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Laboratory analysis of risky driving at 0.05% and 0.08% blood alcohol concentration

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Abstract

Background—The public health costs associated with alcohol-related traffic crashes are a continuing problem for society. One harm reduction strategy has been to employ per se limits for blood alcohol concentrations (BACs) at which drivers can legally operate motor vehicles. This limit is currently 0.08% in all 50 US states. Recently, the National Transportation Safety Board proposed lowering the legal limit to 0.05 % (NTSB, 2013). While research has well-validated the ability of alcohol to impair driving performance and heighten crash-risk at these BACs, relatively little is known about the degree to which alcohol might increase drivers' risk-taking.

Methods—Risk-taking was examined in 20 healthy adults who were each tested in a driving simulator following placebo and two doses of alcohol calculated to yield peak BACs of 0.08% and 0.05%, the respective current and proposed BAC limits. The drive test emphasized risk-taking by placing participants in a multiple-lane, high-traffic environment. The primary measure was how close drivers maneuvered relative to other vehicles on the road (i.e., time-to-collision, TTC).

Results—Alcohol increased risk-taking by decreasing drivers' TTC at the 0.08% target BAC relative to placebo. Moreover, risk-taking at the 0.05% target was less than risk-taking at 0.08% target BAC.

Conclusions—These findings provide evidence that reducing the legal BAC limit in the USA to 0.05% would decrease risk-taking among drivers. A clearer understanding of the dose-response relationship between various aspects of driving behaviors, such as drivers' accepted level of risk while driving, is an important step to improving traffic safety.

Keywords

Alcohol; simulated driving; risk-taking; traffic safety; blood alcohol concentration; legal limit

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Conflict of interest

All authors declare that they have no conflicts of interest

1. Introduction

In the United States, driving while intoxicated leads to an estimated 120 million occurrences of impaired driving per year (e.g., Blincoe et al., 2015; Jewett et al., 2015). In the US, drivers may be arrested for driving under the influence of alcohol (DUI) if their blood alcohol concentration (BAC) exceeds the “per se” legal limit of 0.08%. However, it is well-known that individuals differ in their responses to alcohol and individuals may be impaired well below this limit (for a review, see: Ogden and Moskowitz, 2004). Indeed, many countries have adopted lower BAC limits (i.e., between 0.02% and 0.05%) in an effort to reduce motor vehicle crashes (MVCs) and improve public safety. Recently the National Transportation Safety Board issued a recommendation that the United States lower its legal BAC limit from 0.08% to 0.05% (NTSB, 2014). As such, it is important to determine precisely how the adverse effects of alcohol on driving behavior are lessened when the BAC of the driver is reduced from 0.08% to 0.05%.

For many years laboratory studies of simulated driving have sought to determine factors that contribute to MVCs. Two aspects of driving performance shown to contribute to MVCs are drivers’ skill and their propensity to engage in risk-taking behaviors. In terms of driver skill, it is suggested that MVCs are caused by deficits in basic skills, such as slowed reaction times and poor motor coordination. Such skill deficits may result in increased rates of swerving, exaggerated and delayed steering wheel manipulations to correct for lane position, and greater deviations of vehicle drive speed (for a review, see Ranney, 1994). However, it is also recognized that MVCs may be caused by the driver engaging in risk-taking behaviors. Indeed, reports indicate that risky driving accounts for a significant proportion of traffic fatalities in young adults (Department of Transport and Main Roads, 2011). Risk-based models of driving behavior suggest that drivers select a level of risk for traffic injury/collision they are willing to accept (i.e., a safety margin) and then drive in accordance with that risk level. Risk-taking is often measured by proxemics, indicated by instances where drivers maneuver close to other vehicles on the road. For example, drivers who adopt a high-risk acceptance are more likely to place their vehicle closer to other vehicles (e.g., tailgating) on the road compared with drivers with low-risk acceptance. This risk-taking behavior is quantified by determining drivers’ time-to-collision (TTC). TTC is a time-related safety margin measure determined by the bumper-to-bumper distance between the driver’s vehicle and other vehicles on the road, divided by the closing speed of the vehicles (Taieb-Maimon and Shinar, 2001; Zhang and Kaber, 2013). Thus, TTC provides a measure of the time (in seconds) it would take for a collision to occur between two or more vehicles on the roadway (Zhang et al., 2006). Risky driving is evidenced by lower TTC values compared with non-risky driving. Research indicates that greater risk-taking, as measured by TTC, is associated with increased risk for MVCs (e.g., Hayward, 1972; Ranney, 1994; Summala, 1985, 1988; Wilde, 1982).

