaction, $F(5, 190) = 15.96$, $p < .001$, $\eta_p^2 = .30$. This effect is also plotted in Figure 6. Similar to willingness to drive, the figure indicates that, for both groups, ratings of driving ability were generally higher under placebo than under alcohol, and increased over time under both doses.

Figure 6. Willingness and ability to drive a motor vehicle

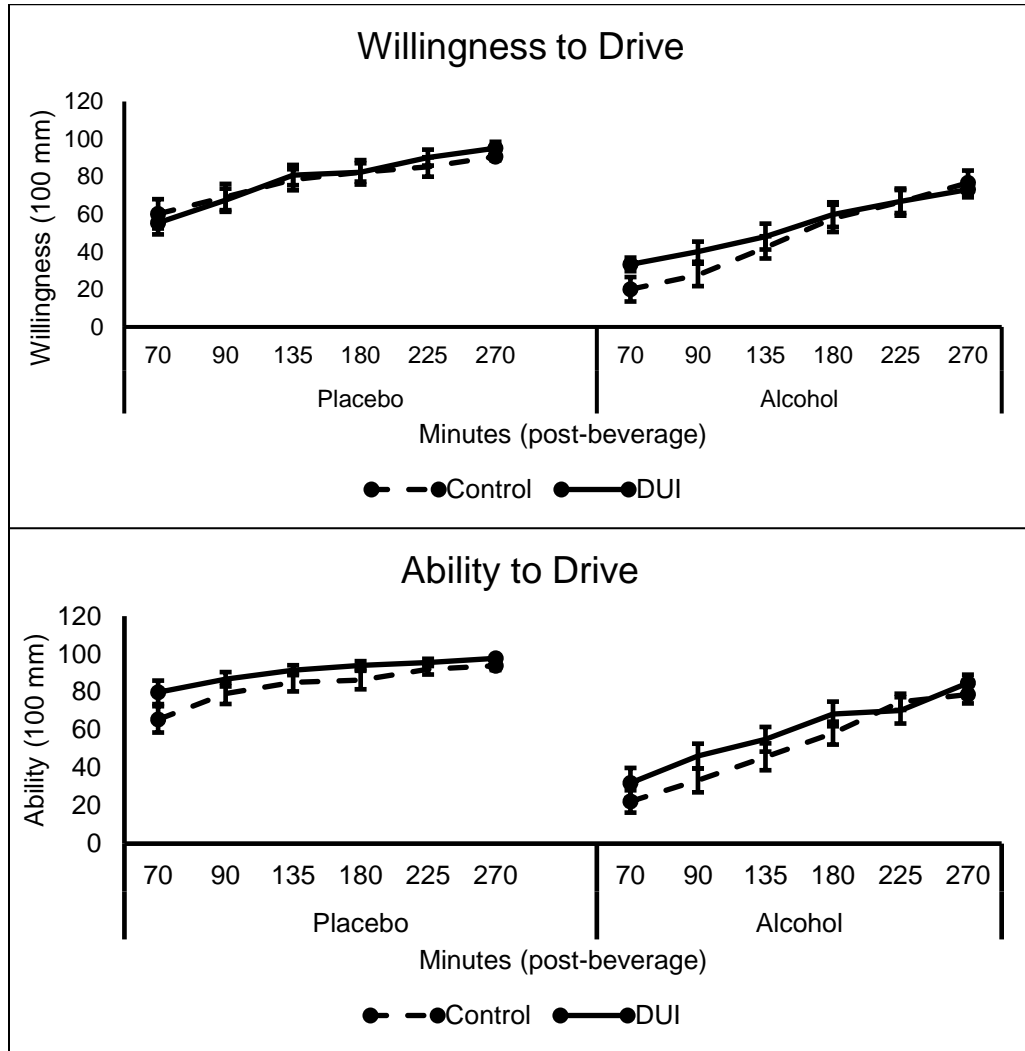


Figure 6. Self-reported ratings of willingness (top panel) and ability (bottom panel) to drive a motor vehicle on 100-point visual analogue scales following 0.65 g/kg alcohol and placebo for DUI and control drivers. Error bars indicate standard error of the mean. *Subjective intoxication*

The ANOVA analyzing subjective intoxication ratings revealed a significant three-way interaction between group, dose, and time, $F(5, 190) = 2.74, p = .021, \eta_p^2 = .07$. This effect is plotted in Figure 7. The figure indicates that subjective intoxication differed as a function of dose, such that ratings of intoxication in both groups were generally higher under alcohol than under placebo, and decreased over time, as BrACs

decreased. Moreover, while the groups reported almost identical subjective intoxication at each timepoint under placebo, the groups differed in ratings of subjective intoxication under alcohol. DUI participants tended to report less subjective intoxication early in the time-course before ratings converged with those in the control group.

