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COGNITIVE AND BEHAVIORAL MECHANISMS UNDERLYING ALCOHOL-INDUCED RISKY DRIVING

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COGNITIVE AND BEHAVIORAL MECHANISMS UNDERLYING ALCOHOL-INDUCED RISKY DRIVING

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

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ABSTRACT OF DISSERTATION

COGNITIVE AND BEHAVIORAL MECHANISMS UNDERLYING ALCOHOL-INDUCED RISKY DRIVING

Alcohol intoxication represents one situation an individual might increase their amount of risk taking when driving. This dissertation is comprised of three studies that investigate the mechanisms by which alcohol increases driver risk-taking. Study 1 examined the effect of alcohol on driver risk-taking using a proxemics approach. The study also tested whether alcohol-induced increases in risky driving co-occurred with pronounced impairment in the driver's skill. The study also examined whether the most disinhibited drivers were also the riskiest. Indeed, alcohol increased driver risk-taking and impaired driving skill. The study also revealed risky driving can be dissociable from impairing effects on driver skill and that poor inhibitory control is selectively related to elevated risky driving. Studies 2 and 3 built on this work by addressing whether the apparent dissociation between behavioral measures of driver risk and skill was mediated by perceptions the drivers held. While maintaining the distinction between driver risk and skill, Study 2 tested the relationship between drivers' BAC estimations and their tendency to take risks on the roadway. Drivers who estimated their BAC to be lower were the riskiest drivers following both alcohol and placebo. Study 3 addressed whether risky driving could be increased by environmental factors that shape perceptions the driver holds. There is evidence post-licensure training programs might inadvertently generate overconfidence in drivers' perceived ability to operate a motor vehicle and thus fail to perceive dangers normally associated with risky driving behavior. To test this hypothesis, twenty-four drivers received either advanced skill training or no training in a driving simulator. Drivers who received skill training showed increased risky driving under alcohol whereas those who received no training tended to decrease their risk taking. Trained drivers also self-reported more confidence in their driving ability. Taken together, these studies represent a large step towards the betterment of laboratory-based models of driving behavior. The work highlights the importance of distinguishing between driver risk-taking and driving skill. The studies also identified that drivers' personal beliefs influence alcohol-induced risky driving; this suggests training programs focused on correcting drivers' misconceptions might be most efficacious in reducing their risk taking on the roadway.

KEYWORDS: Alcohol, Simulated Driving, Risk Taking, Inhibitory Control, BAC Estimation, Driver Confidence

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COGNITIVE AND BEHAVIORAL MECHANISMS UNDERLYING ALCOHOL-INDUCED RISKY DRIVING

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Chapter 1

OVERVIEW

The social cost associated with driving under the influence (DUI) of alcohol is significant. The World Health Organization (2007) estimates the annual cost of medical care and destruction of property resulting from DUI-related incidences to be approximately $51.1 billion in the United States. This financial burden is due to the high rates of DUI-related traffic injury and fatality. Intoxicated drivers were involved in over 10,000 traffic fatalities in 2012, accounting for nearly one third of all deaths that took place on United States roadways during that year (NHTSA, 2013). This rate is surprising in consideration of the stigma surrounding the act of drunk driving. DUI offenses are determined by a “per se” law for which the legal blood alcohol concentration (BAC) limit is 80 mg/100 ml (limit for the United States). However, many alcohol-related traffic collisions occur when the driver is below the legal limit. It is commonly thought BAC is the key determinant of impairment. However, individual differences in response to the same dose of alcohol can be marked and have been documented for some time (e.g. Linnoila et al., 1986; Fillmore & Vogel-Sprott, 1998). Indeed, individuals at the same BAC can differ greatly in their response to alcohol with some individuals displaying pronounced impairments of functioning whereas others display little or no observable signs of intoxication. Such individual differences call for efforts to better understand the complex causes of DUI-related accidents and fatalities.

Research has sought to understand the role of basic behavioral skills relevant to driving in DUI-related offense. However, these basic skills, such as reaction time and motor coordination, fail to distinguish between safe drivers and those involved in motor vehicle collision (MVC). This has led researchers to move beyond skill-centered models of driving to consider other potential causal factors of MVC, such as driver risk-taking. Risky driving includes on-road behaviors the driver engages in such as speeding, driving too close to vehicles in traffic, using a mobile phone while driving, violating traffic rules, driving at night or while under the influence of alcohol. Risk-based models of driving are concerned with the relationship between perceived and objective risk. Objective risk is the actual probability of being involved in an accident (Deery, 2000; Grayson & Groeger, 2000) while perceived risk refers to the subjective experience of risk. It has been theorized that risk perception is influenced by two inputs. The first is the identification of potential hazards in the driving situation (i.e. hazard perception; Brown & Groeger, 1988; Armsby et al., 1989). The second is drivers' perception of their ability to avoid potential hazards by maneuvering the vehicle to prevent collision (i.e. perceived ability).

Risk-based models of driving assert hazard perception and perceived ability determine drivers' 'risk threshold' (Bloomquist, 1986; Wilde, 1976; Näätänen & Summala, 1974; Stein & Allen, 1987; Janssen & Tenkink, 1988). Drivers select the amount of risk for injury/collision they are typically willing to accept in a driving situation and then behave in accordance with that level of risk acceptance. An individual might increase the amount of risk they are willing to accept for different reasons. Some drivers might increase their risk-taking owing to poor risk perception (e.g. perceive low levels of risk associated with speeding) while others accurately perceive risk in a driving situation and decide to accept it. For instance, a driver may accept the risk associated with speeding to minimize time delays. Personal characteristics of the driver can also influence their risk threshold (Brown & Groeger, 1988; Chalmers et al., 1993; Laapotti, 1994; Twisk, 1995; Gregersen & Bjurulf, 1996; Deery, 2000; McCartt et al., 2009).

The components of risk-models of driving behavior relevant to this dissertation are (1) drivers' actual risk-taking behaviors, (2) their actual driving skill, and (3) their level of confidence as it pertains to driving. There has been no systematic examination of how these components interact in a controlled laboratory setting. Further, these concepts have not been well incorporated into studies of alcohol effects on driving. Although degree of individuals' risky driving might largely account for DUI-related accidents, this has been without concern for the potential confound of alcohol-induced impairments in drivers' skill. It has been assumed alcohol affects both skill and risky driving with equal causal role. As a consequence, little is known about the potentially distinct cognitive-behavioral mechanisms that underlie driver risk-taking and driver skill. Coming to understand how alcohol mediates the relationships between driver risk-taking, skill, and confidence by empirical means will provide information about factors that contribute to DUI-related MVCs.

The studies in this dissertation examine the relationships among the three basic components central to risk-based models of driving in the sober and the intoxicated states. Three experiments were conducted, designed in consideration of three working hypotheses: (1) Alcohol could increase risk-taking behavior in a driver without necessarily producing pronounced impairment in their skill. (2) Poor behavior control and perceiving low impairment by alcohol could contribute to alcohol-induced increases in driver risk-taking. (3) Driver confidence could be a key determinant in the amount of risk one is willing to take when intoxicated. These working hypotheses are developed in Chapters 2, 3 and 4 respectively. Each chapter covers one study in its entirety. To test these hypotheses, studies were designed to (1) determine the effect of alcohol on driver risk-taking and driving skills, and test the relationship between driver risk and skill, (2) examine the cognitive-behavioral profile of individuals who increase risk taking under alcohol and (3) to test whether confidence in driving skill increases risk taking.

Chapter 2

SIMULATED DRIVING PERFORMANCE UNDER ALCOHOL: EFFECTS ON DRIVER-RISK VERSUS DRIVER-SKILL (STUDY 1; Laude & Fillmore)

Introduction

Early research on alcohol-intoxicated driving focused on the impairing effects of the drug on driving behavior, with emphasis on how this pertains to skill. Skills integral to driving include attention, perceptual functions, motor coordination, and reaction time, all of which are sensitive to the impairing effects of alcohol (for a review see Fillmore, 2007). Further, the threshold BACs for such impairments pertaining to alcohol-related traffic injury are well known. There is also evidence that alcohol impairs several aspects of simulated driving performance that are related to the drivers' skill including (1) increased within-lane deviation, (2) slowed braking time and (3) a reduced ability to detect potential hazards on the roadway (Liguouri, 2009; Martin et al., 2013). Furthermore, such impaired functioning is reliably observed at BACs as low as 50 mg/100 ml, with higher BACs generally resulting in greater behavioral impairment (Fillmore, 2007; Holloway, 1995). However, driving skills do not have a strong predictive power on accidents (Sümer et al., 2006). As such, research has shifted to investigate the potential differences in personality characteristics between drivers who are at-risk for DUI-related incidences and those who are not.

Researchers have made great progress towards identifying the psychological attributes of drivers that place them at risk for DUI offense and traffic-related injury. There is growing recognition that DUI offenses and high rates of accidents might be symptomatic of deficient behavioral regulation characterized by impulsivity (Fillmore, 2003; Ryb et al., 2006). The vast majority of this research has relied on surveys and personality inventories. Driving records show that DUI offenders commit more moving violations, such as speeding, and are involved in more accidents compared with the general population (Bishop, 2011; Donovan et al., 1983; McMillen et al., 1992). Personality inventories of DUI drivers reliably show high levels of impulsivity and low risk perception (Hubicka et al., 2010; Miller & Fillmore, 2014; Ryb et al., 2006). These results suggest impulsivity could play an important role in decisions to drive while intoxicated and in patterns of reckless driving.

Impulsivity as a personality construct has been fractionated into different domains: lack of premeditation (i.e., limited forethought), lack of perseverance (i.e., willingness to give up on a task), sensation-seeking (i.e., preference for exciting and stimulating experiences), and urgency (i.e., proneness to react to an emotional state; Whiteside & Lynam, 2001; Whiteside, Lynam, Miller, & Reynolds, 2005). DUI offenders are often characterized by high sensation seeking (Chalmers et al., 1993). Those high in sensation seeking show a tendency to speed, not wear seat belts, drink frequently, drive after drinking and perceive a low risk of detection for impaired driving (Jonah, Thiessen, & Au-Yeung, 2001). Together, these lines of evidence suggest drivers high in trait impulsivity and sensation seekers might tend to increase their risk taking on the roadway.

While there has been increased interest in the possibility that impulsivity might contribute to risky driving behavior, laboratory studies of alcohol impaired driving in simulated environments typically fail to distinguish between the contributions of risk-taking and conventional measures that emphasize impaired driving skill. As such, little is known about how impulsivity might contribute specifically to patterns of risky driving under the influence versus impaired levels of driving skill under the drug. In addition, impulsivity is a multifactorial construct and it is unclear which aspects of impulsivity might play central roles in risky driving behavior. As such, a central aim of the first study of this dissertation was to examine how alcohol contributes to patterns of risky driving separate from its effect on drivers' skill, while also testing the relationship of such driving behaviors to a behavioral mechanism underlying impulsivity; inhibitory control.

Impulsivity and Inhibitory Control

Broadly defined, impulsivity refers to a pattern of under-controlled behavior in which the individual lacks the ability to delay gratification and acts without forethought or consideration of potential consequences. It is important to understand the basic mechanisms that underlie impulsive behavior. Considerable research has focused on individuals' ability to inhibit inappropriate action. The ability to inhibit or suppress an action enhances the organism's behavioral repertoire by affording it some control over when and where responses might be expressed. As such, the inhibition of behavior is an important function that sets the occasion for many other activities that require self-restraint and regulation of behavior. Theories in cognitive neuroscience postulate that the control of behavior is governed by distinct inhibitory and activational systems (Fowles, 1987; Gray, 1975, 1976; Patterson & Newman, 1993; Quay, 1997; Nigg, 2000). Indeed, studies in neuropharmacology and neuroanatomy have identified neural systems that implicate separate inhibitory and activational mechanisms in the expression of under-controlled, impulsive behavior (Diekhof & Gruber, 2010; Fillmore, 2003; Lyvers, 2000; Miller & Cohen, 2001). The orbitofrontal and medial prefrontal cortex contain neural substrates that subserve the inhibition and suppression of behaviors. Substrates of the mesolimbic system mediate behavioral activation and reward-seeking through dopaminergic pathways that are responsive to reinforcing stimuli, including drugs of abuse. It is further suggested that impulsivity reflects an imbalance in these countervailing mechanisms due to poor behavioral inhibition and/or heightened reward-seeking (de Wit, 2009; Fillmore & Weafer, 2011).

Deficits of inhibitory control are measured by reaction time models, such as the cued go/no-go task, which test ones' ability to inhibit action (e.g., Fillmore, 2003). The cued go/no-go task measures subjects' ability to inhibit pre-potent responses to the sudden presentation of a no-go target stimulus. The psychometrics of these models have been well documented; measures of inhibitory control have shown high degrees of test-retest reliability and validity as evident by deficits in inhibitory control displayed in certain clinical groups (e.g. individuals with ADHD; Weafer, Milich, & Fillmore, 2011). Studies also show that the cued go/no-go task is sensitive to the disinhibiting effects of alcohol with impairment observed at BACs as low as 50 mg/100 ml, below the legal limit of intoxication for driving in the United States (Marczinski & Fillmore, 2005, 2009; Fillmore et al., 2005; Fillmore & Weafer, 2011).

Impulsivity, Inhibitory Control and Risk Acceptance among Drivers

Impulsivity may play an important role in the amount of risk a driver is willing to take behind the wheel. Researchers have moved beyond skill-centered models of driving to consider other potential causal factors in MVC, such as drivers' motivational state. These frameworks focus on what the driver actually does behind the wheel, rather than what the driver is capable of doing. Chief among these frameworks are risk models. Risk-based models recognize that drivers select the amount of risk for injury/collision they are typically willing to accept in a driving situation and then behave in accordance with that level of risk acceptance. Such risk-based models of driving have taken to the measurement of risky driving based on proxemics analyses that examine the position of the driver's vehicle relative to other vehicles, while also considering speeds of the vehicles in the situation. Riskier driving is indicated by behaviors that place the driver's vehicle closer to others on the roadway (e.g., tailgating), and is considered to be a major contributing factor in MVCs (Taieb-Maimon & Shinar, 2001; Zhang & Kaber 2013).

Driving often poses response conflicts for drivers in which they must inhibit instigations to speed or to tailgate slower drivers in efforts to arrive at a destination on time, especially in situations of heavy traffic. Drivers with poor inhibitory control might be especially vulnerable to risk taking in these situations. With regard to the effects of alcohol, it is possible that the drug may exert effects on risk-taking by compromising inhibitory control. This may be independent of the drug's disruptive effects on the driver's skill that operates by impairing motor coordination, visual attention, and reaction time. One method to test such an assertion is to compare alcohol effects on behavior in driving situations where participants are instigated into risk-taking versus those that emphasize a high level of visual-motor skill. Indeed, the impairing effects of alcohol on inhibitory control might be particularly important to driving behavior in situations in which individuals must overcome the impulse to take risks, such as speeding and tailgating. By contrast, the impairing effects of alcohol on basic skills, such as motor coordination and attention might be especially critical to driving in situations that require continued vigilance to a changing roadway or in situations in which potential distractions are present. It is also possible drivers who are generally impulsive and high in sensation seeking would tend to increase their risk taking in both sober and intoxicated states.

Distinguishing Alcohol Effects on Driver Risk versus Driver Skill

Previous work in our laboratory has pointed to the potential importance of drivers' inhibitory control as a factor that can influence the degree to which alcohol impairs driving performance (e.g. Fillmore et al., 2008). However, the extent to which the drivers' inhibitory control selectively contributes to indices of risky driving behaviors (e.g., tailgating), or more generally to all indices of driving behavior, including measures of driving skill (precision of lane position), is unknown. Alcohol-related MVCs are often attributed to reckless and impaired driving with little attention to the relative contribution of these potentially distinct drug affects. It is generally assumed that alcohol affects both skill and risky driving with equal causal role. However, it is possible that alcohol might increase risk-taking behavior in a driver without necessarily producing pronounced impairment in the driver's skill (Barry, 1973). This might be especially evident in drivers with poor inhibitory control who might be more vulnerable to the disinhibiting effects of the drug. That is, individuals who are more disinhibited by alcohol might not be similarly sensitive to alcohol-induced disruptions of their visual-motor skills. So too, drivers with greater inhibitory control might be less vulnerable to the disinhibiting effects of the drug, and this might have little to do with their sensitivity to alcohol's impairing effects on their visual-motor skills.