It is also recognized that alcohol likely contributes to MVCs by its joint effects of impaired driver skill and increased risk-taking behavior. Laboratory studies of the acute impairing effects of alcohol using high-fidelity driving simulators have clearly established the ability of alcohol to impair several basic driving behaviors reflective of skill. Indeed, research indicates that alcohol-induced impairment of driving performance leads to increased

standard deviation of the vehicle's lane position on the road (SDLP), increased and delayed steering corrections, and increased lane exceedances (for a review, see: Ogden and Moskowitz, 2004). As such, intoxicated drivers are less able to execute small, continuous steering wheel manipulations necessary to maintain the center position of their lane than sober drivers. Moreover, there is evidence that alcohol impairs these skill-based driving behaviors at and below the current legal limit BAC in the United States, 0.08% (e.g., Mitchell, 1985; Moskowitz and Fiorentino, 2000; Moskowitz and Robinson, 1988).

By contrast, less is known about alcohol effects on risk-taking at BACs below 0.08%. To our knowledge, only a few laboratory studies have examined risky driving in response to alcohol (see: Burian et al., 2002, 2003; Cohen et al., 1958; Laude and Fillmore, 2015; Leung and Starmer, 2005). In general, these studies have shown that alcohol increases risky decisions while driving. For example, studies have found that intoxicated drivers are more willing to choose risky traffic lanes over less-risky options (Burian et al., 2002, 2003), maneuver through narrower gaps (Cohen et al., 1958), and underestimate potential collision time with oncoming traffic (Leung and Starmer, 2005). A recent study conducted in our laboratory examined driver risk-taking as measured by TTC following placebo and an acute dose of alcohol designed to produce a peak BAC of 0.08% (Laude and Fillmore, 2015). Under alcohol, drivers decreased their TTC by driving closer to other vehicles on the roadway relative to placebo. Examination of individual differences in response to alcohol showed that the magnitude of alcohol effect on risk-taking was independent of the magnitude with which the drug impaired drivers' skill. As such, it is possible for alcohol to promote risk-taking in drivers even in cases where the drug has little effect on their skill. While this hypothesis has received little research attention, the assumption that driver skill could be distinguished from driver risk-taking has been held for some time (Barry, 1973).

Increased risk-taking while intoxicated is likely due in part to the disinhibiting effects of the drug on impulse control. Laboratory evidence implicates inhibitory control as an important contributor toward maladaptive, impulsive driving behaviors. Indeed, in a laboratory study of alcohol effects, we have shown that individuals whose inhibitory control was most impaired by alcohol on a cued go/no-go task also displayed the greatest level of risky driving behaviors under the drug (Fillmore et al., 2008). This relationship suggests that risky driving could be decreased in situations in which inhibitory control is improved. A number of studies have examined the effect of alcohol on inhibitory control using alcohol doses that produce peak BACs between 0.05% and 0.08% (for a review, see: Weafer and Fillmore, 2016). In general, these studies provide some evidence that the disinhibiting effect of alcohol is less pronounced at a BAC of 0.05%, compared with 0.08% (Marczinski and Fillmore, 2003). Given the importance of inhibitory control to risky driving behavior, there is reason to suspect that risky driving might also decrease in a similar manner at BACs below 0.08%.

The current study tested this hypothesis in a sample of healthy adult drivers who completed a risky driving scenario in a driving simulator following placebo and active doses of alcohol calculated to yield target BACs of 0.08% and 0.05%, the respective current and recently proposed BAC limits in the United States. The driving scenario placed drivers in a high-traffic, urban setting and encouraged risky driving by providing monetary incentive for completing the drive scenario quickly. It was predicted that alcohol would increase risky

driving, relative to placebo. Moreover, it was predicted that risky driving under alcohol would be significantly diminished at a BAC of 0.05% compared with 0.08%.