Figure 7. Subjective intoxication

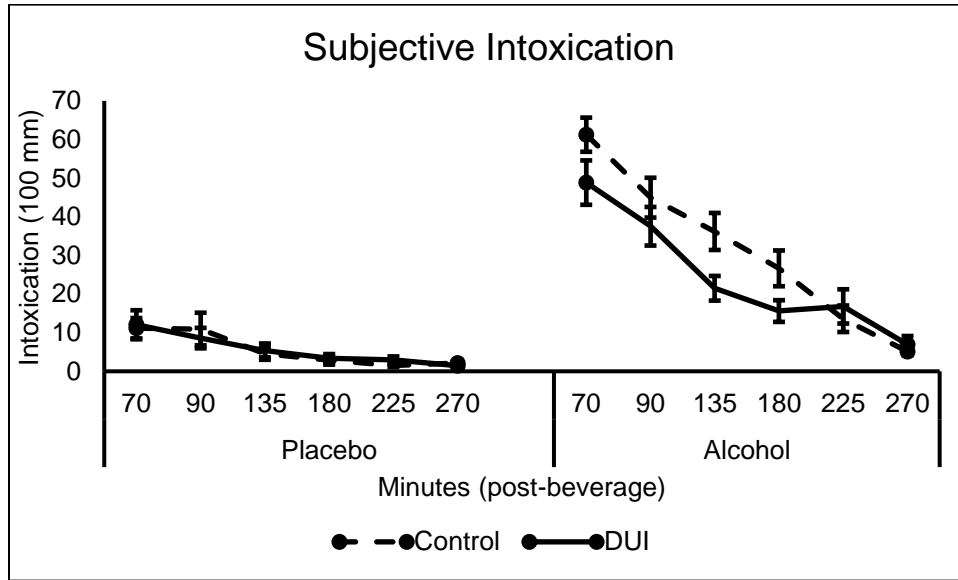


Figure 7. Mean subjective intoxication ratings on 100-point visual analogue scales following 0.65 g/kg alcohol and placebo for DUI and control drivers. Error bars indicate standard error of the mean.

Estimated blood alcohol concentrations (BAC)

The ANOVA examining participants' BAC estimations revealed a significant dose X time interaction, $F(5, 190) = 22.58, p < .001, \eta_p^2 = .37$. This effect is plotted in Figure 8. The figure indicates that both groups estimated higher BACs under alcohol compared with placebo. The figure also indicates that both groups estimated lower BACs over time, as actual BACs decreased.

Figure 8. Estimated blood alcohol concentrations

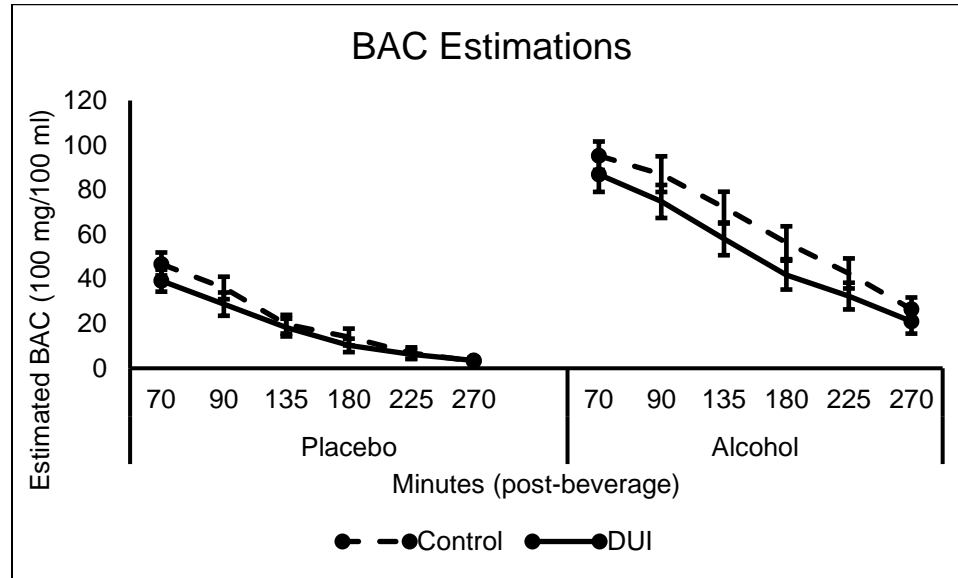


Figure 8. Mean estimated BAC ratings on a scale ranging from 0.0 mg/100 ml to 160 mg/100 ml following placebo and 0.65 g/kg alcohol for DUI and control drivers. Error bars indicate standard error of the mean.

Stimulation and sedation

The ANOVA of self-reported stimulation revealed significant main effects of dose, $F(1, 38) = 6.63, p = .014, \eta_p^2 = .15$, time, $F(5, 190) = 7.81, p < .001, \eta_p^2 = .17$, and a significant group X time interaction, $F(5, 190) = 5.09, p < .001, \eta_p^2 = .12$. Figure 9 plots these effects. The figure indicates that, for both groups, stimulation ratings were higher under placebo than under alcohol, and generally increased over time. Moreover, under both doses, group interacted with time such that DUI participants reported more stimulation early in the time-course and less stimulation later in the time-course, compared with controls.

With regard to self-reported sedation, the ANOVA revealed significant main effects of dose, $F(1, 38) = 17.05, p < .001, \eta_p^2 = .31$, and time, $F(5, 190) = 12.11, p < .001, \eta_p^2 = .24$. These effects are also plotted in Figure 9. The figure indicates that both

groups similarly self-reported higher sedation under alcohol compared with placebo, and decreased sedation over time.