Study 1 of the dissertation sought to test the separate effects of alcohol on adult driver's risk taking and their skill level during tests of simulated driving. Drivers were tested in two different simulated driving scenarios. One scenario was a "skill-relevant" situation that emphasized driver's visual motor skill as measured by ability to maintain precise lane position over a winding road. The other drive presented a "risk-relevant" situation that instigated risk-taking behavior by placing the participant in a high-traffic driving situation; the primary measure captured how close drivers maneuvered among other vehicles in traffic while also accounting for the closing speed of the vehicles in the situation. Tests were completed under two doses of alcohol: 0.65 g/kg alcohol, and 0.0 g/kg (placebo). The study also examined the relationship between alcohol-induced disinhibition and driving behavior. It was predicted that alcohol would impair driving skill and increase risky driving. It was also anticipated that poorer inhibitory control would be associated with increases in risky driving, especially under alcohol. Lastly, we expected heightened levels of trait impulsivity and sensation seeking would be predictive of increased risk taking on the roadway but not necessarily predictive of poor driving skill following alcohol and placebo.

Methods

Participants

Thirty-four adults between the ages of 21 and 34 (20 women and 14 men) participated in the study. 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 performance. Volunteers had to be consumers of alcohol and hold a valid driver's license. Individuals were also excluded if their current alcohol use met dependence/withdrawal criteria as determined by the substance use disorder module of the Structured Clinical Interview for DSM-IV (SCID-IV). Individuals reporting any psychiatric disorder, CNS injury, or head trauma were excluded from participation. Urine samples were tested for the presence of drug metabolites (ICUP Drug Screen, Instant Technologies). Any volunteer who tested positive for the presence of any of these drugs during any test session was excluded. However, participants who tested positive for tetrahydrocannabinol (THC) were retained provided they did not self-report any past 24 hour use. No female volunteers who were pregnant or breast-feeding participated in the research, as determined by self-report and urine human chorionic gonadotrophin levels (Icon25 Hcg Urine test, Beckman Coulter). Sessions were conducted in the Human Behavioral Pharmacology Laboratory of the Department of Psychology. Volunteers were required to abstain from alcohol for 24 hours and fast for 4 hours prior to each treatment session. Test sessions were initiated between 10:00 a.m. and 6:00 p.m. At the beginning of each session, a zero BAC was verified by the Intoxilyzer. The University of Kentucky Medical Institutional Review Board approved the study. All study volunteers provided informed consent and received $110 (plus bonus money earned in drives) for their participation.

Materials and Measures

A computerized driving simulator was used to measure driving behaviors (STISIM Drive, Systems Technology Inc., Hawthorne, CA). The simulations 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. The participant had full view of the road surroundings and instrument panel, which included an analog speedometer. 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.

Test of Driver Skill (see Figure 2.1, left panel). This drive was designed to test skill-related driving performance. This 15-minute simulated driving course consisting of 80,000 feet winding two-lane highway through a rural setting with overcast skies, buildings and trees. Drivers were instructed to maintain a constant speed of 55 mph while remaining in the center of the right lane for the duration of the drive. The drive scenario included both straight and winding sections, requiring vigilance on the part of the driver in order to maintain the vehicle in the center of the lane.

Test of Driver Risk-Taking (see Figure 2.1, right panel). This 5-10 minute drive (depending on the speed of the participant) was designed to test risky driving behavior. This simulated driving scenario required participants to drive 21,100 feet on a busy 4-lane street within metropolitan setting. There was no posted speed limit. Each direction of traffic was comprised of two lanes. The driver was free to navigate among other vehicles within the driver's two lanes of traffic. Other vehicles were presented at various speeds in both lanes such that the driver had to change lanes to overtake vehicles in order to maintain speed. To instigate the potential for risk-taking, drivers could earn monetary reinforcement for quickly completing the drive: $5 for completion in under 5 minutes, $4 for 5–6 minutes, $3 for 6–7 minutes, $2 for 7–8 minutes, $1 for 9–10 minutes, and $0.50 for over 10 minutes. There was a penalty for crashing (loss of $0.25/crash), which conflicted with the incentive to speed during the trip. Response conflict of this kind has been used in other research (Fillmore, Blackburn, & Harrison, 2008) and affected driving behavior.

Cued Go No-Go Task. Inhibitory control was measured by a cued go/no-go reaction time task used in other research to measure the disinhibiting effects of alcohol (e.g., Fillmore et al., 2008). E-Prime experiment generation software (Schneider et al., 2002) was used to operate the task, which was performed on a PC. The task requires finger presses on a keyboard, and measures the ability to inhibit the pre-potent behavioral response of executing the key press. Cues provide preliminary information regarding the type of imperative target stimulus (i.e., go or no-go) that is likely to follow, and the cues have 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. Key presses were made with the right index finger. To encourage quick and accurate responding, feedback was presented to the participant during the inter-trial interval by displaying the words correct or incorrect along with the reaction time in milliseconds.

Barratt Impulsiveness Scale (BIS). This 30-item self-report questionnaire is designed to measure the personality dimension of impulsivity (Patton & Stanford, 1995). Participants rate 30 different statements, such as “I act on impulse” and “I consider myself always careful,” 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.

Urgency, Premeditation, Perseverance, Sensation Seeking Scale (UPPS). The UPPS is a 45-item scale designed to assess urgency, lack of planning, lack of perseverance, and sensation seeking. Participants are presented with items such as "I generally seek new and exciting experiences and sensation" and "I quite enjoy taking risks," which they are to rate on a Likert scale ranging from 1 (*agree strongly*) to 4 (*disagree strongly*; Whiteside and Lynam, 2001). The different scales of the UPPS have demonstrated high convergent and discriminant validity (Smith et al., 2007). Higher scores within each of the four sub-scales indicate higher levels of self-reported impulsiveness.

Drinking Habits. The Timeline Follow-back calendar (TLFB; Sobell & Sobell, 1992) was used to assess daily patterns of alcohol use over the past 90 days. This measure uses a structured calendar anchored with notable dates to facilitate recall of past drinking. The TLFB provided a measure of drinking days, total number of drinks consumed and the number of drinking days that they felt drunk (drunk days) in the past 90 days.

Driving History and Experience Questionnaire (DHEQ). This self-report questionnaire gathered information on driving history such as driving experience, length of time holding a driver's license, and number of days driven/week. The questionnaire also provided information about participants' driving behaviors, such as traffic accidents and traffic tickets.

Procedure

Familiarization Session. The purpose of this session was to familiarize participants with the laboratory procedures, obtain information on driving history (DHEQ), drug use (Drug Use and SCID interviews), drinking patterns (TLFB), general health status and demographic characteristics. Participants also practiced the skill and risk-relevant drives as well as the cued go/no-go task.

Test Sessions. Each dose was administered on a separate test session, and all participants received each dose. Dose administration was blind, and dose order across the sessions was counterbalanced across participants. At the beginning of each session, participants received either 0.65 g/kg alcohol or a placebo. The 0.65 g/kg dose was administered as 95% alcohol containing one part alcohol and three parts carbonated mix. The placebo (0.0 g/kg) consisted of a volume of carbonated mix that matched the total volume of the 0.65 g/kg alcohol drink. A small amount (3 ml) of alcohol was floated on the surface of the beverage. Glasses were sprayed with an alcohol mist that resembled condensation and provided a strong alcoholic scent as beverages were consumed. The timing of placebo beverage consumption was identical to the active dose. The active dose typically produces an average peak BAC of 80 mg/100 ml, approximately 60-70 min after drinking. The dose was chosen based on prior research that has shown that the dose reliably affects driving behavior in driving simulations (Harrison & Fillmore, 2005; Weafer & Fillmore, 2012). Women can achieve higher BACs than men for a given alcohol dose. To correct for potentially higher BACs among women, they received 86% of the dose (Fillmore, 2001).

Subjects performed the task battery, which consisted of the cued go/no-go task, skill drive and risk drive post-alcohol administration. The test battery was initiated at 20 min and ended at 70 min post alcohol administration. Tests were separated by 5 min rests. Thus, all testing occurred during the ascending period of the BAC curve. BACs were measured at 40 and 70 minutes post beverage administration (Intoxilyzer Model 400, CMI Inc.). Participants also provided breath samples following placebo ostensibly to measure their BAC. After a test session concluded, participants relaxed in a waiting room within the laboratory. Participants received a meal and remained at leisure until their BAC fell below 20 mg/100 ml. Transportation home was provided. Upon completing the final session, participants were paid and debriefed.

Criterion Measures

Standard Deviation of Lane Position (LPSD). The primary measure of driving skill was LPSD (see Figure 2.2). This is an indicator of the degree of adjustment that a driver implements to maintain a desired position within the lane. The driver's lane was 12 feet wide and the within-lane position of the vehicle was obtained by averaging the deviation measures sampled at each foot of the driving test. LPSD is the standard deviation of the driver's average within-lane position and is a primary indicator of driving impairment. Greater LPSD indicates poorer driving precision and the measure has been shown to be a sensitive indicator of alcohol intoxication (e.g., Harrison & Fillmore, 2005; Weafer & Fillmore, 2012). Average drive speed was measured in terms of miles per hour (mph) averaged over the drive. Accidents were measured by the number of times drivers crashed into another vehicle or by going off road.

Time to Collision (TTC). The primary measure of driver risk-taking was TTC (see Figure 2.3). TTC is a time-related safety margin measure (Taieb-Maimon & Shinar, 2001), determined by the bumper-to-bumper distance between two vehicles divided by the closing speed of the vehicles (Zhang & 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 the lead and the driven vehicle were to continue on the same course (Zhang & Kaber 2013). A TTC value was calculated for each traffic situation encountered by the driven car. The TTC score for a given subject was then defined as the minimum TTC value in the distribution of traffic encounters. This encounter represents the riskiest instance, or the point the driver came closest to an accident across the drive. Riskier driving was indicated by smaller TTC values (seconds). Average drive speed (mph) and accident frequency were also recorded.

Inhibitory Control. Failures of response inhibition in the cued go/no-go task were measured as the proportion of no-go targets in which a participant failed to inhibit a response (p-inhibition failures). The measure of interest was the proportion of inhibition failures in the go cue (i.e., pre-potent) condition. This proportion was calculated based on the 25 trials in which no-go targets were preceded by go cues. Greater p-inhibition failures indicate poorer inhibitory control (i.e., disinhibition). Speed of responding to targets in the go cue condition was measured by the participant's average reaction time (msec) for a test.

Results

Demographics, Drinking and Driving History, and other Drug Use

The racial makeup of the sample was 68% Caucasian, 20% African-American, 9% Asian and 3% other. Mean scores regarding months of licensed driving and driving days per week as indicated by the DHEQ demonstrate that participants were experienced drivers and drove weekly (Table 2.1).

Subjects tended to drink on 1/3 of the 90 days prior to their scheduled sessions (see Table 2.1 for drinking habits). Participants did not report any withdrawal symptoms during the SCID-IV. The majority of subjects reported caffeine use (n=29). Tobacco use (n=11), stimulant use (n=2), and THC use (n=11) was also reported. No other drug use was reported. No participant reported daily use of any drug except for caffeine. Urine analyses indicated that participants were negative for the use of all drugs except for THC. Of the 11 subjects who reported past month THC use, 7 of them actually tested positive. No subject reported using THC within twenty-four prior to testing.

Blood Alcohol Concentrations

No detectable BACs were observed under the placebo condition. BACs following the active dose were examined by a 2 (sex) x 2 (time) mixed-model analysis of variance (ANOVA). All terms in the model were nonsignificant, $ps > 0.12$, indicating that BACs across sex and time were comparable. The mean BAC (mg/100 ml) at each time point collapsed across sex was as follows: 40 min = $M = 61.79$, $SD = 16.13$, 70 min = $M = 71.65$, $SD = 12.98$, yielding an average change of 9.85 mg/100 ml ($SD = 16.76$ mg/100 ml) over the 30 minute time period.

Test of Driver Skill

A one-way repeated-measures ANOVA confirmed that drivers' standard deviation of lane position (LPSD) was significantly greater under alcohol compared with placebo. $F(1, 33) = 15.17$, $p < 0.001$, $\eta p2 = 0.31$. Figure 2.4 (left panel) plots mean LPSD values, which increased under alcohol relative to placebo during the skill-relevant drive. Thus, drivers were less able to maintain their vehicle in the center of the lane under active dose.

Drivers were in more off-road accidents under alcohol, $M = 2.24$, $SD = 4.48$, relative to placebo, $M = 0.56$, $SD = 1.11$, $F(1, 33) = 6.44$, $p = 0.02$, $\eta p2 = 0.16$. No significant effects on drive speed were found under placebo relative to alcohol $F(1, 33) = 0.52$, $p = 0.48$. Drivers also abided by the 55 mph speed limit under placebo, $M = 54.64$, $SD = 2.60$, and alcohol, $M = 55.15$, $SD = 3.24$, $ps > 0.43$, conditions.

Test of Driver Risk-Taking

A one-way repeated-measures ANOVA revealed a significant dose effect on time to collision, (TTC), $F(1, 33) = 6.85$, $p = 0.01$, $\eta p2 = 0.17$. Figure 2.4 (right panel) plots mean TTC values, which shows that TTC was reduced following alcohol, indicating a reduced time to a potential collision with other vehicles.

Drivers were in more accidents under alcohol *M* = 0.91, *SD* = 0.93, relative to placebo, *M* = 0.38, *SD* = 0.74, *F* (1, 33) = 6.77, *p* = 0.01, ηp2 = 0.17. No significant difference in drive speed was found between placebo, *M* = 48.39, *SD* = 9.90, and alcohol, *M* = 48.65, *SD* = 10.11, conditions, *F* (1, 33) = 0.04, *p* = 0.84.

Relations of Drivers' Skill to their Risky Driving

Correlational analyses were performed to test associations between risk (TTC) and skill-related driving (LPSD). Testing revealed that TTC and LPSD were not related under placebo, *r*(33) = 0.01, *p* = 0.95, or following the active dose, *r*(33) = -0.20, *p* = 0.26. These analyses indicate that risky driving behavior was not necessarily accompanied by poor driving skill.

Inhibitory Control

Failure of response inhibition was measured as the proportion of no-go targets in which a subject failed to inhibit a response. These p-inhibition failure scores were calculated for the go cues. Alcohol impairment of p-inhibition failures was analyzed by a one-way repeated-measures ANOVA and revealed a significant difference between alcohol and placebo tests, *F* (1, 33) = 7.02, *p* < 0.01, ηp2 = 0.17. Figure 2.5 (left panel) shows that alcohol impaired inhibitory control, as evident by an increase in p-failures under alcohol relative to placebo. A one-way repeated-measures ANOVA revealed that the difference in reaction times between placebo and alcohol tests was nonsignificant, *F* (1, 33) = 2.33, *p* = 0.14 (right panel in Figure 2.5). This indicates that p-inhibition failures scores were not produced by a speed-accuracy tradeoff.

Relation of Impulsivity to Drivers' Risk and Skill

Zero-order correlations were performed to test associations of inhibitory control with measures of participants' risk and skill-related driving in both the sober and intoxicated states. In the sober state, it was found that greater inhibitory failures predicted lower TTC values during the risk-related driving task, TTC, $r(33) = -0.40$, $p = 0.02$. However, in the intoxicated state, inhibitory failures were not related to TTC, $r(33) = -0.001$, $p = 0.99$. With respect to drivers' skill, inhibitory failures showed no relationship to drivers' LPSD as measured by the skill-relevant drive in the sober, $r(33) = 0.04$, $p = 0.84$, or intoxicated state, $r(33) = -0.09$, $p = 0.61$.

Given the evidence that drivers' TTC scores could be predicted by their inhibitory control, a multiple regression analysis examined the degree to which TTC and LSPD could each account for unique variance in drinker's inhibitory control. The analysis was conducted separately for the measures obtained in the sober state (placebo) and in the intoxicated state (alcohol). In the sober state (placebo), TTC, $b = -0.40$. $SE = 0.17$, $t(31) = 2.40$, $p = 0.02$, but not LPSD, $p = 0.80$ accounted for a unique amount of variance in driver's inhibitory control. In the intoxicated state, neither TTC nor LPSD accounted for variance in inhibitory control. $ps > 0.61$.

Trait levels of impulsivity as indicated by the total score on the BIS did not significantly predict driving skill or risky driving under placebo or active dose, $ps > 0.31$. There was also no evidence of a relationship between sensation-seeking as indicated by the UPPS and driving behaviors across sober or intoxicated states, $ps > 0.05$.

Driving Behavior in THC Users

Eleven subjects reported use of THC in the past 30 days. It is conceivable that such individuals might differ in their responses to alcohol relative to non-users. As such, we conducted exploratory analyses for possible differences between THC users and the non-users in their response to alcohol on LPSD and TTC driving measures. Two subject groups were formed: 11 THC users and 23 non-users and dependent measures were analyzed by 2 (group) X 2 (dose) ANOVAs. The group factor did not interact with dose effects on an either driving measure ($ps >$ 0.31). Thus, marijuana users did not differ from non-users in their reactions to alcohol.