2. Materials and methods

2.1. Participants

Twenty licensed adult drivers (10 men and 10 women) between 21 and 35 years of age participated in this 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 and mental performance. Interested individuals called the laboratory and completed a telephone screen that gathered information on demographics, drinking habits, other drug use, and physical and mental health status. Volunteers who self-reported head trauma, psychiatric disorder, or substance abuse disorder were excluded from participation. All volunteers had to drive a motor vehicle and consume alcohol at least one day per week. Individuals were excluded if their current alcohol use met dependence/withdrawal criteria as determined by the substance use disorder module of the *Structured Clinical Interview for DSM-IV (SCID-IV).* No participant reported the use of any psychoactive prescription medication and recent use of amphetamines (including methylphenidate), barbiturates, benzodiazepines, cocaine, opiates, and tetrahydrocannabinol was assessed by means of urine analysis (ICUP Drug Screen, Instant Technologies). Any volunteer who tested positive for the presence of any of these drugs (with the exception of THC) was excluded from participation. Current marijuana users were instructed to abstain from use for at least 24 hours prior to participation. No female volunteers who were pregnant or breast-feeding participated in the research as verified by self-report and urinalysis (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, food for 4 hours, and water/fluids for 2 hours prior to each test session. Test sessions were initiated between 10:00 a.m. and 6:00 p.m. At the beginning of each session, a zero blood alcohol concentration (BAC) was verified by Intoxilyzer, Model 400 (CMI Inc., Owensboro, KY). The University of Kentucky Medical Institutional Review Board approved the study. All participants provided informed consent, and received $130 compensation for their participation plus any bonus money based on their simulated driving performance (see 2.2.1 Risk-based Drive Scenario).

2.2. Apparatus and materials

A computerized driving simulator measured driving performance (STISIM Drive, Systems Technology Inc., Hawthorne, CA). In a small room, participants sat in front of a 19-inch computer display, which presented the driving simulation at a 60 degree horizontal field of view. The simulation placed the participant in the driver seat of the vehicle, which was controlled by steering wheel movements and manipulations of the accelerator and brake pedals. At all times, the participant had full view of the road (lane width = 12 ft) 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.

2.2.1. Risk-based drive scenario—This simulated driving scenario was designed to test risky driving behavior and required participants to drive 21,100 feet on a busy 4-lane street within a metropolitan setting. There was no posted speed limit. Each direction of traffic comprised 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 3–4 min, $4 for 4–5 min, $3 for 5–6 min, $2 for 6–7 min, $1 for 7–8 min, and $0.50 for over 8 min. Drivers were penalized $0.50 for each crash. This response conflict scenario is designed to mimic everyday driving behaviors in which drivers are rewarded by arriving at their destination on time at the cost of potential traffic citations, and has been successfully used in other research in our laboratory (e.g., Van Dyke and Fillmore, 2015; Fillmore et al., 2008).

The primary measure of driver risk was time-to-collision (TTC). This is a time-related safety margin measure (Taieb-Maimon and Shinar, 2001), determined by the bumper-to-bumper distance between two vehicles, divided by the closing speed of the vehicles (Zhang and Kaber, 2013). TTC is operationally defined as the time that remains until collision occurs if both the lead and the driven vehicle continue on the same course (Zhang et al., 2006). It is obtained by taking the minimum value of the riskiest instance in which the driven car approaches a lead car throughout the drive, sampled at each foot of the driving test. Riskier driving is indicated by smaller TTC values (seconds). Average drive speed (mph) and accident frequency were also measured.

2.2.2. Subjective intoxication—Drivers provided a rating of their level of intoxication on a 100 mm visual-analogue scale with anchors of 0 "not at all" to 100 "very much." This scale is sensitive to the effects of alcohol at the doses used in the current study (e.g., Harrison and Fillmore 2005; Harrison et al., 2007).

2.2.3. Recent drinking habits—Recent patterns of alcohol use were measured by the Timeline Follow-back (TLFB, Sobell and Sobell, 1992). The TLFB assessed daily patterns of alcohol consumption over the past 90 days. The measure is structured with prompts to facilitate participants' recall of past drinking episodes to provide a more accurate retrospective account of alcohol use during that time period. The TLFB provided a measure of the total number of drinking days, the total number of drinks consumed, drinking days they felt drunk (drunk days), and binge drinking episodes. A binge was defined as a drinking episode in which the individual drank to achieve a resultant BAC that was equal to or greater than the current legal limit (i.e., 0.08%). The resultant BAC was estimated for each drinking episode based on the participant's reported number of drinks, the duration of the episode, and the participant's gender and body weight. Estimated BACs were calculated using well-established, valid anthropometric-based BAC estimation formulae which assume an average clearance rate of 15 mg/100 ml per hour of the drinking episode (McKim, 2007; Watson et al., 1981).

2.2.4. Driving History and Experience Questionnaire — DHEQ (Harrison and Fillmore, 2005)—This self-report questionnaire gathered information on driving history

and behaviors. Included in the questionnaire are measures of driving experience such as length of time holding a driver's license and number of days and miles driven per week. The questionnaire also gathered information about participants' driving behaviors, such as license revocations, traffic accidents, and traffic tickets.