Figure 9. Self-reported stimulation and sedation

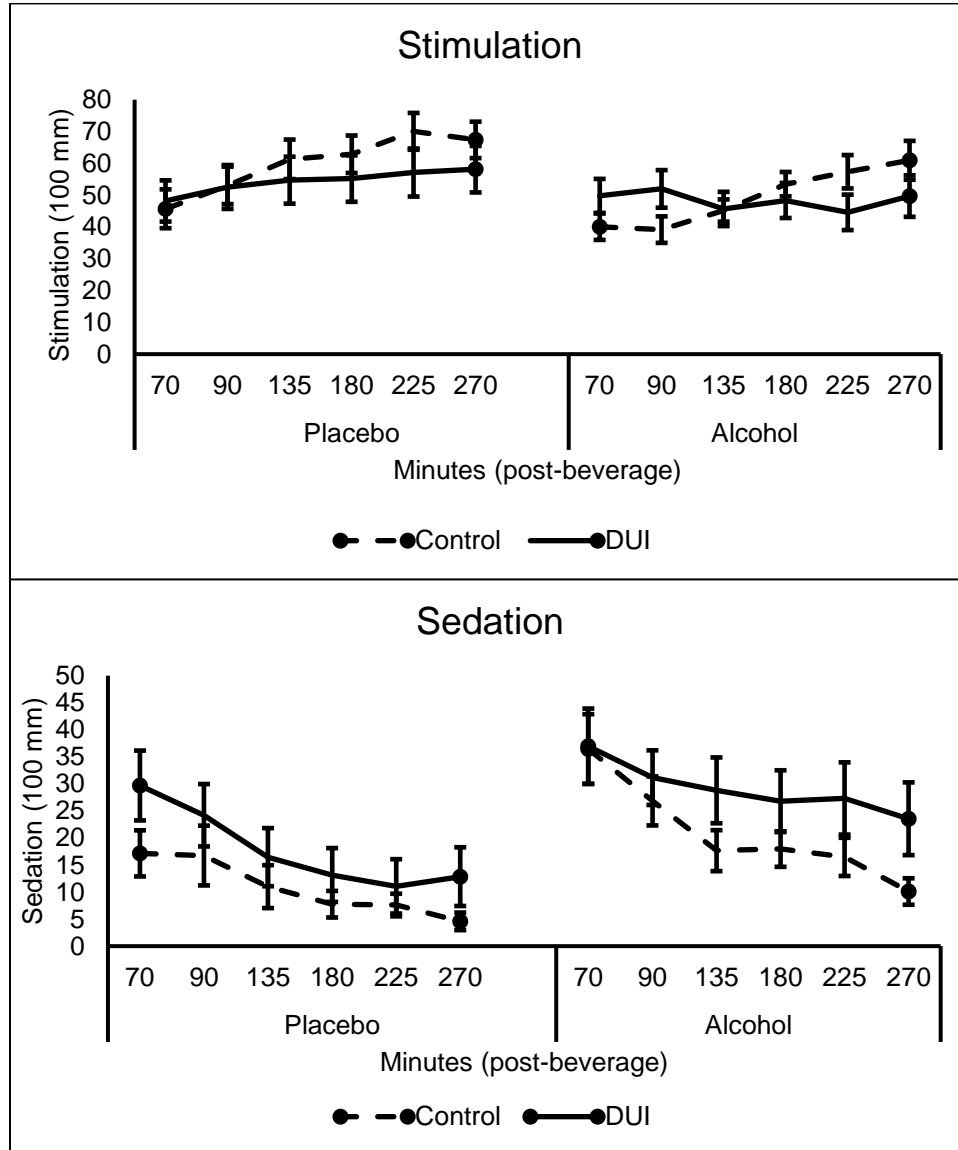


Figure 9. Mean ratings of subjective stimulation and sedation on a 100-point visual analogue scale following 0.65 g/kg alcohol and placebo for DUI and control drivers. Error bars indicate standard error of the mean.

Peak effects

Analyses of peak subjective ratings were conducted to determine if DUI offenders differed from controls in their maximum rating of effects. Two-sample t tests compared the mean maximum self-reported value of each outcome measure based on the highest reported value across the six assessment time points for each dose. The mean peak ratings are reported in Table 9. While there were no statistically significant differences between DUI offenders and controls on any subjective rating under placebo or alcohol, there were trends toward higher peak ability to drive ratings under placebo, $t(38) = 1.92, p = .062, d = .61$, and higher sedation ratings in DUI offenders following placebo, $t(38) = 1.98, p = .055, d = .63$. All other comparisons under placebo and alcohol were not significant (all $ps > .10$; $ds: .05 - .53$).

Table 9. Perceived driver fitness scale peak effects

	Controls		DUI Offenders		<i>t</i>	<i>p</i>
	M	(SD)	M	(SD)		
Placebo						
Willingness	91.70	(13.8)	95.80	(8.61)	1.13	0.27
Ability	94.85	(8.21)	98.50	(2.19)	1.92	0.06
Intoxication	15.25	(18.36)	14.30	(17.07)	0.17	0.87
BAC est.	48.00	(22.62)	40.75	(23.69)	0.99	0.33
Stimulation	74.10	(24.99)	63.70	(31.60)	1.16	0.26
Sedation	23.95	(25.23)	41.75	(31.25)	1.98	0.06
Alcohol						
Willingness	78.50	(18.24)	83.85	(18.13)	0.93	0.36
Ability	83.15	(16.67)	88.20	(16.62)	0.96	0.34
Intoxication	63.90	(16.93)	52.65	(24.54)	1.69	0.10
BAC est.	97.75	(29.49)	87.38	(35.16)	1.01	0.32
Stimulation	69.40	(20.02)	65.45	(22.89)	0.58	0.57
Sedation	45.00	(23.05)	52.45	(31.31)	0.86	0.40

Table 9. Mean ratings of the highest self-reported value for each measure on a 100-point visual analogue scale, under placebo and alcohol, for each group. BAC estimation assessed as the lowest estimated BAC, which confers the highest risk; Willingness = willingness to drive a motor vehicle; Ability = ability to drive a motor vehicle; Subj.

intoxication = subjective intoxication; BAC estimation = estimated BAC on a scale ranging from 0 mg/100 ml to 160 mg/100 ml; Stimulation = self-reported stimulation; sedation = self-reported sedation.