Discussion

This study tested the relationship between alcohol's effects on risky driving and its impairing effects on driver skill. It also examined whether driver inhibitory control contributed to driver's risk level but not necessarily to driving skill. To examine these hypotheses, participants completed the two driving simulation tasks (skill and risk-relevant drives) and the cued go/no-go task under two doses of alcohol: 0.65 g/kg alcohol, and 0.0 g/kg (placebo). The active dose of alcohol impaired driving skill (increase in LPSD), increased risk-related driving (lower TTC values), and produced an increase in disinhibition (failures of response inhibition). Driver's poor inhibitory control predicted an increase in the amount of risk the driver was willing to accept in the sober state. We did not did find evidence that risky driving was related to driving skill. Lastly, impulsivity as a personality construct and sensation seeking were not significantly related to impairments in drivers' skill or increased risky driving.

That alcohol impaired a principal indicator of skill-related driving replicates earlier work (see Moskowitz & Fiorentino, 2000, for a review; Harrison & Fillmore, 2005; Miller, Weafer, & Fillmore, 2012). The result indicates that intoxicated drivers show a reduced ability to control a motor vehicle. It was also found that alcohol increased risky driving. This indicates that intoxicated drivers select greater risk for injury/collision in a driving situation. Evidence that elevated risk level might increase under alcohol despite a concomitant impairment of skill highlights the serious potential hazards associated with driving under the influence.

This study also tested whether alcohol's effects on risky driving were related to its impairing effects on driver skill. Attempting to isolate risky driving from driver skill is important given that risky driving accounts for 78.9% of fatal crashes in young adults (Department of Transport and Main Roads, 2011), and this number only increases under alcohol. However, whether such accidents were a result of general elevation in risky driving or some action slip related to impairment in driver skill is unknown. Risk and skill-relevant driving were not related in the sober or intoxicated states in this study. We also examined the possibility that a relationship between skill and risk could be observed in terms of the degree to which these measures changed from the sober to the intoxicated state. To examine this, we computed the difference in LSPD between placebo and alcohol and difference in TTC between the two dose conditions. A Pearson correlation between the two sets of difference scores revealed no significant relationship, $p > 0.05$. Collectively, these data suggest that DUI-related accidents may result from drivers who either display alcohol-induced increases in risk acceptance, impaired skill, or some combination of both. In considering the individual differences commonly observed in response to alcohol, it is perhaps unsurprising that elevated risk taking is not always accompanied by high skill impairment. Thus, although alcohol-related accidents have been found to result from both increased risky driving and impairments in skill, our data suggest that any given accident does not necessarily result from the co-occurrence of these two factors.

The present study highlights that drivers differ in levels of risk elevation and skill impairment in response to alcohol. Individuals who show elevations in risk taking despite high skill impairment may be generally insensitive to their reduced ability to drive under alcohol. As a result, they may also be prone to making more impulsive decisions, such as driving after drinking. Such drivers would likely represent high-risk for DUI-related crashes and injury. Another type of driver would be one who shows elevated risk-taking but low impairment of skill from alcohol. These individuals might overestimate their ability under alcohol and consequently fail to consider hazards/risks on the road. Indeed, there is evidence that extreme reliance on driving skill is accompanied by low levels of safety skills, and that this produces risky driving (e.g., Deery, 2000; Gregerson, 1996). In sum, our failure to find support for the relationship between sensitivity to alcohol-induced changes in driver skill and driver risk, suggests that individuals could have different behavioral profiles in how they typically respond to alcohol in terms of their skill and their motivational state. As such, it would be important to determine the reliability of such response profiles among drivers and identify their underlying cause which could involve pharmacological factors, such as alcohol tolerance, as well as psychological characteristics, such as the driver's personality.

The current study provided some new evidence that poor inhibitory control may contribute to risky driving behavior. In line with prior work from our laboratory, it was found that alcohol decreased inhibitory control. Indeed, the present study showed that the same dose of alcohol that increased drivers' risk acceptance also increased their level of disinhibition. This association was also evident at the level of the individual. Following placebo, drivers with poorest inhibitory control displayed the greatest risk level in their driving behavior. This correlation was not observed under alcohol. However, as drivers became more risky under alcohol, their TTC values approached the floor value of zero, restricting the variance of the measure, which was reduced relative to placebo. Taken together, the results suggest that drivers with poor inhibitory control could be especially vulnerable to risk taking.

The present study found that neither impulsivity as a personality characteristic nor levels of sensation seeking predicted driver risk or skill. Insufficient variability across measures could explain our failure to detect significant correlations; most scores were in the first quartile for the BIS and UPPS measures. It could also be that more extensive personality assessments, such as the revised NEO Personality Inventory (NEO PI-R; Costa, & McCrae, 1995), are needed to detect relationships between impulsivity and sensation seeking to risky driving. Alternatively, impulsivity as a personality characteristic and sensation seeking might be too broad of constructs to reliably predict driving behavior in specific situations. The observed relationship between inhibitory control, which is thought to underlie impulsive behavior, and risky driving, supports this idea. Personality constructs might relate to more general tendencies or habits of the driver.

With regard to limitations, it is important to recognize that neither driving scenario was a pure test of risk or of skill. Despite our attempt to isolate risk and skill as they pertain to driving, the drive tests were likely affected by both factors. However, our goal was to design ecologically valid driving scenarios that emphasized one factor while minimizing the influence of the other. For example, in the skill drive, there was a set speed limit, which minimized the likelihood that participants would speed, something that contributes to risky driving. With regard to the risk-relevant drive, there was no set speed limit and response conflict was introduced to encourage risky behavior. It should also be noted that the risk and skill-relevant drive tests occurred in a fixed order. Although there was no significant change in BAC across these tasks, which would render interpretation of these results problematic, future work should counterbalance the order of the drives.

A further limitation of this research is that the assessments of driving behaviors were limited to the ascending limb of the BAC curve. Acute alcohol tolerance refers to the observation of reduced impairment at a given BAC in the later phase of a drinking episode (e.g., Vogel-Sprott, 1979; Schweizer & Vogel-Sprott, 2008). The decision to drive tends to occur after drinking and as such, driving under the influence likely coincides with the descending limb of the BAC curve. The present study found a relationship between risky driving and inhibitory control. It has also been demonstrated that disinhibition does not show acute tolerance to the impairing effects of alcohol (Ostling & Fillmore, 2010). Taken together, these findings suggest that risky driving may not display acute tolerance owing to a lack of the necessary inhibitory control needed to minimize the level of risk acceptance. Thus, studying acute tolerance to risk acceptance could provide information concerning DUI-related accidents and fatalities.

Future research should investigate how other at risk populations, such as those who use illicit substances, may differ in their response to alcohol on measures of driver risk and skill. In the present study, nearly half of the sample self-reported THC use. Although no interactive effect between responses to alcohol on measures of driving behavior and THC use was found, further research is warranted.

We also recognize that we are advancing the conclusion that skill and risk can be independent based on the absence of a correlation. It is possible that a larger sample size would have allowed for us to detect correlations among measures of driver risk and skill. However, it should be noted that samples of this size that have a within subjects component are robust to detecting relationships (e.g. Harrison & Fillmore, 2005). Nonetheless, a relationship may be evident in different populations or conditions.

In conclusion, this study is the first to isolate alcohol-induced increases in risk-related driving that can occur independent of alcohol-induced impairments in skill-related driving. These findings highlight the need to further examine the psychological profile of individuals that have risky driving styles. To this point, a personal characteristic of drivers that could place individuals at risk for DUI was identified in this study. It was found that disinhibited drivers demonstrated pronounced risky driving in the sober state. These data highlight the need to apply such a fundamental distinction between risk and skill-related driving in the investigation of problems concerning DUI-related accidents in future research. That alcohol-induced risk-taking behaviors are dissociable from impairing effects on driver skill could provide new information on how personal characteristics interact with alcohol to produce DUI-related accidents and fatalities.

The present study successfully demonstrated that the concept of driver risk-taking could be empirically tested in the laboratory. The research also showed alcohol-induced increases in risky driving do not necessarily co-occur with alcohol-induced impairments in the driver's skill. While considering this fundamental distinction, a personal characteristic of risky driving was also identified; disinhibited drivers demonstrated elevations in risk taking in the sober state. Further examination of the psychological and behavioral profile of individuals who display increased risk taking despite high skill-impairment by the drug seems critical, such is the goal of Study 2 of the dissertation.

Table 2.1

Background characteristics of sample. Months driving = total months of licensed driving; Driving frequency = total number of driving days per week. Drinking measures were calculated on the basis of the TLFB; Drinking Days = TLFB total drinking days in the past 3 months; Total Drinks = total drinks consumed in the past 3 months; Drunk Days = total number of days in which the participant drank to a level that they felt drunk

	M	*SD*
Months Driving	91.06	47.98
Driving Frequency	5.00	2.31
Drinking Days	30.29	18.75
Total Drinks	106.78	85.31
Drunk Days	9.59	8.76

Figure 2.1

Figure 2.1. The left panel shows a screen shot from the test of driver skill, used in Experiments 1 and 2 in which the speed limit was 55 mph. The same drive scenario was used in Experiment 3 as a test of driver risk-taking and their skill level in which subjects could drive anywhere between 45-65 mph. The right panel displays a scene from the test of driver risk-taking used in Experiments 1 and 2 in which speed was free to vary.

Figure 2.2

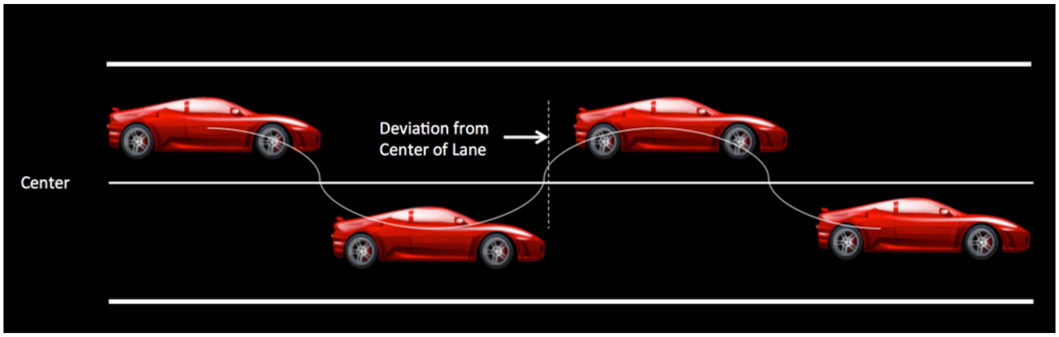

Figure 2.2. Above is a visual representation of the criterion measure, Lane Position Standard Deviation (LPSD), which is a measure of driving skill. LPSD measures the ability of the driver to maintain the position of their vehicle in the center of the right lane (measured in ft). The illustration shows the driver deviating from the center of the lane. Greater deviation is represented by larger LPSD values. A driver with a LPSD value of 1.2 ft is said to be more skilled than a driver with a LPSD value of 2.0 ft. The driver depicted here might be seen as unskilled due to the extent he deviates from the center of the lane.

Figure 2.3

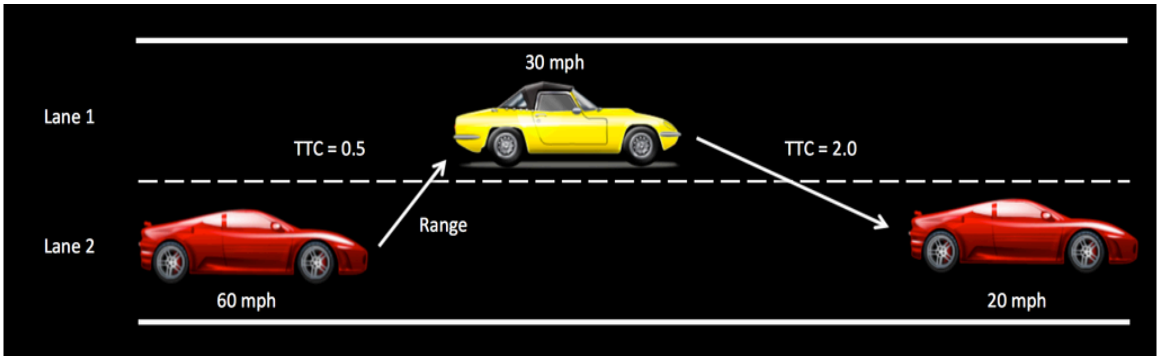

Figure 2.3. Above is a visual representation of the criterion measure, Time to Collision (TTC), a measure of driver risk-taking obtained in Experiments 1 and 2. TTC is a time-related safety margin measured (seconds). It captures the bumper-to-bumper distance between two vehicles while also accounting for the closing speed of the vehicles. The depiction above shows the first red car has a TTC of 0.5 s in relation to the yellow car. This value was calculated by considering how close the red car was to the yellow car (determined by the range), while also accounting for the fact it is traveling 30 mph faster than the yellow car. The driver in the red car would crash into the yellow car if his reaction time to respond to the yellow car merging into his lane, for example, was longer than half of a second. The driver in the yellow car is a comparatively safer driver because he is a further distance from the red car in front of him and is traveling only 10 mph faster than said car (TTC value 2.0 s). A driver with a TTC value of 0.5 s is riskier than one with a TTC of 2.0 s.

Figure 2.4

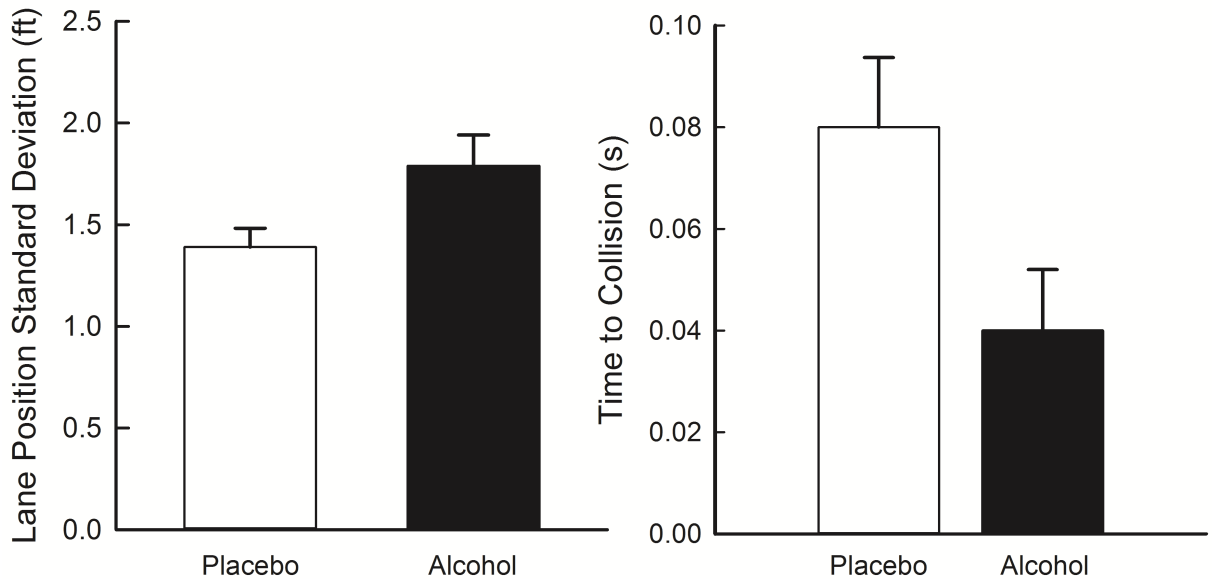

Figure 2.4. Criterion measures for skill and risk-relevant drives. The left panel shows the mean deviation of lane position (LPSD) from the skill-relevant driving simulation under placebo and 0.65 g/kg alcohol. The right panel depicts the mean time to collision values (TTC) from the risk-relevant driving situation under placebo and 0.65 g/kg alcohol in the risk-relevant driving simulation. Capped vertical lines indicate standard error of the mean.