2.2.5. Drug Abuse Screening Test — DAST (Skinner, 1982)—This 28-item self-report questionnaire screened for drug abuse problems. A score of six or more has been suggested as indicative of a drug use disorder (Skinner, 1982).

2.2.6. Alcohol Use Disorders Identification Test — AUDIT (Babor et al., 1989)—This 10-item self-report questionnaire assessed consequences of harmful drinking. Higher total scores indicate greater problems with alcohol.

2.3. Procedure

2.3.1. Familiarization session—The purpose of this session was to familiarize participants with laboratory procedures, obtain information on recent drinking history (TLFB), driving history (DHEQ), risky drug use (DAST and AUDIT), and general health status and demographic characteristics. Participants also completed practice versions of the risky driving scenario.

2.3.2. Test sessions—Alcohol effects on driving performance were examined in a within-subjects design where each participant was tested under 0.70 g/kg, 0.50 g/kg, and 0.0 g/kg (placebo) alcohol on separate days in counterbalanced order. Dose administration was blind to each participant. Sessions were separated by a minimum of one day and a maximum of one week. The alcohol dose was calculated based on body weight and administered as absolute alcohol (95% alc/vol) mixed with three parts carbonated lemon/lime flavored soda. The soda mixer was clear in color and did not contain any active ingredients. Participants consumed each dose in six minutes. The 0.70 g/kg dose was expected to produce an average peak BAC of 80 mg/100 ml (0.08%) approximately 60–70 min after consumption, and the 0.50 g/kg dose was expected to produce an average peak BAC of 50 mg/100 ml (0.05%) in the same timeframe. The placebo beverage consisted of a volume of carbonated mix that matched the total volume of the 0.50 g/kg alcohol beverage. A small amount (i.e., 3 ml) of alcohol was floated on the top of the placebo beverage and each glass was sprayed with an alcohol mist that provided a strong alcoholic scent as the beverage was consumed.

For each dose session, BACs were sampled every five minutes until participants were within 5 mg/100 ml of the target BAC (i.e., 50 mg/100 ml; 80 mg/100 ml) for each active dose, after which testing began. Thus, the onset of testing varied across participants and dose. Testing under placebo followed the same procedure, with the exception that the onset of testing was fixed at 50 min post-beverage consumption for all participants. This timing procedure was chosen to be comparable to the anticipated onset of testing for the 0.05% target BAC condition. Immediately following completion of the risky drive test, participants provided a BAC sample and rated their level of intoxication. Afterwards, participants relaxed at leisure in a lounge area where they remained until their BAC reached 20 mg/100 ml.

Transportation home was provided after the sessions. Participants were paid and debriefed upon completion of the final session.

3. Results

3.1. Demographics, drinking and driving history, and other drug use

The racial makeup of the sample was 90% Caucasian and 10% Asian. Table 1 lists drivers' background characteristics, including driving experience and recent drinking history. Mean scores indicate that the sample consisted of experienced drivers who consumed alcohol on a regular basis. In terms of other drug use, some subjects reported using caffeine ($n = 18$), marijuana ($n = 5$), and tobacco ($n = 6$) in the past 30 days. Two subjects tested positive for THC at testing, though both self-reported abstaining for more than one week prior to participation.

3.2. Blood alcohol concentrations

Drivers' mean BACs at the 0.05% (0.50 g/kg) and 0.08% (0.70 g/kg) target BAC doses, calculated by taking the average of pre- and post-test BACs were 52.5 mg/100 ml ($SD = 7.8$) and 83.0 mg/100 ml ($SD = 11.2$), respectively. Table 2 reports pre- and post-test mean BACs for each dose by sex. The table shows higher BACs following 0.70 g/kg versus 0.50 g/kg alcohol and also shows higher BACs in women compared with men. A 2 dose (0.50 vs. 0.70 g/kg) X 2 time (pre-test vs. post-test) X 2 sex mixed-model analysis of variance (ANOVA) confirmed main effects of dose, $F(1, 18) = 163.34$, $p < .001$, $\eta_p^2 = 0.90$, and sex, $F(1, 18) = 9.78$, $p = .006$, $\eta_p^2 = 0.35$. No interactions were found ($ps > .264$). The mean number of minutes from the onset of drinking to the onset of testing for the 0.05% and 0.08% target BACs was 47.3 min ($SD = 5.0$) and 59.9 min ($SD = 8.1$), respectively.