Factors that relate to alcohol's effect on impulsive behaviors and driving performance

Several demographic/questionnaire variables were selected for correlational analysis based on their recognized relevance to impulsivity and drinking and driving behaviors. For all correlational analyses, one primary outcome variable from each measure was identified, and zero order correlations were conducted to examine relationships between the chosen predictor variables and behavioral outcome measures. The chosen predictor variables included recent drinking habits (total drinks), driving experience (number of months of licensed driving), lifetime drinking and driving experience (number of past year driving occasions after 5 drinks in 2 hours), and subjective evaluations (i.e., willingness, intoxication) at the peak of the BAC curve (i.e., time point 1). The behavioral measures of interest included magnitude of alcohol effect on: impulsive choice (TCIP), inhibitory control (cued go/no-go), driving skill, and risky driving. To examine relationships between the predictor variables and the alcohol responses, a single variable was first created to quantify each alcohol response as the difference in performance under the alcohol dose from performance under placebo. Thus, the correlations examined how individual differences in the predictor variables might relate to the degree of alcohol impairment on each of the behavioral tasks. See Table 9 and Table 10 for a summary of these relationships.

Factors that influence alcohol's effect on impulsive choice and inhibitory control

Total drinks in the past 90 days (TLFB) was significantly related to the effect of alcohol on drivers' impulsive choices in the entire sample, $r(38) = 0.32, p = .043$, such

that participants who drink the most outside the laboratory displayed the greatest alcohol-induced increases in impulsive responding on the TCIP. No other relationship between any of the predictor variables and impulsive choices were found in the sample or in either group individually. With regard to inhibitory control, no significant relationships between any of the predictor variables and impulsive choices or inhibitory control were found (see table 10).

Table 10. Factors that relate to alcohol’s effect on behavioral impulsivity

<i>Pearson’s r</i>	Impulsive Choices			Inhibitory Control		
	DUI	Control	Sample	DUI	Control	Sample
Total drinks	.26	.20	.32*	-.10	.14	-.03
Drive exp.	.01	.10	.04	-.35	-.03	-.20
Drink drive	-.14	.11	-.06	.13	-.17	.01
Willingness	.44*	-.27	-.04	-.27	-.04	-.12
Intoxication	.01	.25	-.004	-.36	.27	-.07

Table 10. Pearson’s *r* correlation coefficients. Total drinks = TLFB total drinks in the past 90 days; Drive exp. = total months of licensed driving; Drink drive = number of occasions driving after drinking 5 drinks in 2 hours; Willingness = willingness to drive on 100-mm visual analogue scale; Intoxication = perceived intoxication on 100-mm visual analogue scale. * = significant at $p < .05$.

Factors that influence alcohol’s effect on simulated driving performance

Total drinks in the past 90 days was significantly related to driving skill (SDLP) in the entire sample, $r(38) = 0.38, p = .015$. The nature of the positive relationship indicates that participants who consume the most alcohol outside the laboratory displayed greater alcohol-induced degradations of driving skill. When breaking down the relationship by group, a significant relationship was found in the DUI group, $r(18) = 0.52, p = .020$, but not the control group. A similar pattern was found for the relationship

between self-reported intoxication and driving skill. A significant positive relationship in the entire sample was found, $r(38) = 0.38, p = .015$. When looking at the relationship self-reported intoxication and driving skill by group, there was only a significant relationship among the DUI group, $r(18) = 0.48, p = .030$. Thus, participants self-reporting higher levels of intoxication are also showing the greatest alcohol-induced impairment of driving skill, particularly in the DUI group. No other relationships involving driving skill or risky driving were found (see Table 11).

Table 11. Factors that relate to alcohol’s effect on simulated driving performance

<i>Pearson’s r</i>	Driving Skill			Risky Driving		
	DUI	Control	Sample	DUI	Control	Sample
Total drinks	.52*	-.11	.38*	.05	.06	.05
Drive exp.	.12	.04	.10	.42	-.11	.21
Drink Drive	-.16	.02	-.08	-.21	-.16	-.17
Willingness	-.25	.11	-.10	-.29	.21	-.02
Intoxication	.49*	.32	.38*	.03	.37	.16

Table 11. Pearson’s r correlation coefficients. Total drinks = TLFB total drinks in the past 90 days; Drive exp. = total months of licensed driving; Drink drive = number of occasions driving after drinking 5 drinks in 2 hours; Willingness = willingness to drive on 100-mm visual analogue scale; Intoxication = perceived intoxication on 100-mm visual analogue scale. * = significant at $p < .05$.

Relationship of trait impulsivity and behavioral impulsivity

To examine the relationship between trait impulsivity and behavioral impulsivity, correlational analyses were conducted to examine the relationship between BIS scores and performance on the TCIP and cued go/no-go task. See Table 12 for a summary of the correlations. There was evidence of significant relationships between BIS scores and the degree to which alcohol increased impulsive choices $r(18) = .51, p = .022$, albeit only for

the control group. With regard to inhibitory control, there was a significant relationship between BIS scores and inhibitory control in the sample, $r(18) = .42, p = .008$, likely driven by the significant relationship in the control group, $r(18) = .64, p = .002$. In both cases, the nature of relationships indicates that, for control participants, higher trait impulsivity is associated with greater alcohol-induced increases in impulsive choice behavior and greater alcohol-induced decreases in inhibitory control. However, no significant relationships were found in the DUI group ($r_s < .11; p_s > .21$). When looking at the relationship between the impulsive choices and inhibitory control, correlational analyses found no relationships, under placebo or alcohol, in either group or in the entire sample ($r_s < .20; p_s > .22$). Thus, it appears the two tasks are distinct and likely tapped into different mechanisms of behavioral impulsivity.