Figure 2.5

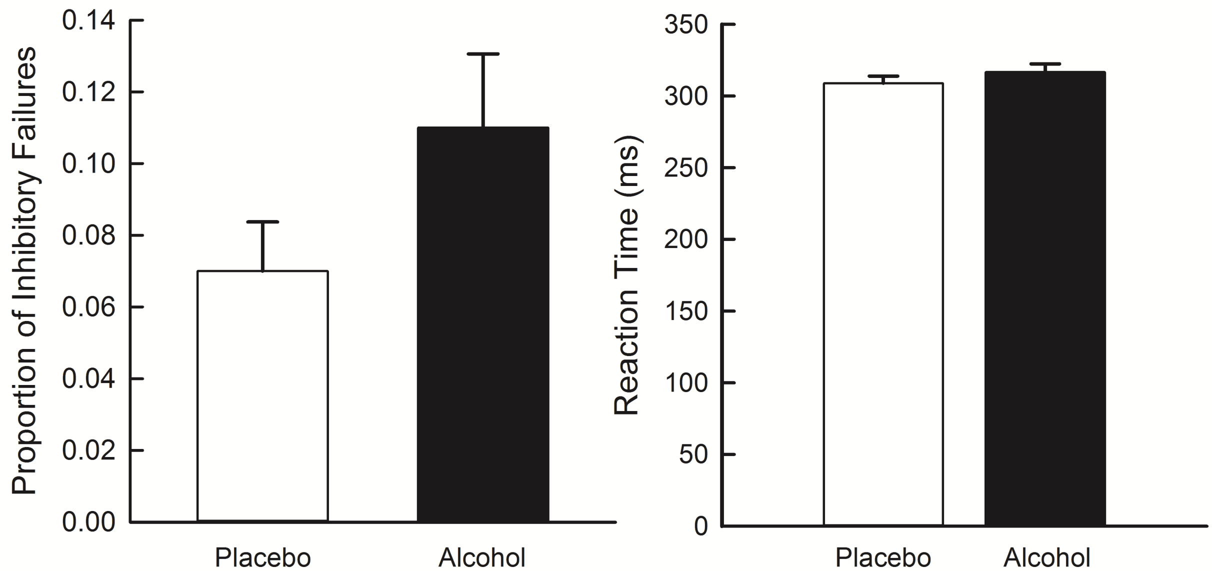

Figure 2.5. Performance measures in cued go/no-go task. The left panel shows the mean proportion of inhibitory failures on the cued go/no-go task under placebo and 0.65 g/kg alcohol. The right panel depicts reaction time to the go cue task under placebo and 0.65 g/kg alcohol. Capped vertical lines indicate standard error of the mean.

Chapter 3

DRIVERS WHO SELF-ESTIMATE LOWER BLOOD ALCOHOL CONCENTRATIONS ARE RISKIER DRIVERS AFTER DRINKING (STUDY 2; Laude & Fillmore)

Introduction

From Study 1, we learned that driver risk and skill were not necessarily related in both the sober and the intoxicated states, which implies there is some degree of independence in the extent alcohol affects these measures. Such individual differences suggest certain factors may differentially influence these distinct driving behaviors under alcohol. The prior study also revealed some drivers displayed pronounced alcohol-induced impairment of skill, but this was not always accompanied by an elevation in risky driving behavior. Those who displayed marked increases in risky behavior in response to alcohol, despite high skill-impairment, would appear to be of greatest risk for traffic-related injury. As such, it is important to identify these drivers and determine personal characteristics that might reliably differentiate them. One such characteristic may pertain to a reduced sensitivity to the drug's subjective effects, which may function to increase driver risk-taking. The role of such sensitivity to the effects of alcohol on risky driving will be the focus of the second experiment proposed.

Drinkers' Self-perceptions of Alcohol Intoxication and Decisions to Drive

One personal characteristic that has attracted research attention concerns the drinker's self-perception of alcohol intoxication (e.g. Beirness, 1987). Such self-evaluations are influenced by a host of factors, including interoceptive cues (e.g. euphoria, light headedness) and behavioral changes associated with intoxication (e.g. slurred speech, impaired gait). These cues can serve as a basis for drinkers to estimate their BAC, which can affect efficacy judgments concerning their overall functioning (Verdejo-Garcia et al., 2012). However, drinkers tend to be naive about alcohol pharmacokinetics and there is often a discrepancy between their estimated BAC after drinking and their observed BAC (Martin et al., 1991; Grant et al., 2012). Indeed, errors of overestimation and underestimation of BAC have been reported (Beirness, 1984, 1987). Underestimation is thought to result from reduced sensitivity to interoceptive and behavioral cues that signal impairment. Errors of underestimation are especially dangerous if drinkers perceive they are fit to drive despite elevated BACs (Martin et al., 1991, Grant et al., 2012).

Indeed, laboratory studies find that underestimators are more willing to drive when above the legal limit relative to those who are more accurate in their estimations (Beirness, 1984, 1987; Mundt et al., 1993). There is also some evidence that such individual differences in patterns of BAC estimation and willingness to drive remain stable over time (Quinn & Fromme, 2012). Underestimators also tend to generally prefer risky over safer alternatives (e.g. Proestakis et al., 2013). Those who underestimate their BAC also report more problems with alcohol (Bois & Vogel-Sprott, 1974; Lansky et al., 1978; Beirness, 1984, 1987; Aston & Liquori, 2013; Aston et al., 2013). Collectively, the results suggest BAC underestimation might be characteristic of impulsive individuals that could account for their increased willingness to drive after drinking.

BAC Estimation Error and Driver Risk-Taking

There is convincing evidence that BAC underestimation can promote the decision to drive after drinking. However, little is known about how underestimation of BAC might affect driving behaviors. Alcohol impairs driving skills including steering and the ability to maintain vehicle position on the roadway (Moskowitz & Fiorentino, 2000; Liguori et al., 2009). Alcohol also increases driver risk-taking, such as tailgating (Fillmore, Blackburn, & Harrison, 2008; Laude & Fillmore, 2015). Some drivers experience elevations in their risk-taking while driving skill is minimally impaired, whereas others show little change in risk-taking following alcohol but display considerable impairment in their skill (Study 1).

BAC underestimation could account for individual differences in risky driving under alcohol. Those who believe they are below their actual BAC might perceive fewer negative consequences from their behavior and thus increase the amount of risk they are willing to accept when driving (Fromme et al., 1997). In contrast, those who overestimate their BAC may be more cognizant of potential hazardous consequences of alcohol-related impairments, and reduce the amount of risk for injury/collision they are willing to take when driving.

Study 2 sought to test the role of BAC estimation error on adult drivers' risk taking and their skill level during tests of simulated driving. Drivers were tested in two different simulated driving scenarios. One scenario was a "skill-relevant" situation that emphasized drivers' visual motor skill, as described in Study 1. The other drive presented a "risk-relevant" situation that instigated risk-taking behavior (i.e., tailgating) by placing participants in a high-traffic situation, also described in Study 1. Drinkers' self-estimation of their BAC was obtained using a Likert-type rating scale. Tests were completed under an active dose of alcohol and a placebo. The active dose of alcohol was expected to impair driving skill and increase risky driving. We also predicted that drivers who estimated lower BACs would display the greatest risk-taking under the drug.

Method

Participants

Forty adults between the ages of 21 and 34 (21 women and 19 men) participated in the study. They were recruited by the same means and using the same criteria for selection used in Experiment 1. Pre and post-session protocol was also the same. The University of Kentucky

Medical Institutional Review Board approved the study. All study volunteers provided informed consent and received $110 (plus any additional money earned in the risk-relevant drive) for their participation.

Materials and Measures

The same computerized driving simulator from Experiment 1 was used in Experiment 2 to measure driving behaviors. For a more detailed description, refer to Experiment 1.

Test of driver risk-taking (see Figure 1, right panel). This drive examines risky driving behavior and was the same as that used in Experiment 1.

Test of driver skill (see Figure 1, left panel). This drive was designed to test skill-related driving performance and was the same as that used in Experiment 1.

BAC Estimation. Participants estimated their BAC on a Likert-type rating scale ranging from 0 to 160 mg/100 ml with graduated demarcations each 5 mg/100 ml. The current legal driving limit for intoxication in the United States (80 mg/100 ml) was indicated by the words "legal limit" as the center point on the scale. Drivers were to estimate their BAC relative to the legal limit by putting a slash through the corresponding point on the scale. The legal limit was included as a reference point for subjects because it is a common, lay definition that could be used to make decisions about driving after drinking. This measure has been used in other alcohol studies (e.g. Harrison et al., 2007).

Subjective Intoxication. Participants evaluated their level of intoxication on 100 mm visual-analogue scale with anchors of 0 "not at all" to 100 "very much." This scale has been used in other alcohol studies (e.g., Harrison et al., 2007).

Driving History and Experience Questionnaire (DHEQ). This self-report questionnaire, used in Study 1 gathered information on length of time holding a driver's license, and number of days driven/week.

Drinking Habits. As in Study 1, drinking habits were measured by the Timeline Follow-back calendar (TLFB; Sobell & Sobell 1992) as the number of days subjects drank alcohol over the past 90 days and the total number of drinks consumed over that period. The Personal Drinking Habits Questionnaire (PDHQ) measured the subject's customary number of standard drinks and weekly frequency of drinking (Vogel-Sprott, 1992).

Procedure

Familiarization Session. The purpose of this session was to familiarize participants with laboratory procedures, obtain information on driving history, drug use, drinking patterns, general health status and demographic characteristics. Participants also practiced the risk and skill-relevant drives.

Test Sessions. Dose sessions operated as they did in Experiment 1 with slight modification in the test battery. Subjects performed the task battery: (1) driver skill test; (2) driver risk-taking test; (3) subjective intoxication self-report; (4) BAC estimation self-report. Drive tests were presented in a fixed order to avoid generalization of incentivizing behavior from the test of driver risk to the test of driver skill. The test battery began 40 min post-drinking and ended at 70 min. All testing occurred during the ascending period of the BAC curve. BrACs were measured at 40 and 70 min (Intoxilyzer Model 400, CMI Inc.). Breath samples were also taken following placebo ostensibly to measure BrAC. After a test session concluded, participants relaxed in a waiting room. They received a meal and were released when their BrAC fell below 20 mg/100 ml. Transportation home was provided. Upon completing the final session, participants were paid and debriefed. The test battery was initiated at 40 mins and end at 70 mins post-alcohol administration; all testing occurred during the ascending period of the BAC curve. BACs were measured at 40 and 70 minutes post beverage administration.

Criterion Measures

The criterion measures for risky driving and driving skill were the same as those used in Study 1. The test of driver risk provided the primary measure of risky driving, Time to Collision (TTC; see Figure 3). The test of driver skill will provide the primary measure of skill, Lane Position Standard Deviation (LPSD; see Figure 2). Drive speed and accidents were recorded during both drive tests. Refer to Study 1 for more detail.

Results

Demographics, Drug and Alcohol use, and Driving History

Table 3.1 lists demographic and other background characteristics of participants. The racial makeup of the sample was as follows: Caucasian (n=28), African-American (n=7), Asian (n=4) and one participant who reported belonging to a category not listed. The sample was comprised of experienced drivers who regularly operated a motor vehicle. On average, participants drank on one third of the last 90 days, 3 drinks per occasion (Table 3.1). Regarding past 30-day drug use, the sample reported tobacco (n=13), THC (n=15), and stimulant drug use (n=2). No daily use of any drug except for caffeine was reported. Ten participants tested positive for THC but reported they had not used within 24 hours prior to each session.

Observed and Estimated Blood Alcohol Concentrations

BACs following the active dose were comparable across time in both male and female drivers. A 2 (sex) x 2 time (40 min vs. 70 min) mixed-model analysis of variance (ANOVA) obtained no significant main effects or interactions, *ps* > 0.06. Based on the entire sample, the mean BrAC was 62.7 mg/100 ml (*SD* = 14.0) at 40 min and 71.4 mg/100 ml (*SD* = 13.1) at 70 min. No BAC was detected following placebo.

Drivers' estimations of their BAC were higher following alcohol than placebo (Alcohol: *M* = 84.6 mg/100 ml, *SD* = 31.6; placebo, *M* = 36.9 mg/100 ml, *SD* = 27.2), and this was confirmed by a significant one-way ANOVA of dose condition, $F\ (1, 39) = 80.47$, $p < 0.01$, $\eta^2 = 0.67$. Estimation error was quantified by taking individuals' estimated BAC minus their observed BAC at that time (70 min post drinking). Drivers' mean estimated BAC was significantly greater than their mean observed BAC, $t(39) = 2.49$, $p = 0.02$. The average degree of overestimation was 13.2 mg/100 ml (*SD* = 33.6)

Test of Driver Risk-Taking

Alcohol reduced drivers' time to collision (TTC) with other vehicles (i.e. riskier drivers). This was indicated by a 2 dose (placebo vs. alcohol) repeated measures ANOVA, $F\ (1, 39) = 5.96$, $p = 0.02$, $\eta^2 = 0.13$. Figure 3.1 (left panel) shows drivers' TTC scores decreased under alcohol compared with placebo.

Although accidents were rare with less than a single accident per drive, they were statistically more frequent under alcohol, *M* = 0.83, *SD* = 0.90, compared with placebo, *M* = 0.40, *SD* = 0.74, $F\ (1, 39) = 5.24$, $p = 0.03$, $\eta^2 = 0.12$. Drivers traveled at comparable speeds following placebo, *M* = 48.03 mph, *SD* = 9.81, and alcohol, *M* = 48.91 mph, *SD* = 9.92, $F\ (1, 39) = 0.47$, $p = 0.50$.

Relation of Drivers' BAC Estimation Error to Their Risk-Taking

Hierarchical regression analyses tested the degree to which BAC underestimation was associated with risky driving under alcohol independent of drivers' observed BrAC. Drivers' observed BrAC (step 1) and their error in BAC estimation (step 2) served as predictors in the model and were regressed onto the drivers' TTC scores. The Tolerance test indicated low multicollinearity between the predictors (Tolerance = 0.88). Drivers' BAC estimation errors, but not their observed BrACs, accounted for a significant amount (30%) of the variance in drivers' TTC scores, $t(37) = 4.08$, $p < 0.01$. The regression statistics are presented in Table 3.2. The positive slope relating BAC estimation error to TTC indicates that lower estimated BACs were associated with lower TTC scores (i.e., riskier driving).

Driving Skill (LPSD)

Alcohol reduced drivers ability to maintain their vehicle in the center of the lane, as indicated by a significant increase in LPSD under alcohol versus placebo, $F(1, 39) = 20.30$, $p < 0.01$, $\eta^2 = 0.34$ (Figure 3.1, right panel)

More accidents were observed following alcohol, $M = 1.95$, $SD = 4.18$, compared with placebo, $M = 0.48$, $SD = 1.04$, $F(1, 39) = 6.79$, $p = 0.01$, $\eta^2 = 0.15$. Drivers' speed did not significantly differ across dose conditions, $F(1, 39) = 0.88$, $p = 0.36$. Per instructions, drivers maintained an average speed of 54.67 mph ($SD = 3.09$).

Relation of Drivers' BAC Estimation Error to their Skill

Neither BAC estimation errors nor observed BrACs significantly contributed to driving skill under alcohol. A hierarchical regression of BrAC (step 1) and error in BAC estimation (step 2) onto drivers' LPSD obtained no significant effects *ps* > 0.11 (Table 3.2).

Relation of Drivers' BAC Estimation to their Subjective Intoxication and Drinking Habits

Individuals perceived greater intoxication following alcohol ($M = 61.79$, $SD = 22.5$) than placebo ($M = 11.57$, $SD = 14.98$) and this difference was confirmed by a one-way ANOVA of dose, $F(1, 39) = 140.19$, $p < 0.01$, $\eta 2 = 0.81$. Pearson correlations showed that drivers' BAC estimations under alcohol were not related to their level of subjective intoxication, $p = 0.23$, or to their drinking habits as measured by the TLFB and PDHQ, $ps > 0.36$.

BAC Estimation and Driving in the Placebo Condition

Individuals who estimated higher BACs following alcohol also tended to estimate higher BACs following placebo, as was indicated by a significant correlation of BAC estimations between the two dose conditions, $r(39) = 0.34$, $p = 0.03$.

Pearson correlations showed that drivers who estimated lower BACs after drinking the placebo also tended to be riskier drivers during the placebo session, $r(39) = 0.44$, $p < 0.01$, but their BAC estimates had no relationship to their driving skill (LPSD, $r(39) = -0.16$, $p < 0.32$.

Discussion

The present study provides new information on a potential determinant of driver risk-taking under alcohol. Those who displayed the greatest alcohol-induced increases in risky driving were also those who tended to estimate lower BACs. Reasons for the relationship are not known, but could involve a failure to actively inhibit impulses to take risks under the drug. Laboratory measures show that alcohol impairs drivers' ability to inhibit behavioral impulses and that more disinhibited drivers display greater risk-taking in simulated driving scenarios (Fillmore et al., 2008; Laude & Fillmore, 2015). However, drinkers can also compensate for the disinhibiting effects of alcohol, effectively reducing the tendency for impulsive action, when they are aware of the potential for impairment (Vogel-Sprott & Fillmore 1999; Marczinski & Fillmore, 2005). It is possible that drivers in the current study who estimated higher BACs were more cognizant of the impairing effects of alcohol on their driving and as such, actively sought to resist risky driving by maintaining sufficient safety margins. By contrast, those who estimated lower BACs might have perceived little potential for impairment and thus failed to actively compensate for the disinhibiting effects of the drug on their risk-taking.