3.3. Risky driving behavior

Figure 1 plots the mean TTC values under each dose. The figure indicates that alcohol generally increased risky driving, with the greatest levels of risk-taking seen under the 0.08% target BAC. A 3 dose (placebo; 0.50 g/kg; 0.70 g/kg) × 2 sex mixed-model ANOVA of risky driving revealed a significant main effect of dose on drivers' risk-taking, $F(2, 36) = 3.86$, $p = .030$, $\eta_p^2 = 0.18$, indicating a general increase in risk-taking under alcohol. No main effect of sex or interaction between dose and sex was found ($ps > .358$). Given no sex differences in risky driving, subsequent a priori paired-sample t tests comparing risky driving under each dose were collapsed across sex. In line with previous research in this area, risky driving under the 0.08% target BAC was significantly greater than risk-taking under placebo, $t(19) = 2.48$, $p = .023$, $d = 0.60$. Moreover, risk-taking at the 0.05% target BAC was significantly lower than risk-taking at the 0.08% target BAC, $t(19) = 2.15$, $p = .045$, $d = 0.48$. The difference in risk-taking between placebo and 0.05% was not statistically significant, $t(19) = 0.76$, $p = .460$, $d = 0.14$.

With regard to the effect of alcohol on secondary simulated driving outcome measures, Table 3 reports drivers' mean number of motor vehicle crashes, mean speed, and monetary rewards earned on the risky drive scenario. The table shows that crashes were infrequent, averaging less than a single crash during the drive. A 3 dose (placebo; 0.50 g/kg; 0.70 g/kg) × 2 sex

mixed-model ANOVA of crashes showed a significant dose effect, $F(2, 36) = 3.75$, $p = .033$, $\eta_p^2 = 0.17$. Table 3 reports that crashes increased as function of dose. No main effect of sex or dose by sex interaction was found (ps > .299). With regard to drivers' mean speed and monetary rewards earned on the risky drive scenario, no significant main effects of dose or sex, or interactions between dose and sex were found (ps > .181).

3.4. Subjective intoxication

Subjective intoxication was analyzed by a 3 dose (placebo; 0.50 g/kg; 0.70 g/kg) × 2 sex mixed-model ANOVA and revealed main effects of dose, $F(2, 36) = 27.68$, $p < .001$, $\eta_p^2 = 0.61$, and sex, $F(2, 36) = 4.45$, $p = .049$, $\eta_p^2 = 0.20$. The interaction between dose and sex was marginally significant, $F(2, 36) = 3.16$, $p = .054$, $\eta_p^2 = 0.15$. For men, the mean (SD) intoxication ratings for the placebo, 0.50 g/kg, and 0.70 g/kg doses were 14.7 (20.2), 41.6 (23.7), and 42.3 (27.1), respectively. For women the mean intoxication ratings for the placebo, 0.50 g/kg, and 0.70 g/kg doses were 20.2 (28.0), 53.8 (23.3), and 75.7 (16.1). Thus, women reported higher ratings of intoxication than men.

4. Discussion

The present study examined the acute effect of alcohol on driver risk-taking at the current and recently proposed BAC limits of 0.08% and 0.05%, respectively. Results indicated that alcohol increased risk-taking by significantly decreasing drivers' safety margins (lower TTC) at the 0.08% target BAC relative to placebo. This finding provides important replication of previous work in this area that reports significantly elevated risk-taking under a comparable dose and BAC (Laude and Fillmore, 2015). These findings also provide corroborating evidence of TTC as a laboratory measure of risk-taking that is sensitive to moderate doses of alcohol. Results also indicated that risk-taking at the 0.05% target BAC was significantly less than risk-taking at the 0.08% target BAC, such that drivers increased their safety margins under the 0.05% target BAC. This finding provides laboratory-based evidence that adherence to a lower BAC limit of 0.05% could function to decrease driver risk-taking. Risk-taking at the 0.05% target BAC showed no statistical increase relative to placebo. With regard to self-evaluations of intoxication, as expected, drivers self-reported greater levels of intoxication as a function of increasing dose.