Table 12. Relationship of trait impulsivity and behavioral impulsivity

<i>BIS total scores</i>	Impulsive Choice			Inhibitory Control		
	DUI	Control	Sample	DUI	Control	Sample
Placebo	-.03	-.16	-.10	.22	-.32	-.10
Alcohol	-.13	.42	-.03	.28	.24	.25
Alcohol Effect	-.12	.51*	.03	.13	.64**	.42**

Table 12. Pearson's r correlation coefficients. Relationships of BIS total scores and impulsive choices (TCIP); BIS total scores and inhibitory control (cued go/no-go). Placebo = task performance in the placebo condition; Alcohol = task performance in the 0.65 g/kg alcohol condition; Alcohol effect = impairment score by subtracting placebo from alcohol. * = significant at $p < .05$; ** = significant at $p < .01$.

Relationship of driving skill and risky driving

To examine relationships between the two drive test scenarios, relationships between driving skill and risky driving were examined. Results indicated that driving skill was not related to risky driving, under placebo, $r(38) = .27, p = .09$, or alcohol, $r(38)$

= -.09, $p = .59$, or in the degree to which alcohol affected both measures, $r(38) = -.11$, $p = .49$.

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Discussion

The present study examined the acute impairing effects of alcohol on behavioral mechanisms of impulsivity, simulated driving performance, and self-evaluations of driving fitness and intoxication across the declining limb of the BAC curve in a sample of DUI offenders and a comparison control group. The dose of alcohol produced an average peak BAC of 76 mg/100 ml (.076%) and was found to increase risk-taking or decrease task performance on all of the behavioral criterion variables. More specifically, with regard to behavioral mechanisms of impulsivity, the dose of alcohol increased impulsive responding on the TCIP and inhibitory failures on the cued go/no-go task. Moreover, alcohol interacted with group such that DUI offenders exhibited alcohol-induced increases in impulsive responding, while no such increase was observed in the control group. The degree to which alcohol decreased inhibitory control did not differ between the groups.

Alcohol also affected multiple criterion measures of simulated driving performance. Alcohol produced decreases in drivers' level of skill and increases in risky driving behaviors relative to placebo. Compared with placebo, participants' performance under alcohol on the skill drive test was characterized by increased deviations of the lateral position of the driver's vehicle within the driven lane, a greater number of crossings outside the driver's lane, and an increased number of vehicle crashes, and performance on the risk drive test was characterized by decreased distances between the

driver's vehicle and other vehicles on the road. However, once again the degree to which alcohol decreased driving skills or increased risk-taking behaviors did not differ between the DUI and control groups.

With regard to self-evaluations of willingness and ability to drive, and perceived intoxication and BAC estimations, there was evidence that subjective evaluations changed as a function of dose and time. More specifically, ratings of willingness and ability to drive were lower, and perceived intoxication and BAC estimations were higher, under alcohol compared with placebo. Furthermore, ratings of willingness and ability to drive generally increased over time, while ratings of intoxication and BAC estimations decreased over the same period. Interaction effects involving the group factor indicated that DUI offenders differed from controls on ratings of subjective intoxication and stimulation as a function of dose and time. Generally, DUI offenders less subjective intoxication and more stimulation under alcohol, primarily within the first two hours on the descending limb of the BAC curve, when decisions to drive are often made.

Impulsivity in DUI offenders

Building upon the literature indicating the importance of understanding the role of impulsivity in substance using behaviors, and decades of survey studies indicating that DUI offenders have higher levels of impulsivity compared with non-offenders (e.g., Chalmers et al., 1993; Ryb et al., 2006), the current study examined two mechanisms of behavioral impulsivity that likely contribute to risky substance use. The finding that impulsive choice behavior in DUI offenders is increased by alcohol, but not in controls, is novel to the field in multiple ways. First, this finding provides the first pieces of evidence that individuals arrested for DUI show susceptibility to alcohol-induced increases in

impulsive choice behavior. Thus, during a drinking episode, DUI offenders might have particular difficulty abstaining from decisions that produce immediate gratification in favor of delayed, but often safer behaviors. This supports the notion that DUI offenders may be unable to delay impulses to drive after drinking to get home quicker instead of the safer decision to wait for a taxi home.

Next, as mentioned in the introduction, it is becoming increasingly recognized that experiential models, in which participants must experience the temporal delays in real-time, benefit from increased validity over traditional hypothetical models in which participants must make assessments between arbitrary rewards and time periods (Reynolds et al., 2007). Thus, the current study's inclusion of the TCIP to assess participants' tendencies to discount delayed rewards for immediate rewards adds to the handful of existing studies that have detected drug-induced increases in discounting behavior using experiential models in drug administration studies (e.g., McCarthy et al., 2012; Reynolds et al., 2009) and supports the use of such tasks in future studies in these areas.