The study showed that alcohol impaired driving skill (LPSD) compared with placebo. However, drivers' BAC estimation errors showed no relation to individual differences in their driving skill under the drug. Non-decision based aspects of driving, such as the precision at maintaining ones' lane position, are considered largely automatic operations requiring little conscious awareness from the driver (Michon, 1985; Salvucci, 2006). As such, driving skill might not be influenced by the driver's perceived BAC. By contrast, more volitional aspects of driving, such as risk-taking in which drivers make conscious decisions about whether or not to execute certain risky driving maneuvers might be more apt to be influenced by the driver's perceived level of impairment and estimated BAC. The finding that drivers' beliefs about their BAC could specifically influence decision-based aspects of driving behavior is also consistent with evidence that BAC underestimation can contribute to the decision to drive after drinking (Beirness, 1987). Indeed, the tendency to estimate lower BACs could support a series of high-risk decisions, regardless of ones' actual BAC.

Consistent with prior research (Beirness, 1984, 1987; Mudane et al., 1993), drinkers in the present study made errors when estimating their BAC. There is some evidence that BAC estimation is a product of interoceptive cues and behavioral changes associated with intoxication (Bois & Vogel-Sprott, 1974; Lansky et al., 1978; Beirness, 1984, 1987; Aston & Liquori, 2013; Aston et al., 2013). The development of tolerance to subjective effects, often seen in heavy drinkers, could contribute to lower estimates of BAC. However, we found that BAC estimation errors bore no relation to drivers' levels of subjective intoxication following alcohol, nor were such errors related to individuals' drinking habits. One possibility is that nonpharmacological factors contribute to self-estimations of BACs. Our study showed that subjects who estimated higher BACs following alcohol also tended to estimate higher BACs even after a placebo was administered. Basing one's BAC estimations on the physical properties of the drinks could explain the consistency in subjects' estimates across dose conditions. Participants might have been influenced by the taste and smell of the drinks and used that information to estimate their BACs, along with the number of glasses and volume of the beverage (all properties that were consistent across the alcohol and placebo sessions). It is also conceivable that the rating scale used to measure estimations of BACs contributed to this correlation. Individual differences in BAC estimations could also be due in part to different response styles of the subjects to such rating scales, and thus represent a systematic source of method variance. Collectively, these findings suggest that the tendency to over or under estimate one's BAC might be determined by factors other than interoceptive cues of intoxication, drinking habits, and other pharmacological-based factors.

It is also noteworthy that drivers who estimated lower BACs following placebo tended to be riskier drivers in the placebo session. This suggests the mere expectation of receiving alcohol could elicit risk-taking in certain drivers, which is a notion that has been raised by others (e.g. McMillen & Wells-Parker, 1987; Burian et al., 2003). However, the current study was not designed to fully examine this account. Tests of the role of expectancies requires manipulating the expectation of alcohol independent of its administration, and an assessment of the specific types of effects drivers expect from alcohol on a variety of driving behaviors, including risk-taking.

It is also worthwhile to address some potential experimental factors that could have influenced the results. Evidence that drivers' BAC estimations predicted the measure of driving risk but not driving skill could be due entirely to monetary incentives which were present in the risk drive but not in the skill drive. The skill drive tested lateral precision at a constant speed over the sustained driving period; I wanted to avoid any potential factors that could affect the drivers' motivation. By contrast, the risk drive emphasized completing the course in the least time needed. Such a demand necessitates motivation by external rewards, and in this case, the use of monetary incentives for quick completion of the drive. Further, incentives were included to model conditions under which risky driving is likely to occur. Outside of the laboratory, drivers engage in risk-taking because they are motivated to do so by some incentive or punisher (e.g., speed to avoid being late). Indeed, without any incentives present, simulated driving can be argued to be essentially risk-free as even vehicle crashes in the simulator present no risk of injury or harm to a subject. As such, models of risk-taking must incorporate some external reinforcers that can be acquired or lost based on driving behavior.

Task feedback during the drives could also influence drivers' BAC estimations. For example, drivers who experienced a crash during a drive might view themselves as more intoxicated, and thus estimate higher BACs. However, supplemental analyses tested the relationships between accidents in the simulator and drivers' BAC estimations and did not yield support for the hypothesis that crashes might be associated with higher BAC estimations.

Table 3.1

Background characteristics of sample. Age = years of age; Years driving = total years of licensed driving; Driving frequency = total number of driving days per week. PDHQ Frequency = PDHQ typical number of times per week that subjects reported drinking. PDHQ Drinks = PDHQ typical number of drinks subjects consumed during any given drinking episode. TLFB drinking days = TLFB total drinking days in the past 3 months; TLFB total drinks = TLFB total drinks consumed in the past 3 months

	M	*SD*
Age	24.08	4.03
Years Driving	7.50	4.00
Driving Frequency	5.00	2.26
PDHQ Frequency	2.49	1.47
PDHQ Drinks	3.34	1.53
TLFB Drinking Days	30.25	17.93
TLFB Total Drinks	103.24	80.27

Table 3.2

β (b)-Coefficients and statistics obtained from two hierarchical regressions of Observed BAC and BAC Estimation Error to (1) risky driving (time to collision; TTC) and (2) driver skill (deviation of lane position; LPSD)

Drive measure	Variable	*b*	*SE*	*t*	*p*
TTC	Observed BAC	0.14	0.001	0.90	0.38
	Estimation Error	0.59	<0.001	4.08	<0.01
LPSD	Observed BAC	-0.03	0.011	0.21	0.84
	Estimation Error	-0.28	0.004	1.64	0.11

Figure 3.1

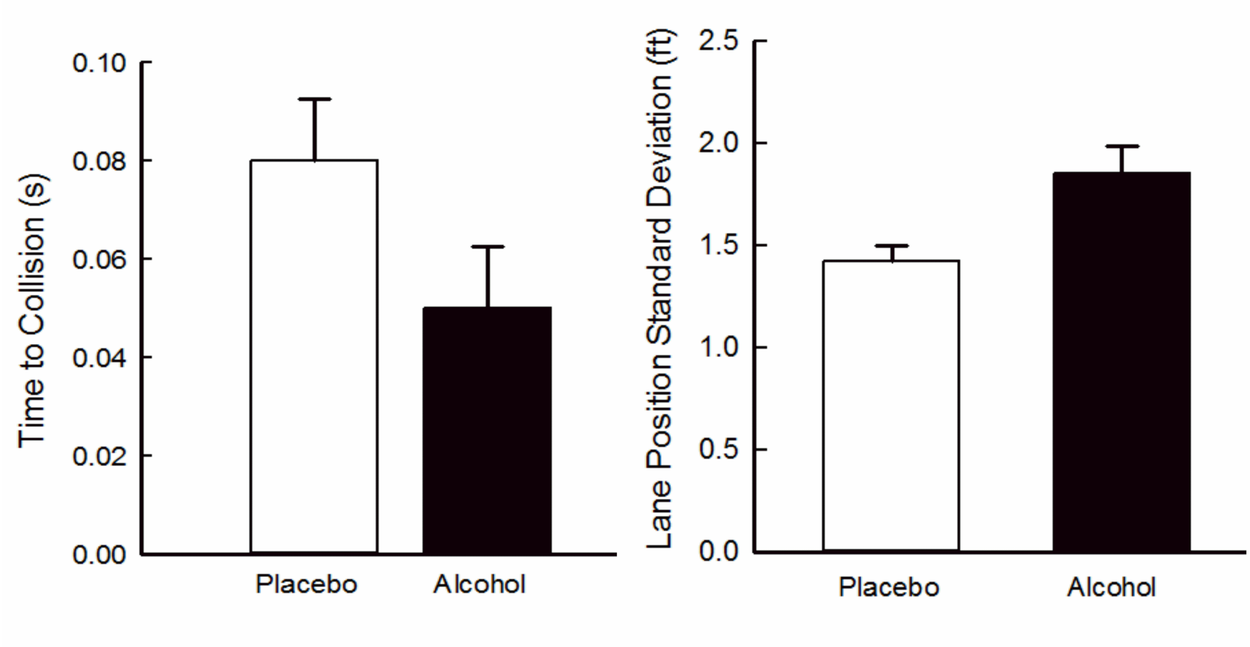

Figure 3.1. The figure plots the criterion measures for the test of driver risk-taking and driver skill. The left panel depicts the mean time to collision values (TTC) from the test of driver risk-taking under placebo and alcohol. The right panel shows the mean deviation of lane position (LPSD) from the test of driver skill under placebo and alcohol. Capped vertical lines indicate standard error of the mean

Chapter 4

PRACTICE MAKES PERFECT?: AN IRONIC EFFECT OF DRIVER TRAINING ON PERFORMANCE UNDER THE INFLUENCE OF ALCOHOL (STUDY 3; Laude & Fillmore)

Introduction

Study 1 revealed driver risk and skill were not necessarily related under placebo or alcohol conditions. Study 2 showed that risky driving was correlated with the driver's beliefs about their perceived BAC. Study 3 builds on this work and attempts to experimentally manipulate the driver's beliefs to affect their risk taking; this will further inform whether the apparent dissociation between behavioral measures of driver risk and skill are mediated by perceptions the driver holds. The study tests the possibility that training programs aimed at increasing driving skill may have the effect of increasing perceived but not actual ability, and this may encourage risky driving. Perceiving high skill independent of actual ability may also have implications for driver risk-taking in the intoxicated state as trained drivers may deem compensating for the otherwise impairing effects of alcohol unnecessary.

The Effect of Driver Training Programs on Motor Vehicle Crashes

Crash statistics show that novice drivers have greater risk for motor vehicle collisions (MVCs), than experienced drivers (Brown & Groeger, 1988; Laapotti, 1994; Twisk, 1995; Gregersen & Bjurulf, 1996; Deery, 2000; McCartt et al., 2009). This observation is often attributed to a lack of driving experience wherein the skills necessary for safe driving are not fully developed (Laapotti, 1994; Ranney, 1994; Twisk, 1995). An intuitive solution has been to increase driver skill through training. Many advanced driver-training programs are aimed at young, inexperienced drivers, and are thought to hasten learning through experience and the acquisition of safety skills. However, the expected safety effects of this training have been questioned, and there is some evidence that training increases the risk of crash (Gregersen, 1994; Glad, 1988; Jonah, 1986; Elvik et al., 2009). For instance, completion of a driver training-program that included learning to recover from a skid (skid training) was associated with a 20% increase in MVCs compared to a control group who had not received this training (Jones, 1993). Most of what we know about the role of driver training on risk for MVC is based on self-reported accident data obtained approximately one year after completion of skid training (Glad, 1988; Jones, 1993; Christensen & Glad, 1996).

Skill-Based Training Affects Perceived Level of Skill

One explanation for increased accidents in young drivers following driving training is that increases in driving skill are accompanied by an increase in drivers' perceived level of skill. It is possible ones' perceived skill level might far exceed the driver's actual skill. As stated in the Introduction of this dissertation, theories of risky driving behavior (e.g., speeding, tailgating) argue that drivers select the amount of risk for injury/collision they are typically willing to accept in a driving situation and then behave in accordance with that level of risk acceptance (e.g., Janssen & Tenkink, 1988; Näätänen & Summala, 1974; Wilde, 1976). These theories point to perceived skill level as an important contributing factor to risky driving. Drivers who perceive themselves as highly skilled are likely to accept greater risks while driving, such as speeding and tailgating, because their perceived skill level is assumed to nullify the risks normally associated with such behaviors. Indeed, studies report that individuals who believe they are highly skilled drivers tend to drive at higher speeds (Moe, 1986).

The successful completion of a skill-oriented driver training-program is an important formative experience for young drivers that could increase their perceived skill level and bolster confidence as able drivers. In fact, some research has found driver training causes individuals to overestimate their ability to maneuver their vehicle (Katila et al., 1996; Katila et al., 2004). As such, one potential reason for the increase in MVCs following driver training might be a training-induced increase in perceived ability to control ones' vehicle. Risk of crash could be further exacerbated if ones' belief in their ability exceeded their actual skill level (Groeger & Brown, 1989; Deery, 2000).

Alcohol and Motor Vehicle Collisions

Research indicates that alcohol contributes to MVCs by impairing driver skill and increasing driver risk-taking (NHTSA, 2013; FARS). Studies conducted in the laboratory using simulated driving scenarios have also found alcohol increases driver risk-taking, evidenced by increased drive speed (Fillmore, Blackburn, Harrison, 2008), and impairs driving skill, indicated by drivers' reduced ability to maintain vehicle position (Moskowitz & Fiorentino, 2000). The drug is also known for its disruptive effect on drivers' inhibitory control (Fillmore, 2003). Further, drivers who are more sensitive to alcohol's disinhibiting effects are especially prone to risky driving (Fillmore, Blackburn, & Harrison, 2008). As such, driving under the influence of alcohol represents an important situation in which to examine the hypothesis that driver training can increase risky driving behavior.

The purpose of the present study was to determine whether drivers who recently completed driver training would be inclined to take risks under the influence of alcohol owing to increased confidence in their driving ability. To test this hypothesis, drivers were randomly assigned to receive training on a driving simulator (training group) or to not receive training (control group). To determine the effect of training, subjects completed a drive test that measured their level of risk taking and driving skill under two doses of alcohol: 0.00 g/kg and 0.65 g/kg. The 0.65 g/kg dose was chosen because it yields peak BACs of approximately 80 mg/100 ml at which most aspects of behavioral functioning are reliably impaired (Fillmore, 2007, Holloway, 1995). The BAC also represents the legal limit BAC for driving while impaired based on per se laws throughout the United States. As such, the dose has social and legal relevance. Driver confidence was also measured. It was predicted that trained drivers would be more confident about their driving skill and demonstrate increased risk taking in response to alcohol, relative to untrained drivers.

Methods

Participants

Twenty-four adults (13 women, 11 men) between the ages of 21 and 35 years participated in the study. Volunteers had to be consumers of alcohol and hold a valid driver's license. Individuals with a Short Michigan Alcoholism Screening Test (S-MAST) score of 5 or higher, psychiatric disorder, CNS injury, or those taking prescription medication were not invited to participate. Females who were pregnant or breast-feeding, as determined by self-report and urine tests (Icon25 Hcg Urine test, Beckman Coulter), were also ineligible. Volunteers who tested positive for drugs during any session were excluded (ICUP Drug Screen, Instant Technologies). However, participants who tested positive for tetrahydrocannabinol (THC) were retained provided they did not self-report any past 24-hour use.

Materials and Measures

The same driving simulator used in Experiments 1 and 2 of the dissertation was used in Experiment 3. The simulations 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. The participant had full view of the road surroundings and instrument panel, which included an analog speedometer. Crashes, either into another vehicle or off the road, resulted in the sound of a shattered windshield. The program then reset the driver in the center of the right lane at the point of the crash.

Driver Confidence. Participants evaluated confidence in their (1) ability to take risks, (2) driving ability, (3) ability to safely take risks while traveling at high speeds and (4) the extent they believed they were an above average driver. Responses were made on a 100-mm visual-analogue scale with anchors 0 “not at all” to 100 “very much.” Driver confidence was defined as the average of the four items.

Drinking Habits. The Personal Drinking Habits Questionnaire (PDHQ) was used to obtain information on individuals’ customary number of standard drinks and weekly frequency of drinking (Vogel-Sprott, 1992).

Procedure

Volunteers responded to online postings seeking individuals for studies on the effects of alcohol on behavioral performance. Sessions were conducted in the Human Behavioral Pharmacology Laboratory of the Department of Psychology. The University of Kentucky Medical Institutional Review Board approved the study. Volunteers provided informed consent and received $85 for their participation.

Pre-Training Driving Test. Informed consent and background information were obtained in the pre-test session. Subjects also became familiar with the driving simulator. A pre-test measure of driving skill and of driver risk-taking was obtained using a 15-min simulated drive (Figure 4.1, left panel). The drive consisted of 80,000 feet of a winding two-lane highway, through a rural setting with buildings and trees. Participants were instructed to drive between 45-65 mph while maintaining their vehicle in the center of the right lane throughout the drive. A pre-test measure of driver confidence was then obtained.

Group Assignment. Following the pre-test, participants were randomly assigned to either the *Training group* or the *Control group*, with the constraint that equal numbers of males and females be assigned to each group.