Despite the novel finding that DUI offenders showed particular sensitivity to alcohol-induced increases in impulsive responding, there was no evidence for group differences in the degree to which alcohol decreased inhibitory control. This finding is consistent with a prior study in our laboratory that found similar levels of alcohol-induced impairment of inhibitory control in using comparable sized samples of DUI offenders and controls (Van Dyke and Fillmore, 2014). It is possible that the failure to detect differences on levels of inhibitory control, when differences were found with impulsive choices, is due to the multifaceted nature of impulsivity. The cued go/no-go

task used in the current study measured levels of inhibitory control as the ability to suppress a prepotent response. However, impulsivity could also be manifest as heightened approach tendencies toward appetitive or rewarding stimuli which often leads to a failure to delay gratification (Christiansen, Cole, Goudie, & Field, 2012). Thus, it might be that DUI offenders are more sensitive to the impairing effects of alcohol on the ability to delay reward, but not necessarily on the ability to inhibit pre-potent actions. Indeed, there is some evidence that supports this stance. Recent research examined the effects of alcohol on impulsive behavior of drivers who reported drinking and driving in the past year (McCarthy et al., 2012). They found that, under alcohol, these drivers readily discounted rewards that were delayed, showing a preference for immediate rewards. Taken together, these findings suggest that DUI offenders may not have a susceptibility to the impairing effects of alcohol on the ability to suppress responses in the context of seconds, but that their impulsivity may be manifest as a more of a macro-level inability delay immediate rewards, despite possible negative consequences (e.g., DUI arrest).

In light of these findings, it is important to consider the complexity of the domain of impulsivity. It is increasingly recognized among researchers that impulsivity is multifaceted. Indeed, recent research has examined relationships between survey assessments of impulsivity and common laboratory tasks used by researchers to assess impulsivity. Several studies have reported dissociations between survey or questionnaires used to assess impulsivity and laboratory tasks, in addition to dissociations between various tasks (for a review, see: Cyders and Coskunpinar, 2012). When looking at the relationships between the measures of impulsivity in the current study, there were no significant

correlations between BIS scores and impulsive choices, or between impulsive choices and inhibitory control. There was a relationship between BIS scores and the degree to which alcohol impaired inhibitory control, but this relationship was not present under either dose individually. Thus, it is likely that the assessments of impulsivity in the current study tapped into mechanisms of impulsivity that are at least somewhat distinct.

Simulated driving performance

Results of the simulated drive tests provide insight into the degree to which DUI offenders and control drivers might differ on their level of driving skill and their tendency to engage in risk-taking behaviors while driving. The finding that DUI offenders were equally impaired as controls in terms of alcohol-induced increases in risky driving is novel to the small literature base on the driving habits of DUI offenders in response to a dose of alcohol. However, it is unclear why DUI offenders in the current study did not engage in greater risk-taking behaviors in response to alcohol given the prevailing reports that DUI offenders generally display risk-taking behaviors. Indeed, as mentioned in the introduction, DUI offenders tend to show higher levels of impulsive traits (e.g., sensation seeking), perceive less risk while driving (Deery and Love, 1996), and analysis of driving records indicates higher levels of tickets, motor vehicle crashes, and speeding behaviors than individuals without a DUI (e.g., Dahlen and White, 2006; Lajunen and Parker, 2001; Matthews et al., 1991). Given that these traits generally predict increased sensitivity to alcohol's impairing effects in other impulsive populations (i.e., Adults with ADHD), including in a previous study from our laboratory that employed a similar risky driving scenario (Laude and Fillmore, 2015), it is unclear why DUI offenders in the current study did not show higher levels of risk-taking while driving than controls.

One explanation could be that the sample of DUI offenders in the current study was not distinct enough from the control group in terms of the traits that might contribute to risky driving behaviors. The DUI group did not differ from controls in many traits and behaviors, including impulsivity, and showed comparable reactions to alcohol in inhibitory control and driving skill. In other words, perhaps the current sample of DUI offenders too closely resembled the control group in terms of traits that might predict or contribute to increased sensitivity to alcohol-induced increases in risky driving. It is also worth considering the drive scenario used to assess risky driving behaviors in the current study might have led all drivers to display high levels of risk-taking. Drivers in the current study were informed they would be rewarded monetarily for completing the drive scenario in the shortest time, and penalized a fraction of the possible reward for vehicle crashes. This methodology has been used in several studies in our laboratory (Fillmore et al., 2008; Fillmore and Harrison, 2007; Laude and Fillmore, 2015; Van Dyke and Fillmore 2014) to produce the conflicted state drivers encounter while driving outside the lab in which they are rewarded by arriving at a destination on time at the cost of potential infractions for speeding, etc. However, this system may have unintentionally increased risk-taking in all drivers, such that both groups showed a tendency place their vehicle very close to other vehicles (i.e., tailgating) to navigate narrow gaps between vehicles in order to finish the drive test quickly. Perhaps increasing the monetary penalty for vehicle crashes may have decreased risk-taking overall, and thus made it easier to detect group differences in risky driving. It is also worth noting that while the current study is one of the first to employ a proxemics model to assess risky driving behaviors in the laboratory, and the benefits of this model are recognized (e.g., Taieb-Maimon and Shinar, 2001), this

is only one possible interpretation of risky driving. Other research groups have implemented alternative methods to assess risk-taking behaviors in driving simulations (Burian et al., 2002, 2003; Cohen et al., 1958; Leung and Starmer, 2005).

The finding that DUI offenders were equally impaired by alcohol in terms of driving skill replicates prior work in our laboratory (Roberts and Fillmore, 2016; Van Dyke and Fillmore, 2014). As mentioned in the introduction, the majority of existing 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, only recently have studies begun to examine how DUI offenders actually respond to alcohol in terms of their driving performance. A common assumption among researchers 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). Given that the DUI offenders consumed more alcohol than controls, it could be assumed they would be more tolerant to alcohol's impairing effect than control.

However, because driving skills in both groups were equally impaired by alcohol, there is little reason to suspect tolerance could have contributed to the findings. Thus, despite differences in drinking habits, there was no evidence that the DUI offenders were tolerant to the disrupting effects of alcohol on behavior.

Subjective evaluations

The current study also adds to the limited existing knowledge on how DUI offenders make subjective evaluations about factors that contribute to decisions to drive

after drinking. The interactions indicated that DUI offenders differed from controls in ways that could contribute to an increased likelihood to drive after drinking. Namely, under alcohol DUI offenders reported less subjective intoxication, and greater stimulation than controls early (within 2 hours) in the declining limb, when decisions to drive are often made. It is well-known that the chances of being caught drinking and driving are extremely low and drivers often drive drunk many times before being caught (Evans, 2004). Thus, by the time DUI offenders are arrested for driving under the influence, they may have significantly more experience with drunk driving than drivers without a DUI history.

One explanation for the differences in willingness to drive could be that repeated occurrences of drinking and driving that did not result in a DUI arrest leads them to be more willing to engage in the behavior in the future. Characteristics of the DUI sample in the current study would support this idea. While DUI offenders did not report drinking and driving on more occasions than controls in the past year, they did report a higher frequency of lifetime drinking and driving episodes. The current sample of DUI offenders reported an average time since their last DUI arrest of 21 months. Thus, while results indicate that DUI offenders are still readily engaging in drinking and driving episodes despite their previous arrest(s), it is plausible to assume that the lack of group differences in past year drinking and driving episodes was a result of receiving a DUI within the past year(s), whether this was due to underreporting or actual reductions in the behavior. In sum, it is reasonable to assume that DUI offenders are more willing to drive after drinking due to a greater lifetime history of drinking and driving, most of which went unpunished. Whether DUI offenders will eventually return to their original drinking and

driving habits before the DUI arrest(s) is unknown, but is an important question that taps into the effectiveness of the deterrence strategies of existing DUI prevention and education classes.

There are several other factors that an individual may use to make judgments of their willingness to drive after drinking. Objects external to an individual may serve as clues by which an individual makes these important self-evaluations. In the current study, simulated driving performance and performance on the TCIP and cued go/no-go task likely served as clues to the individual on their levels of alcohol-induced impairment. While DUI offenders and controls were equally impaired on all measures of driving performance and performance on the cued go/no-go task, they did show an increased preference for impulsive choices under alcohol on the TCIP. So while it does not seem plausible that behavioral performance on the driving simulations or cued go/no-go task could explain the increases in willingness to drive in DUI offenders, perhaps their tendency to prefer impulsive choices while under the influence of alcohol contributed to their the increases in willingness to drive. The correlational analyses would support this interpretation as willingness to drive was significantly related to impulsive choices on the TCIP in the DUI group. Thus, DUI offenders might base decisions on how willing they are to drive after drinking on their preference for the more immediate gratification of arriving home sooner.

Interoceptive cues, such as perceived levels of intoxication, may also serve as clues by which participants evaluate their willingness to drive after drinking. At the end of a drinking episode, an individual may evaluate their level of intoxication when deciding whether they will drive home, to another bar, or elsewhere. Given that DUI

offenders did tend to report less subjective intoxication early in the declining limb, it could be argued that the increased levels of willingness to drive in DUI offenders was simply mirroring their perceptions of less intoxication. That is, the DUI offenders might have simply felt less impaired or intoxicated than the control drivers, and as such, feel more willing to drive. However, correlations between willingness to drive and subjective intoxication were all nonsignificant at any time point ($ps > .20$), which limits the interpretation that DUI offenders were basing their willingness to drive on how intoxicated they felt.

Another possible explanation is that there are inherent differences in the personalities of DUI offenders that might make them more likely to display risky behaviors at any given time. If this were true, the intoxicated DUI driver might report always being more willing to drive despite previous punishments and harmful consequences of their actions. This interpretation might make sense as DUI offenders reported a greater willingness to drive despite reporting similar levels of ability and estimating comparable BACs as controls. That is, DUI offenders may not necessarily feel as though they are more able to successfully drive after drinking, but they are just always more willing to drive after drinking. However, the group differences in self-reported willingness to drive only appeared through part of the BAC curve (early in the declining limb), as BACs began to decline. Later in the declining limb, DUI offenders rated themselves just as willing to drive as controls and showed similar ratings in other factors that might contribute to decisions to drive (i.e., ability, intoxication, BAC estimation). Moreover, these findings likely cannot be attributed to any potential group differences in

the pharmacological effects of the dose of alcohol, because DUI offenders estimated similar BACs as controls at each time point.

Limitations and future directions

This dissertation examined the acute responses to alcohol on mechanisms of impulsivity, simulated driving performance, and subjective evaluations that might confer increased risk in a population characterized by risky behaviors. However, there are a number of limitations that need to be considered. First, the current sample of DUI offenders was comprised primarily of first-time offenders, with only three DUI offenders having multiple offenses (i.e., recidivists). 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 that individual. In fact, the self-report and personality measures included in the current study indicated that the DUI sample closely resembled the control drivers. DUI offenders scored significantly higher than controls on two measures of problems related to alcohol use (i.e., AUDIT and S-MAST) indicating that DUI offenders might engage in more risky drinking behaviors. However, the differences on the S-MAST are likely due at least partially to the fact that the questionnaire contains a question asking about previous DUI arrests. The current DUI sample also reported a higher cognitive and emotional preoccupation with alcohol and greater attempts to abstain from drinking alcohol, indicating greater efforts to control their drinking compared to control drivers, possibly as a result of the punishments associated with their DUI arrest. 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 (for a review, see: Cavaola and Wuth, 2002). 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 et al., 2000; Ouimet et al., 2007). Prior laboratory research from our lab has also indicated that recidivist DUI offenders possess higher sober-state levels of attentional bias to alcohol and cognitive preoccupations with alcohol than either first time offenders and controls (Miller and Fillmore, 2014). 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 inhibitory control and measures of driving performance.