Driver Training. Individuals assigned to the training group completed driver training on the driving simulator. The training modeled components of advanced driver-training programs that focus on developing driving skill. Training occurred on a skid pad (9,300 ft x 200 ft) lined by trees on either side (Figure 4.1, right panel). Drivers were required to weave between cones, which formed an obstacle course, without knocking them over. To increase the difficulty of the course, a two-choice reaction-time task was embedded in the drive scenario (Harrison and Fillmore, 2011). At random distances throughout the drive, an arrow (i.e. distractor) appeared in the upper right or upper left corner of the driver's window screen. Participants were instructed to respond to the distractor by pressing a button on the corresponding side (right or left) of the dashboard. The distractor remained on until a response is detected after which another distractor was liable to appear. Subjects were to drive around 45 mph (no strict speed limit), and were permitted to increase their speed with successive iterations of the course. The training exercise took no longer than 20 min to complete, depending on the speed of the participant. Following this training, a post-test measure of driver confidence was obtained.

Post-Training Driving Performance in Response to Alcohol and Placebo. Following the training session, participants returned to have their driving performance tested following 0.65 g/kg alcohol and a placebo. The two doses were administered on separate sessions and the two sessions were completed within 10 days. Dose administration was blind, and dose order was counterbalanced across participants. Volunteers abstained from alcohol for 24 hours and fasted for 4 hours prior to each dose session. A zero BrAC was verified at the beginning of each session

(Intoxilyzer Model 400, CMI Inc.), participants were tested for drug metabolites, and females were tested for pregnancy. At the beginning of each session, prior to dose administration, those in the training group completed a shortened, booster of driver training, which took no longer than 10 min. They then received either the alcohol dose or the placebo. The 0.65 g/kg dose was administered as 95% alcohol containing one part alcohol and three parts carbonated mix. The placebo consisted of a volume of carbonated mix that matched the total volume of the 0.65 g/kg alcohol drink. 3 ml of alcohol was floated on the surface of the beverage and glasses were sprayed with an alcohol mist. The active dose typically produces an average peak BrAC of 80 mg/100 ml, 60–70 min after drinking. After a 50 min absorption period, post-test measures of driving skill and driver risk-taking were obtained using the 15 min simulated drive. BrAC was taken at 70 min. Subjects were released once their BrAC fell below 20 mg/100 ml. In the final session, participants were paid and debriefed.

Control Drivers. Those assigned to the control group did not receive training on the driving simulator beyond initial familiarization. Control drivers underwent identical drive tests as the training group following alcohol and placebo.

Criterion Measures

Standard Deviation of Lane Position (LPSD). Driving skill was measured as the standard deviation of lane position (LPSD). This is an indicator of the extent a subject's vehicle deviates from the center of the driven lane. It is obtained by averaging deviations from the center of the lane sampled at each foot of the test. Higher LPSD values indicate poorer driving skill.

Drive Speed. Driver risk-taking was taken as average drive speed, in terms of miles per hour, across the drive. Drive speed was used over proxemics measures of risk taking due to low traffic on the country road. Higher speeds indicate greater risk taking.

Results

Demographics, Drinking and Driving History, and other Drug Use

On average, drivers were 24 years of age and drank 3 standard drinks twice per week. They also had years of driving experience and drove a motor vehicle nearly every day. Groups (Training vs. Control) did not significantly differ on any of these measures, *ps* > 0.05 (Table 4.1). The racial makeup of the sample was Caucasian (n=20), Hispanic (n=2), Native American (n=1) and other (n=1). The majority of subjects reported caffeine use (n=23). Tobacco (n=4), stimulant (n=1), opiate (n=1), cocaine (n=2) and THC (n=9) use was also reported. Urine analyses confirmed participants were negative for the use of all drugs except for THC; six subjects tested positive.

Blood Alcohol Concentrations

Potential group effects on BrACs before and after the drive test in the active dose condition were examined by a Group (Training vs. Control) x Time (50 min vs. 70 min) mixed-model analysis of variance (ANOVA). All terms in the model were non-significant, *ps* > 0.37. The mean BrACs at 50 and 70 min collapsed across Group were 86.38 (*SD* = 15.30) and 84.83 mg/100 ml (*SD* = 13.59), respectively.

Subjective Effects

Pre driver-training. No pre-existing differences between groups on measures of driver risk-taking or driving skill were observed, *ps* > 0.16. On average, drivers maintained a speed of 55.68 mph (*SD* = 3.65) and their LPSD was 1.78 feet (*SD* = 0.45).

Post driver-training. The effect of training on alcohol-induced driver risk-taking (speed) was tested using a Group x Dose (0.00 g/kg vs. 0.65 g/kg) mixed-model ANOVA. The analysis revealed a main effect of Group, $F(1, 22) = 7.71$, $p = 0.01$ and a Group x Dose interaction, *F*(1,

23) = 4.75, $p = 0.04$. Figure 4.2 shows untrained drivers reduced their speed following alcohol while trained drivers tended to increase their speed under the drug.

The analysis for driver skill (LPSD) revealed a main effect of dose, $F(1, 22) = 7.46$, $p = 0.01$. No other terms in the model were significant, *ps* > 0.35. Figure 4.3 shows alcohol increased drivers' LPSD relative to placebo, which indicates drivers were less able to maintain their vehicle in the center of the driven lane under alcohol.

A Group x Test (Pre vs. Post) mixed-model ANOVA of driver confidence revealed a main effect of Test, $F(1, 22) = 25.83$, $p < 0.01$, but not of Group, $p = 0.44$. The Group x Test interaction was significant, $F(1, 23) = 10.95$, $p < 0.01$ Figure 4.4 shows that the interaction was the result of an increase in drivers' confidence following training that was not observed in the control group.

Discussion

The present study showed that drivers who received training on a driving simulator failed to reduce their risk taking by decreasing their speed when under the influence of alcohol unlike untrained drivers who reduced their speed when intoxicated. Risk taking among the trained drivers occurred despite their driving skill being comparably impaired by alcohol as those who received no training. The study also revealed that trained drivers were more confident in their driving ability compared to untrained controls.

The results provide a possible risk-taking account of the past survey studies that report increased MVCs in young drivers who recently completed driver training programs (Gregersen, 1996; Renge, 2000; Katila et al., 1996; Katila et al., 2004). MVC can occur for several reasons with risky driving as only one possibility; survey studies are limited in their ability to identify risk-taking as a primary causal factor in MVCs. However, by measuring specific indicators of risky driving in the laboratory (e.g., speeding) the current study supports the idea that increased rates of MVC following driver training programs might be due to increased risk-taking on the part of the driver.

The findings also indicate that such risk-taking behavior can increase without any accompanying improvement in driver skill to offset such risks. In fact, this study shows that risk-taking was present in the context of diminished skill owing to the impairing effect of alcohol. A controlled dose of alcohol was used to temporarily reduce drivers' skill level (i.e., increase LPSD). In addition to its utility as a pharmacological technique to manipulate skill, the use of alcohol in the study has considerable ecological relevance to situations in which drivers might operate a motor vehicle. Alcohol itself is a major cause of MVC. Thus any experiences that increase driver confidence to promote risk-taking would be especially hazardous when the drug compromises the driver's skill level. Moreover, it is important to recognize that drugs, such as alcohol, can directly promote risk-taking by impairing impulse control (Fillmore, 2003). Indeed, previous studies have shown that moderate doses of alcohol (BrACs approximately 80 mg/100 ml) can impair the ability to inhibit or suppress pre-potent (i.e., instigated) responses on go/no-go and stop-signal tasks, as well as increase reckless driving behaviors in the simulator (Fillmore, 2003; Fillmore, Blackburn, & Harrison, 2008). Our research has also found some evidence for an association between sensitivity to the impairing effect of alcohol on the drivers' impulse control and the degree to which the drug impairs their driving in the simulator (Fillmore, Blackburn, & Harrison, 2008). Taken together, this evidence suggests that experiences that increase a driver's perceived skill and driver confidence might be especially likely to elicit risk-taking behaviors when cognitive and behavioral functions of the driver are compromised by acute exposure to psychoactive drugs, such as alcohol.

It is also recognized that the training provided to subjects in the study did not improve their driving skill beyond the control group at a level of statistical significance. Despite the lack of improved skill among the trained group, these drivers self-reported marked increases in their driving ability and confidence compared with controls. In fact, the present study demonstrated how easily self-perceptions and confidence could be inflated following less than an hour of training experience. As such, it seems reasonable that the completion of an actual driver-training program must instill considerable driving confidence in many of its graduates.

One limitation of the present study was that driver confidence was only tested when drivers were sober. Driver confidence should also be tested in the intoxicated state. Driver confidence should diminish under alcohol, but this reduction in confidence might be lessened in drivers who have completed driver training. Another potential limitation is the temporal contiguity between driver training and testing. Drivers in the present study completed training and were tested shortly thereafter. Studies outside of the laboratory administer questionnaires years after training, and suggest completion of certain driver-training programs can have lasting effects on drivers' perceived ability and confidence (Groeger & Brown, 1989; Deery, 2000).

In conclusion, this study highlights driver confidence as a potentially important unintentional outcome of driver training programs that could have adverse consequences for young drivers by increasing propensity for risky driving behavior. Moreover, the evidence suggests that risky driving owing to increased confidence is particularly likely in situations where risk-taking behavior is instigated by other factors, such as the disinhibiting effects of alcohol. Heightened confidence in drivers might also instigate risk taking in situations where there is some incentive to speed (being late for an appointment) or in response to peer influence to "joy ride". Driver-training programs should consider the potential influence they can have on the driver's self-perceptions of their driving ability, and recognize the possibility that such self-perceptions can undermine the goal to produce safe young drivers.

Table 4.1

	Control		Training			
	M	*SD*	*M*	*SD*	*t*	*p*
Age	23.08	6.35	25.33	2.61	1.36	0.268
Years Driving	7.18	3.60	8.28	2.44	0.87	0.393
Driving Frequency	6.42	1.06	5.58	2.20	1.18	0.255
PDHQ Frequency	2.63	1.07	2.24	1.08	0.88	0.386
PDHQ Drinks	4.50	2.50	2.96	2.40	1.54	0.138

Note. Comparison of drivers assigned to the Control group relative to the Training group on background characteristics. Age = length of existence in years; Years Driving = total years of licensed driving; Driving Frequency = total number of driving days per week. Drinking measures were calculated on the basis of the PDHQ; PDHQ Frequency = customary number of days alcohol was consumed per week; PDHQ Drinks = typical number of alcoholic drinks consumed per week.

Figure 4.1

Figure 4.1. The left panel depicts a scene from the drive test that measures driver risk-taking and driving skill. The right panel displays a scene from the driver training exercise in which participants had to weave between cones without knocking them over.

Figure 4.2

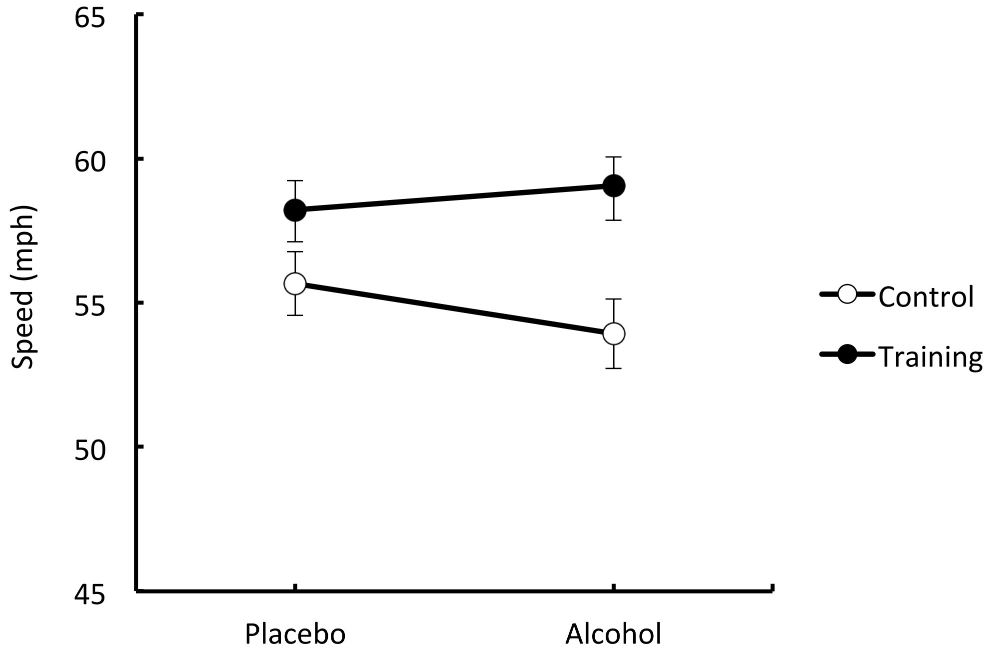

Figure 4.2. The graph shows drivers' mean (± SE) speed under placebo and 0.65 g/kg alcohol as a function of group. Closed circles correspond to the Training group who completed driver training on the simulator. Open circles represent the Control group who did not receive this training.

Figure 4. 3

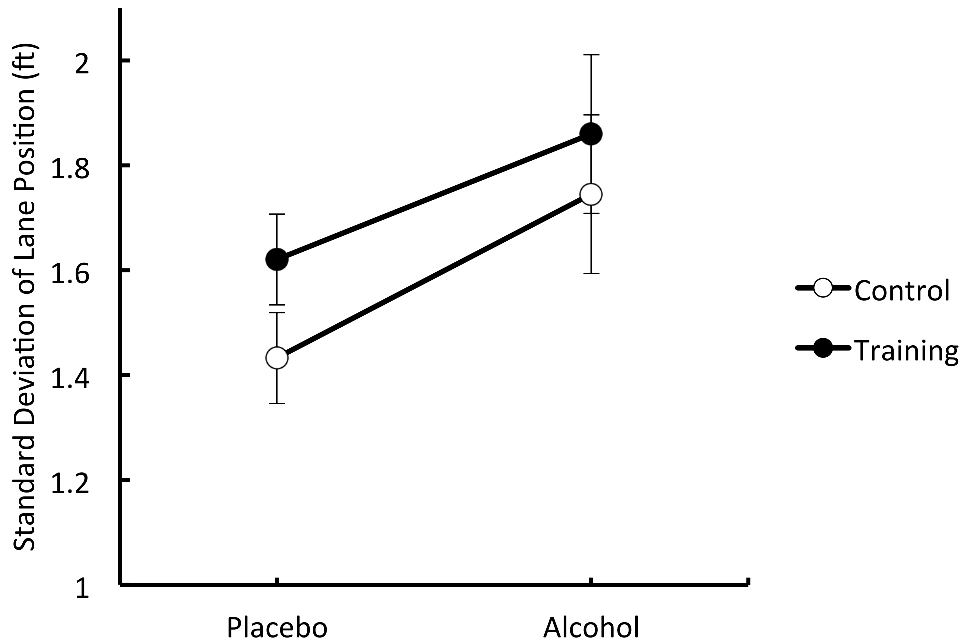

Figure 4.3. The graph shows drivers' mean (±SE) deviation of lane position (LPSD) under placebo and 0.65 g/kg alcohol as a function of group. Closed circles correspond to the Training group who completed driver training on the simulator. Open circles represent the Control group who did not receive this training.

Figure 4.4

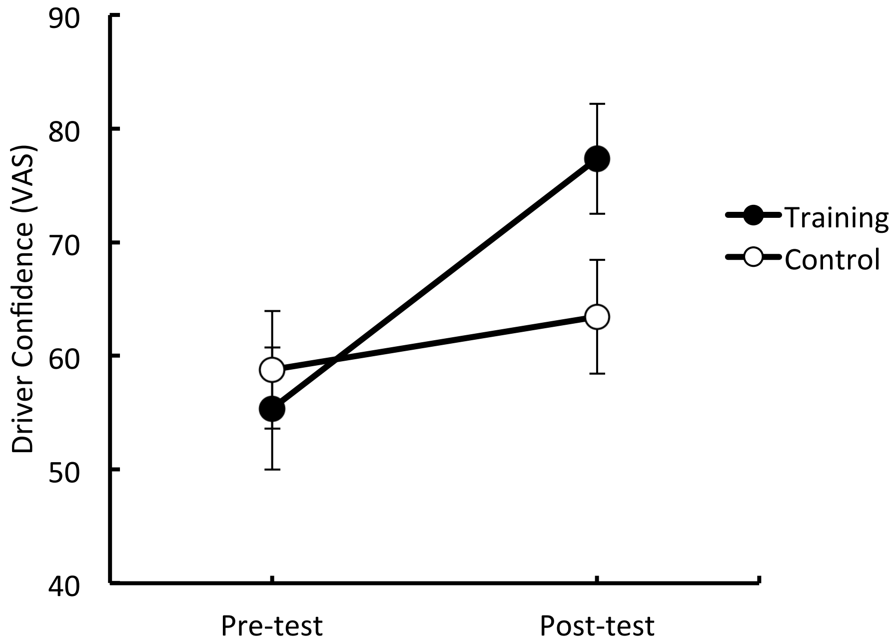

Figure 4.4. The graph shows the mean (±SE) deviation of driver confidence under placebo and 0.65 g/kg alcohol as a function of group. Closed circles correspond to the Training group who completed driver training on the simulator. Open circles represent the Control group who did not receive this training.