It is also worth noting that the current study only examined the impairing effect of alcohol on mechanisms of impulsivity and simulated driving performance on the ascending limb of the BAC curve. While it is informative to understand differences in sensitivity to alcohol in different populations, the declining limb is of particular interest for DUI offenders. This is the period of time in which they are more likely to drive after drinking, and experience negative consequences as a result of drinking and driving, such as traffic crashes and fatalities (Levine and Smialek, 2000). As such, future laboratory assessments would benefit from testing on both the ascending and descending limbs of the BAC curve. Not only would this better inform possible impairment at a time when many DUI offenders are likely engaging in drinking and driving behaviors, but it would increase our understanding of acute tolerance to the impairing effect of alcohol on these tasks. For example, it would be possible to examine whether risky driving behaviors

show acute tolerance such that drivers show less risk-taking under alcohol on the descending limb compared with the ascending limb. Future work could also benefit from testing multiple doses of alcohol to broaden our understanding of thresholds for impairment of driving-relevant behaviors. This is also important to inform public policy surrounding at relevant BACs (e.g., 0.05%) below the current legal limit for driving in the United States. With recent government propositions to reduce the legal driving limit to 0.05% in the US, and Utah adopting this new lowered limit at the end of 2018, it is important for future research to expand our understanding of impairment above and below 0.05%.

In summary, the findings point to the need for future laboratory research to expand our understanding of relevant behaviors encountered outside the lab, particularly in high-risk populations that contribute significantly toward alcohol-related motor vehicle crashes and fatalities. Particularly, future studies should focus on examining how an increased preference for immediate, impulsive choices in DUI offenders could inform treatment and prevention strategies aimed at reducing DUI recidivism. With regard to driving performance, future research in this area should examine other relevant behaviors, such as the role of distraction in driving environments, particularly in populations characterized by impulsivity. Moreover, future studies should consider the inclusion of multiple doses of alcohol and testing across the entire BAC curve to provide a more accurate picture of how these behaviors might be affected differently by alcohol under different doses and across the time course of a drinking episode. In designing future studies to directly target these unanswered questions, it will be important to consider the likely differences within the DUI population (i.e., first-time versus

recidivists). Thus, although recidivist offenders have proven to be difficult to recruit for alcohol administration studies, future research should aim to include separate groups of first-time and recidivist DUI offenders. The integration of such approaches allows long-standing but rarely tested hypotheses to be examined, such as the possibility that recidivist DUI drivers display aberrant reactions to alcohol that could compromise self-regulatory processes and contribute to their decisions to drive after drinking. Such examinations could greatly inform how society approaches the DUI problem.

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CURRICULUM VITAE

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EDUCATION

- Ph.D. **University of Kentucky**, Lexington, KY (expected) August 2018
Experimental Psychology
Advisor: Mark T. Fillmore, Ph.D.
Dissertation: "Acute effects of alcohol on behavioral impulsivity and risky driving in DUI offenders"
- Cert. **University of Kentucky**, Lexington, KY 2015
Graduate Certificate in College Teaching and Learning
Advisors: Morris A. Grubbs, Ph.D.; Linda Worley, Ph.D.
- M.S. **University of Kentucky**, Lexington, KY 2014
Experimental Psychology
Advisor: Mark T. Fillmore, Ph.D.
Thesis: "Acute effects of alcohol on simulated driving performance and self-perceptions of impairment in DUI offenders"
- B.A. **North Dakota State University**, Fargo, ND 2011
Major: Clinical Psychology
Advisors: Brian D. Ostafin, Ph.D.; Wendy Troop-Gordon, Ph.D.

MANUSCRIPTS (PUBLISHED)

- Van Dyke, N. A., & Fillmore, M. T. (2017). Laboratory analysis of risky driving at 0.05% and 0.08% blood alcohol concentration. *Drug and Alcohol Dependence*, 175, 127-132.
- Van Dyke, N. A., and Fillmore, M. T. (2015). Distraction produces over-additive increases in the degree to which alcohol impairs driving performance. *Psychopharmacology*, 232(23), 4277-4284.
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HONORS AND AWARDS

Behavioral Neuroscience and Psychopharmacology Outstanding Student	2018
University of Kentucky Institutional Outstanding Teacher Finalist	2017-2018
NIDA T32 DA07304 Pre-Doctoral Research Traineeship (2 year appt.)	2014-2016
Research Society on Alcoholism Student Merit Award	2013-2017

RESEARCH EXPERIENCE

NIDA T32 Training Grant Pre-doctoral Research Trainee	2014 – 2016
College of Medicine, University of Kentucky	
Principle Investigator: Craig R. Rush, Ph.D.; Co-PIs: William Stoops, Ph.D., Hannah Knudsen, Ph.D.	
Graduate Research Assistant – Fillmore Alcohol Research Lab	2012-present
Department of Psychology, University of Kentucky	
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TEACHING EXPERIENCE

Adjunct Instructor, University of Kentucky (2 years)	2016-present
Adjunct Instructor, Eastern Kentucky University (3 years)	2015-present
Teaching Assistant, University of Kentucky (6 years)	2012-present