Chapter 5

GENERAL DISCUSSION

This dissertation examined factors that moderate risky driving. Study 1 examined the hypothesis alcohol would increase driver risk-taking. Indeed, alcohol-induced elevations in risky driving were observed at 80 mg/100 ml (lower TTC scores). The study also tested whether alcohol would increase risk-taking behavior without necessarily producing pronounced impairment in the driver's skill. Results indicated that while some drivers increased their risk-taking and demonstrated low skill-impairment (smaller LPSD values), other drivers were more cautious and showed high skill-impairment. These series of studies also identified personal characteristics of drivers that contribute to risky driving. It was hypothesized those with poor inhibitory control would tend to increase their risk taking on the roadway. Indeed, Study 1 revealed disinhibited drivers tended to increase their risk taking in the sober state. We also predicted drivers who estimated lower BACs would increase risk taking under the drug. Indeed, Study 2 revealed individuals who underestimated their BAC tended to show the greatest alcohol-induced increases in their risk taking. Study 3 of this dissertation examined whether driver training would moderate risky driving. It was anticipated that drivers who received specialized training on the driving simulator would become overconfident in their ability and thus increase risk taking. In support of this hypothesis, trained drivers increased their speed under the drug and were more confident than untrained drivers. Collectively, these studies increase our knowledge of the cognitive and behavioral factors that moderate risky driving. The results represent a significant step towards the betterment of laboratory-based models of driving, which should help to establish causal mechanisms underlying DUI-related MVCs.

Distinguishing Between Driver Risk-Taking and Driving Skill

One significant contribution of this dissertation is driver risk-taking and driver skill were procedurally dissociated using two different simulated driving scenarios. It had been theorized DUI-related MVCs were caused by alcohol-induced increases in risk taking and impaired driving skill. Although simulated driving scenarios had been developed in the laboratory to inform causes of DUI-related MVCs, measures of driver risk and skill were often confounded. Procedural dissociation of these factors allowed for a test of the association between risky driving and driving skill. Contrary to assumptions made in the literature, the riskiest drivers were not necessarily the most unskilled drivers. This result highlights the importance maintaining the fundamental distinction between driver risk and skill in future research.

Although driving skill as it pertains to visual-motor ability (measured as LPSD) did not relate to risky driving, associations between other types of driving skills could exist. Once such skill is hazard detection, which is the process of identifying hazardous objects and events in a traffic situation and determining the extent they are dangerous (Brown & Groeger, 1988). Hazard perception performance has been identified as one source of individual differences in MVCs (Pelz & Krupat, 1974; Elander et al., 1993). It would be of interest to examine the effect of alcohol on the relationship between proxemics measures of risk-taking and drivers' hazard detection abilities.

This dissertation also tested whether drivers' self-assessment of their driving skill could affect their risk taking. Study 3 of the dissertation revealed providing driver training increased risk taking under the drug. Further, training increased drivers' confidence but not their driving skill. The result is another means of demonstrating driver risk and skill are not necessarily related. Interestingly, perceived skill might play a more substantial role in alcohol-induced increases in risk taking than actual skill.

Distinguishing Driver Risk-Taking Produced by Intention and Habit

Models of risky driving should distinguish between intentional risk-taking and driving style. Theories assert active decision-making processes determine driving style (e.g. Summala, 1974, 1976). However, driving style might refer to more habitual behavior that is not initiated under conscious control, and different from intentional acts of risk taking. Habits are thought to operate automatically, outside of conscious awareness, and are difficult to control (Lally et al., 2010; Wood & Neal, 2009; Wood, Tam, & Witt, 2005; Watson, 1913). The development of a habit tends to diminish the influence of intention on the actual behavior (Lally et al., 2010; Wood & Neal, 2009; Wood, Tam, & Witt, 2005; Watson, 1913). An example of driving style or habit is tending to travel 10 mph over the speed limit (i.e. "strategic" risk-raking; Michon, 1985, 1989). Acts of intentional risk taking are likely to be in response to context-dependent information. An example of intentional risk taking is exceeding the speed limit to arrive at an appointment on time (i.e. "strategic" risk-raking; Michon, 1985, 1989).

Failure to distinguish risky driving produced by active decision-making versus habit could pose problems for training that aims to reduce risk taking. According to learning theory, training strategies that seek to modify habits should differ from those designed to change driver intentions (Watson, 1913). For instance, motivational interventions might be ineffective in decreasing risk taking owing to habit, but could reduce intentional risk taking. As such, an adapted model of driver risk-taking should be considered in which risky driving can result from intention, habit, or some combination.

Contextual Factors Influence Risk Taking

Studies 1 and 2 of the dissertation found alcohol increased risky driving using a proxemics approach. Other laboratory-based studies have reported alcohol-induced decreases in risky driving, or no effect of alcohol, as measured by drive speed (Burian, Liguori, & Robinson, 2002; Banks et al., 2004; Sklar et al., 2014). However, differential effects of alcohol on indicators of risk taking might be due in part to the different contexts in which the measures are obtained. For instance, alcohol-induced decreases in risky driving tend to occur when simulations are not completed under response conflict. If nothing can be gained from taking risks, it is unclear why risky driving would occur. Rather, drivers might decrease risk taking in response to alcohol by reducing their speed to avoid collision. Alcohol-induced increases in risky driving are observed outside of the laboratory and this is likely because the behavior could yield a highly valued outcome.

Laboratory-based models should consider the different contexts in which DUI-related MVCs occur. Many low-speed collisions occur at night in metropolitan areas (FARS). Fatal crashes tend to occur at high speeds in situations of low traffic (FARS). The driving situation should determine the measure of risk taking used. In situations of congested traffic (e.g. metropolitan setting), proxemics measures might be preferred while drive speed is preferred in less congested areas (e.g. country roads). Although drive speed is often used as a measure of risk taking, it does not incorporate other important aspects of the driving scenario including the speed of other cars or the distance maintained between them. One might fail to detect increases in risky driving under alcohol if context is not considered. For instance, although a dose effect on TTC was found in studies 1 and 2 of the dissertation there was no significant effect on drive speed.

Constrained Information Processing and Risky Driving Under Alcohol

Intoxicated drivers might increase their risk taking because of constraints on their information processing. Models of human cognition recognize the existence of capacity limited stages of information processing. These stages include stimulus identification, response selection, and response execution (e.g. Welford, 1952). Stimulus identification and response execution engage motor processes, whereas the central stage involves cognitive processes such as decision making and planning. Information processing at any of these stages can be overloaded and limit ones' ability to respond appropriately to changing environments. If situational processing demands exceed capacity at any stage in a driving situation, driving behavior will be compromised.

Alcohols' disruptive effect on the ability to multitask could place drivers at risk for MVC. Dual tasks procedures have been used to study the limits of information processing and determine the extent each task interferes with response selection (for review see Pashler, 1994). These paradigms demonstrate simultaneous processing of information from multiple sources can lead to selection of a different response than if the sources were processed in isolation. As information processing capacity increases, so too does the ability to simultaneously process both tasks. Research using this dual process model has shown that a moderate dose of alcohol impairs performance of the secondary task (Moskowitz & Burns, 1971; Huntley, 1972; Van Tharp et al., 1974). As such, alcohol could increase driver risk-taking by decreasing drivers' ability to divide attention and detect hazards.

Alcohol-induced deficits in attentional control could lead drivers to select a response unfit to the traffic situation. Safe driving in complex environments (e.g. metropolitan settings) requires dividing attention amongst myriad stimuli and gating out irrelevant information. Identification of the relevant stimulus elements in the risk drive-test used in studies 1 and 2 of this dissertation might have been difficult because of the complexity of the driving scenario (Fuller, 2005). The conflicting response contingencies used in the test might have further increased processing demands. As such, intoxicated drivers might have only attended to the most salient aspects of the traffic situation resulting in a failure to recognize cues that would otherwise lead to selection of a response that would prevent collision.

The Role of Impulsivity in Risky Driving

We hypothesized riskier drivers with poor inhibitory control would tend to increase their risk taking. Study 1 of the dissertation revealed heightened disinhibition predicted an increase in risky driving in the sober state. Disinhibited drivers might struggle with response selection and execution when this requires a change in ongoing behavior; pre-potent responses could interfere with execution of more adaptive responses. This could be especially difficult in situations of response conflict. We did not observe a correlation between alcohol-induced disinhibition and risky driving. One possibility is the TTC measure was zero inflated in the active dose condition, causing issues for our correlational test. Alternatively, only certain measures of risk taking could be influenced by alcohol's disinhibiting effect. For instance, prior work has found a relationship between inhibitory control and drive speed under alcohol (Fillmore, Blackburn & Harrison, 2008).

This dissertation also tested whether generally impulsive drivers would tend to increase their risk taking under alcohol. Study 1 revealed individual differences in impulsivity as a trait failed to predict driver risk-taking. One possibility for the null relationship is the lack of variability in impulsivity scores required to detect relationships among measures was insufficient. However, our laboratory has failed to observe an association between trait impulsivity and simulated driving behaviors across a number of studies (e.g. Fillmore, Blackburn & Harrison, 2008). One could argue a more extensive personality assessment of impulsivity that includes related constructs of impulsivity, such as sensation seeking, might predict individual differences in risky driving. However, we found no relationship between the sensation-seeking component of the UPPS scale and risky driving. It is possible trait impulsivity is too broad a construct to reliably predict driving behavior in specific situations. This is supported by our finding that poor inhibitory control, a behavioral mechanism of impulsivity, (1) predicted elevations in driver risk-taking and (2) trait impulsivity and inhibitory control were dissociated.

If risky driving is indeed produced by decisions driver makes, the extent future outcomes are weighted in the decision-making process could influence driving behavior. Individuals are thought to have different "time horizons" which refers to the extent future-focused information is utilized when making present-based decisions. This concept is related to temporal discounting, or the weighting of proximate versus distal outcomes in decision-making (Bickel & Marsch, 2001). Persons with shorter time horizons assign substantial weight to immediately available information and integrate less information provided by more distal cues. Drivers with shorter time horizons might be biased to attend to immediately available information in the traffic situation, rendering them less able to anticipate and react to developing hazardous situations. Longer hazard detection latencies might not afford the driver the time to select an appropriate response to avoid collision.

Modification of Certain Misperceptions could Decrease Driver Risk-Taking

This dissertation revealed personal beliefs drivers held influenced their risk-taking behavior. Study 2 demonstrated drivers who estimated lower BACs tended to be riskier. This relationship was observed under placebo and active dose, which suggests beliefs about the amount of alcohol in their drinks, influenced their estimations and consequent behavior. It is possible the relationship between lower BAC estimations and risky driving is mediated by driver confidence. Drivers trained to accurately estimate their BAC might tend to reduce their risk taking. Although individuals can learn to discriminate different BACs, when feedback is removed from the situation, errors reemerge, and drivers have trouble using feedback about their BAC in their decision-making (Bois & Vogel-Sprott, 1974; Lansky et al., 1978; Johnson & Voas, 2004). As such, it is unlikely BAC estimation training would function to decrease risky driving.

Although modification of drivers' misperceptions about their BAC might be unsuccessful, other personal beliefs could be amenable to training. Study 3 of the dissertation revealed providing less than one hour of driver training increased risk taking under the drug. This increase in alcohol-induced risk taking was accompanied by an increase in driver confidence. As such, driver training might focus on changing drivers' beliefs about their ability (i.e. confidence), rather than increasing their actual skill level. Indeed, new training programs have been developed, such as "insight" driver-training that aim to calibrate drivers' self-assessment of their driving skill and encourage driving with larger safety margins (Kuiken & Twisk, 2001; Beanland et al., 2013). It is unlikely such introspective skills would transfer to driving under the influence of alcohol when there is a tendency to engage in automatic processing. However, unlike training programs focused on developing driving skill, insight training should not negatively impact driving under the influence.

Perceptions drivers hold about the likelihood of being cited for a DUI offense might also influence driver risk-taking. This might include beliefs surrounding ability to evade detection by police enforcement. Indeed, research indicates those who actively avoid punishment by law for DUI-related offense tend to be riskier drivers (Scott-Parker, Watson & King, 2009; Bıçaksız & Özkan, 2015). Driving after drinking with the intent to evade police detection suggests the driver suspects he is above the legal limit of intoxication. As such, future work might investigate whether individuals who show a lack of concern for social policies about driving after drinking are generally antisocial. If the belief is symptomatic of a personality disorder, it is unlikely to be changed. However, if the belief is specific to DUI-related offense, it might be modified.

Alcohol-Induced Risky Driving in Clinical Populations

Certain clinical populations might be inclined to increase their risk taking under alcohol. This dissertation revealed poor inhibitory control and overestimation of driving ability were factors that contributed to risky driving. Individuals with attention deficit hyperactivity disorder (ADHD) are particularly vulnerable to the disinhibiting effects of alcohol (Weafer, Fillmore & Milich, 2009), and also tend to overestimate their physical abilities (Knouse et al., 2005; Bruce, Ungar, & Waschbusch, 2009). The additive effects of alcohol-induced disinhibition and overestimation of ability might place these drivers at high risk for DUI-related MVC.

DUI offenders might also show alcohol-induced increases in risky driving, based on their tendency to underestimate risk across different scenarios. This population tends to perceive less risk in driving situations (Deery & Love, 1996), and more willing to drive on the declining limb of the BrAC curve (Van Dyke & Fillmore, 2014). One possibility for the tendency to underestimate risk in DUI offenders is they find risk taking reinforcing in itself. Indeed, there is evidence those who like some objectively dangerous activity tend to underestimate the objective risk associated with engaging in that activity (Cooper, 2003; Hatfield et al., 2014). As such, DUI offenders might underestimate the difficulties and dangers associated with taking risks on the road, leading to increases in their risk taking.

Pharmacokinetic Factors

All tests were conducted following two doses of alcohol that were restricted to the ascending limb of the BrAC curve. Future work should establish a dose-response curve to inform social policy on driving while intoxicated. It is possible impairments in driving skill and risk taking would be observed at lower BrACs, which would suggest the legal limit of intoxication should be much lower than 80 mg/100 ml. Past work has shown alcohol does not significantly increase risk taking (using a proxemics approach) at BrACs near 50 mg/100 ml (Leung & Stamer, 2005). However, this study did not test higher doses of alcohol and it thus possible the null outcome was a result of insensitivity of their task to detect alcohol effects.

It is also important to extend testing to the descending limb as the majority of arrests for impaired driving and two thirds of DUI-related fatalities correspond to this time (Levine & Smialek, 2000). Tolerance to the effects of alcohol can occur within a single drinking episode wherein recovery of function is seen in the later phase of the BAC curve relative to the ascending limb at that same BAC (e.g., Hurst & Bagley, 1972, Vogel-Sprott, 1979). Risky driving might not show tolerance to alcohol considering the behavioral profiles of inhibitory control and BAC estimation across the BrAC curve. Although inhibitory control does not show recovery, drivers tend to underestimate their BAC on the descending limb relative to the ascending limb of the BrAC curve (Fillmore et al., 2005; Cromer et al., 2010; Aston & Liguori, 2013). The interaction of these two factors on the descending limb could explain why DUI-related accidents occur more frequently during the later phase of the BrAC curve.

Research on alcohol effects on driving could benefit from greater consideration of the pharmacokinetic profile of the drug. For instance, studies that undershoot a target BAC of 80 mg/100 ml by 30 mg/ 100 ml might be unintentionally administering tests on the descending limb. Although BAC peaks 60-70 minutes post-alcohol administration given a dose that produces a BAC of 80 mg/100 ml, assuming comparable rates of consumption, the peak will be earlier for a dose that yields a BAC of 50 mg/100 ml. As such, future work should interpret results relative to the observed rather than the target BAC, measure multiple points across the curve, and measure BAC near when the tests occur.

Depressant Effects on the Central Nervous System Increase Risky Driving

Drugs that produce depressant effects on the central nervous system (CNS), such as alcohol and marijuana, might generally increase risky driving. These depressant effects have the effect of reducing inhibitory control, a factor that contributes to risky driving (Fillmore, Blackburn, & Harrison, 2008). The anxiolytic effects of CNS depressants might also increase risky driving as low-levels of anxiety have been linked to riskier driving (Mayou et al., 1991; Taylor & Koch, 1995).

Proxemics approaches to driver risk-taking have not been well incorporated into studies of marijuana effects on driving. In addition to marijuana's tendency to increase disinhibiton, it also decreases accuracy in distance judgments (Soueif, 1975; Moreno et al., 2012). A proxemics approach would inform whether marijuana-induced increases in risky driving are due to decreased distance maintained between other vehicles, which conventional measures of risky driving like speed cannot discern. Proxemics approaches will also help us understand how drivers under the influence of marijuana behave in situations of high traffic, which is understudied.

It is important to examine the interaction between marijuana and alcohol on driving. Increasing legalization of marijuana in United States has been associated with escalation in concurrent marijuana and alcohol use (Wen et al., 2015). Although THC and alcohol independently contribute to MVCs, their synergistic effect when used in combination substantially increases the risk of MVCs (Downey et al., 2013; Dubois et al., 2015). Once alcohol is in the bloodstream, blood vessels more readily absorb Δ^9-tetrahydrocannabinol, the active ingredient in marijuana, causing significant impairment even at low doses that would not normally be impairing (Dubois et al., 2015). As such, concurrent alcohol and marijuana use could exponentially increase risky driving beyond when either drug is used alone.

Implications for Lowering the Legal Limit and Prioritizing Research with Applied Value

Results obtained in this dissertation suggest lowering the legal limit BAC for driving while impaired might reduce the number of DUI-related MVCs. We found risky driving increased fourfold beyond sober levels when drivers achieved a BAC near the legal limit of intoxication in the United States. A number of other simulated driving studies provide convergent evidence that suggests the legal limit of intoxication should be lowered (Martin et al., 2013; Starkey & Charlton, 2014). Indeed, there is evidence lowering the legal limit below 80 mg/100 ml would result in fewer DUI-related MVCs (Rafia & Brennan, 2010; Allsop et al., 2015; Wang et al., 2015). Why we have not seen a change in policy in the United States?

Lowering the legal limit of intoxication in the United States does not appear to be politically viable because the drinks industry and perhaps surprisingly, mothers against drunk driving (MADD) and are firmly against it, which is likely unbeatable in state legislatures. Under the current per se law, individuals are convicted of a DUI offense when their BAC is at or above 80 mg/100 ml, but also if they appear behaviorally impaired at a lower BAC. It could be argued that lowering the limit would only affect people below 80 mg/100 ml who do not appear impaired. The question is then whether we want to criminalize such a person. Perhaps research on the effects of alcohol on driving should shift towards taking a harm reduction approach with an emphasis on applied work because it is unlikely the legal limit will change. For instance, research could focus on developing driver-training programs that reduce risk taking under the influence of drugs and alcohol. Models could be developed to inform policy on the effect of increasing punishments for drunk driving and the effect of publicizing law enforcement on reducing risk taking. Researchers might also examine the best means of delivering feedback to intoxicated drivers to maximize the likelihood the information is utilized. It could also be useful to study how partial automation of cars can help to reduce DUI-related MVCs.

This dissertation takes a step towards identifying factors that contribute to risky driving under the influence of alcohol. Different types of driving behaviors should be procedurally dissociated in future work including driver risk-taking from driving skill, and risk taking produced by intentions versus automatic behaviors. If we continue to maintain these distinctions, we can identify ways to reduce DUI-related MVCs.

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Jennifer R. Laude, M.S.

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PhD. Experimental Psychology (Expected May 2016). University of Kentucky

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M.S. Experimental Psychology, University of Kentucky, 2012.

Advisor: Thomas Zentall, PhD.
Program: Cognition, Learning, Behavior and Perception

B.A. Psychology, Departmental Honors, University of Kentucky, 2010.

Grants

2015	American Psychological Association Dissertation Research Award
2014, 2015	Research Society on Alcoholism Student Merit Awards
2010-2015	University of Kentucky Graduate School Travel Grants
2009-2015	University of Kentucky Psychology Department Travel Grants

Fellowships

2014–2016	NIAAA NRSA, Pre-Doctoral Fellowship, F31 AA023694 PI: Jennifer R. Laude; Sponsor Mark T. Fillmore Intoxication in a Rewarding Environment as a Risk Factor for Alcohol Misuse
2014-2015	Presidential Academic Fellowship, University of Kentucky
2005-2008	Presidential Academic Fellowship, Midway University

Awards

2015	Division of Experimental Psychology of the American Psychology Association (Division 3) New Investigator Award
2014	Cognition, Learning, Behavior and Perception, Outstanding Student of the Year Award
2010	Psychology Departmental Honors

Service

2014, 2015	University of Kentucky Graduate Student Representative: Experimental Psychology Program
2015	Behavioral Neuroscience and Psychopharmacology Seminar Organizer and Chair

2015 ABAI 41st Annual Convention; Organizer and Chair of Symposium: Appetitive Properties of Drug Cues in Learning and Memory Processes: Implications for Drug Addiction

2015 ABAI: 41st Annual Convention; Poster Discussant: Psychopharmacology

2011- Ad Hoc Reviewer:

- Addiction
- Alcohol Clinical and Experimental Research
- Behavioural Processes
- Journal of Behavioral Health
- Journal of Experimental Psychology
- Nicotine and Tobacco Research

Publications (N = 23)

Laude, J. R., & Fillmore, M. T. (2016). Drivers who self-estimate lower blood alcohol concentrations are riskier drivers after drinking. *Psychopharmacology*, 1-8.

Laude, J. R., & Fillmore, M. T. (2015). Simulated driving performance under alcohol: effects on driver-risk versus driver-skill. *Drug and alcohol dependence*, *154*, 271-277.

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Daniels, C. W., **Laude, J. R.**, & Zentall, T. R. (2014). Six-Term Transitive Inference with Pigeons: Sequential Followed by Mixed Pair Training. Journal of the Experimental Analysis of Behavior*, 101*, 26-37.
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Laude, J. R., Beckmann, J. S., Daniels, C. W., & Zentall, T. R. (2014). Impulsivity affects suboptimal gambling-like choice by pigeons. *Journal of Experimental Psychology: Animal Learning and Cognition*, *40*, 2.
Laude, J. R., Stagner, J. P., Rayburn-Reeves, R., & Zentall, T. R. (2014). Midsession reversals with pigeons: visual versus spatial discriminations and the intertrial I nterval. *Learning & behavior*, *42*, 40-46.
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Pattison, K. F., **Laude, J. R.**, & Zentall, T. R. (2013). The case of the magic bones: Dogs' memory of the physical properties of objects. *Learning and Motivation*.
Rayburn-Reeves, R. **Laude, J. R.**, & Zentall, T. R. (2013). Pigeons show near-optimal win-stay/lose-shift performance on a simultaneous-discrimination, midsession reversal task with Short Intertrial Intervals, *Behavioral Processes, 92,* 65–70.
Laude, J. R., Pattison, K., & Zentall, T. R. (2012). Hungry pigeons make irrational decisions, less hungry pigeons do not. *Psychonomic Bulletin and Review, 19*, 884-891.
Pattison, K., **Laude, J. R.**, & Zentall, T. R. (2012). Environmental enrichment affects suboptimal, risky, gambling-like choice by pigeons. *Animal Cognition,* 10.1007/s10071-012-0583-x.
Stagner, J. P., Michler, D. M., Rayburn-Reeves, R., **Laude, J. R**., and Zentall, T. R. (2012). Midsession reversal learning: why do pigeons anticipate and perseverate? *Learning and Behavior*. 10.3758/s13420-012-0077-3.
Molet, M., Miller, H., **Laude, J. R.**, Kirk, C. R., Manning, B., & Zentall, T. R. (2012). Decision making by humans in a behavioral task: Do humans, like pigeons, show suboptimal choice? *Learning & Behavior, 40,* 439-447.
Stagner, J. P., **Laude, J. R**., and Zentall, T. R. (2012). Pigeons prefer discriminative stimuli independently of the overall probability of reinforcement and of the number of presentations of the conditioned reinforcer. *Journal of Experimental Psychology: Animal Behavioral Processes, 38,* 446-52.
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Papers in submission (N = 7)

David, S.P., Crew, E., Bailey, S., **Laude, J. R.**, Bryson, S., Varady, A., Lembke, A., McFall, D., Jeon, A., Fujimoto, M., Killen, D., Killen, J. Extended Treatment for Smoking Cessation with Chantix and Varinicline. *JAMA Psychiatry*.
Laude, J. R., MacKillop, J. & David S. P. Chapter 6. Nicotine Dependence Integrating

Psychological and Pharmacological Treatments for Addictive Disorders: An Evidence-Based Guide (Routledge Press, 2016). Edited by MacKillop, J., Kenna, G. A., Lorenzo, L., Ray, L. A. (2016) Routledge Press, 2016, Washington, DC. 2. David SP, Sweet LH, Cohen RA, MacKill

Laude, J. R., Clark, A., & Fillmore, M. T. Poly-drug users' risk perceptions of driving under the influence of marijuana and alcohol. *Journal of Studies on Alcohol and Drugs.*

Laude, J. R., Daniels, C. W., and Wade, J. C., Zentall, T. R. I can Time with a Little Help from my Friends: Effect of Social Enrichment on Timing Processes in Pigeons (Columbia livia), *Animal Cognition.*

Laude, J. R., & Fillmore, M. T. Training-induced overconfidence increases driver risk-taking when under the influence of alcohol. *Psychological Science.*

Laude, J. R., & Fillmore, M. T. The effect of a rewarding environment on subjective responses to alcohol.

Daniels, C. W., **Laude, J. R.**, Sanabria, F. Reinforcement learning can account for suboptimal pigeons and optimal rats.

Selected First Author Presentations (N = 29)

Laude, J. R. & Fillmore, M. T. (2015). The role of differential reinforcement histories on the expected effects of alcohol intoxication. Paper presented at the Pavlovian Society, Annual Meeting: Portland, Oregon

Laude, J. R. & Fillmore, M. T. (2015). The effect of a rewarding environment on subjective responses to alcohol. Paper presented at the Comparative Cognition Conference, Chicago, Illinois.

Laude, J. R. (2015). A study of pigeon and dog intelligence: Who are the real bird brains?. Paper presented at the CEEB 14th annual Spring Symposium in Ecology, Evolution and Behavior, Lexington, Kentucky.

Laude, J. R. & Fillmore, M. T. (2015). Intoxication in a rewarding environment as a risk factor for alcohol misuse. Paper presented at the 41st Society for Quantitative Analysis and Behavior, San Antonio, Texas.

Laude, J. R. & Fillmore, M. T. (2015). Alcohol-induced disinhibition increases risky-driving behavior in social drinkers. Paper presented at the 38th Annual RSA Scientific Meeting, San Antonio, Texas.

Laude, J. R. & Fillmore, M. T. (2014). Blocking by an alcohol cue exacerbates learning as a function of attentional bias. Paper presented at the TriState (Plus) Conference on Learning and Behavior, Windsor, Canada.

Laude, J. R. & Fillmore, M. T. (2014). The role of attentional bias to alcohol-related content in acquisition of pavlovian conditioned inhibition in binge drinkers. Paper presented at the 37th Annual RSA Scientific Meeting, Bellevue, Washington.

Laude, J. R., Case, J., Stagner, J. P., Sticklen, M., & Zentall, T. R. (2014). Towards a better model of the near miss in pigeons. Paper presented at the 40th Annual ABAI Convention, Chicago, Illinois.

Laude, J. R., Fillmore, M. & Zentall, T. R. (2014). Alcohol abuse in humans and gambling in non-human animals is related to a reduced ability to learn about signals that could cue termination of dysregulated behavior in the presence of conditioned reinforcers. Paper presented at the CEEB 13th annual Spring Symposium in Ecology, Evolution and Behavior, Lexington, Kentucky.

Laude, J. R. & Zentall, T. R. (2014). The role of reduced conditioned inhibition in sub-optimal choice by pigeons. Paper presented at the 40th Society for Quantitative Analysis of Behavior, Chicago, Illinois.

Laude, J. R., Stagner, J. P., Beckman, J. S., Daniels, C. W., & Zentall, T. R. (2014). Increased delay-discounting is associated with severity of sub-optimal, gambling-like choice by pigeons. Paper presented at the Comparative Cognition and Learning Conference, Melbourne, Florida.

Laude, J. R., Stagner, J. P., Beckman, J. S., Daniels, C. W., & Zentall, T. R. (2013). Impulsivity affects sub-optimal, gambling-like choice by pigeons: Increased attraction to conditioned reinforcers and reduced conditioned inhibition as a mechanism. Paper presented at the 39th Annual ABAI Convention, Minneapolis, Minnesota.

Laude, J. R., Wade, J. C., & Zentall, T. R. (2013). To what extent do differences in subjective timing account for "cognitive bias" in socially enriched versus socially isolated pigeons?. Paper presented at the TriState (Plus) Conference on Animal Learning and Behavior, Ohio State University, Columbus, Ohio.

Laude, J. R., Pattison, K., & Zentall, T. R. (2012). Environmental enrichment affects suboptimal, risky, gambling-like choice by pigeons. Poster presented at the 2nd Joint Meeting of the Spanish Society for Comparative Psychology and the International Society for Comparative Psychology, Jaén, Spain.

Laude, J. R., Pattison, K., & Zentall, T. R. (2010). Sub-optimal choice in pigeons: Effect of level of motivation for food. Paper presented at the Comparative Cognition and Learning Conference, Melbourne, Florida.

Supervision

2014-2016 **Cognitive Neuroscience and Psychopharmacology Laboratory**
Undergraduate Research Assistant Mentor

2009-2013 **Comparative Cognition Laboratory**
Undergraduate Research Assistant Mentor

2011-2013 **Canine Learning and Behavior Laboratory**
Undergraduate Research Assistant Mentor

2014-2016 **Ariel Clark, Honors Thesis Student**
Papers in preparation: N = 1

2012-2014 **Jacob Case, BA: Honors Thesis Student**
Papers published as co-author: N = 2

Paper presentations: N = 4

2012-2013 **Jordan Wade, BA: Honors Thesis Student**
Papers published as co-author: N = 1
Papers in preparation: N = 2
Paper presentations: N = 3

2011-2013 **Carter Daniels, BA: Honors Thesis Student**
Papers published as co-author: N = 4
Papers in preparation: N = 2
Paper presentations: N = 4

2012-2014 **Melissa Noel, BS; Korey Nicholls, BA:**
Paper presentations

Faculty Appointments (N = 10)

Aug. – Dec. 2016 **Adjunct Professor**, Midway University
PSY XXX Forensics Psychology

Jan. – March 2016 **Adjunct Professor**, Midway University
PSY 315 Biological Psychology

Jan. – March 2016 **Adjunct Professor**, Midway University
PSY 355 Cognitive Theory

Aug. – Dec. 2015 **Adjunct Professor**, Midway University
PSY 355 Research Methods

Jan. – May 2015 **Adjunct Professor**, Midway University
PSY 420 History and Systems of Psychology

Aug. – Dec. 2014 **Adjunct Professor**, Midway University
PSY 355 Research Methods

Aug. – Dec. 2014 **Adjunct Professor**, Midway University
PSY 320 Psychopathology

May. – Aug 2014 **Adjunct Professor**, Midway University
PSY 350 Cognitive Theory

Jan. – May 2014 **Adjunct Professor**, Midway University
PSY 350 Cognitive Theory

Jan. – May 2014	**Adjunct Professor**, Midway University PSY 314 Biological Psychology

Teaching Experience (N = 7):

Aug. – Dec. 2013	**Laboratory Instructor,** University of Kentucky PSY 552 Animal Behavior
Jan. – May 2013	**Laboratory Instructor,** University of Kentucky PSY 216 Application of Statistics in Psychology
May – Aug. 2013	**Laboratory Instructor,** University of Kentucky PSY 216 Application of Statistics in Psychology
Aug. – Dec. 2012	**Laboratory Instructor,** University of Kentucky PSY 216 Application of Statistics in Psychology
Jan. – May 2012	**Laboratory Instructor,** University of Kentucky PSY 216 Application of Statistics in Psychology
Aug. – Dec. 2011	**Laboratory Instructor,** University of Kentucky PSY 552 Animal Behavior
Jan. – May 2011	**Laboratory Instructor,** University of Kentucky PSY 100 Introduction to Psychology

Professional Affiliations:

2015	Pavlovian Society
2013-2015	Research Society on Alcoholism
2013-2015	Association of Behavior Analysis International
2013-2015	Society for the Quantitative Analysis of Behavior
2012-2015	Dog Science Incorporated (Director of Research)
2010-2015	Psi Chi
2009-2015	American Psychological Association
2009-2015	Comparative Cognition Society

Programming:

STISM
MED-PC
E-Prime
E-Prime Extensions for Tobii
Tobii Studio

Statistical Software Proficiency:

SYSTAT
SPSS
JMP
SAS
AMOS