A limitation commonly reported in simulated driving studies concerns the degree to which driving simulators model driving behavior outside the laboratory. Although measures of simulated driving performance attempt to model more complex, "real-life" activities, ironically they often come under greater scrutiny with regard to their ecological validity than do simple laboratory tasks. A common criticism is that simulated driving might overestimate poor or reckless driver behavior because it does not engender the same degree of driver motivation as actual driving, since there is no actual risk to personal injury. However, despite the lack of injury risk in the laboratory, drivers display little tendency for risk-taking unless there is some explicit incentive to do so. In this study, risk-taking was instigated by providing monetary incentive to complete the drive quickly. Such incentives are necessary to prompt risky driving maneuvers in order to examine how this behavioral tendency can be exacerbated by alcohol. We chose monetary incentives because they are potent reinforcers of

risky driving behavior in the laboratory as demonstrated in previous studies (e.g., Fillmore et al., 2008; Laude and Fillmore, 2015). Outside the laboratory, instigation to engage in risky driving is commonplace in many driving situations. Being late and in a hurry to get somewhere is a familiar example of an instigation for a driver to risk-take and there is a strong incentive to speed in order to arrive on time and avoid possible punishment for being late for work or some other important engagement. As such, it is important for researchers to consider incentives to risk-take in laboratory analyses of risky driving behaviors.

It is important to consider how these findings impact public policy surrounding proposals to lower the legal driving limit. Although the sample mean BACs for each dose were close to the desired 0.05% and 0.08% targets, unavoidable variation in rates of absorption and metabolism following oral alcohol administration resulted in individual participant BACs that in some cases were above or below the desired targets. In addition, variation was introduced as a result of women achieving slightly higher BACs than men, although no sex differences in the response to alcohol were observed. Examination of the BAC distributions for the 0.05% and 0.08% target BACs using stem and leaf plots confirmed the majority of BACs were close to the desired targets. Analyses revealed the range between the lower and upper quartiles around the median BACs for the 0.05% and 0.08% target BACs was 8.5 mg/100 ml and 13.5 mg/100 ml, respectively. Although oral dosing provides ecological validity, future studies could limit the effect of BAC variation by employing clamping techniques to maintain steady-state BACs during assessment of risk-taking over longer periods of time. Similarly, it should be noted that testing in the current study occurred predominately on the ascending limb of the BAC curve. Given that decisions to drive after drinking often occur as BACs are declining, it is important for future research to consider alcohol's effect on risk-taking across the entire curve.

It is also important to consider how alcohol effects on driver risk-taking can be influenced by the situation and the characteristics of the driver. The drive scenario in the current study was relatively short (i.e., ~5 min) and only required drivers to manipulate the steering wheel and accelerator and brake pedals to overtake nearby vehicles. It is recognized that this situation is somewhat simplistic given that everyday driving also requires individuals to simultaneously contend with a multitude of distractions, such as numerous dashboard controls, passengers in the vehicle, and cellular telephones. Laboratory research has shown these forms of distraction impair driving skill, especially in drivers under the influence of alcohol (e.g., Harrison and Fillmore, 2011; Rakauskas et al., 2008; Van Dyke and Fillmore, 2015). At present it is unclear how such distracting or high demand driving environments might affect drivers' proclivity for risk-taking, and the degree to which alcohol might increase such risky driving. Thus, the possibility that alcohol-induced risky driving may be increased in the presence of common sources of distraction and/or longer commutes is unknown. Such findings would have considerable implications on public policy surrounding drinking and driving.

In terms of driver characteristics, it is recognized that drivers in the current study were healthy adults with no history of psychiatric disorder, criminal offense, or substance use disorder. At-risk populations, such as binge drinkers, adults with ADHD, individuals who readily drive after drinking, or have been arrested for DUI, who are characterized by traits of

impulsivity, might be particularly susceptible to risky driving. As mentioned in the introduction, aspects of impulsivity (e.g., inhibitory control) have shown to be related to risky driving (Fillmore et al., 2008). This effect has also been shown on an individual basis, such that individuals who are most susceptible to the impairing effect of alcohol on inhibitory control exhibit the greatest risk-taking (Laude and Fillmore, 2015). Thus, at-risk populations who are known to act impulsively might not only be more likely to engage in day-to-day risky driving, but might be particularly vulnerable to increased risk-taking after consuming alcohol.

In conclusion, the findings from the current study provide the first pieces of evidence that a reduction in the legal driving limit in the United States from 0.08% to 0.05% could function to reduce risky driving behaviors. Further research will be needed to determine how these findings relate to other scenarios and at-risk populations, such as individuals who regularly engage in risky driving or those who have been arrested from drinking under the influence of alcohol. A clearer understanding of the dose-response relationship between various aspects of driving behaviors, such as drivers' accepted level of risk while driving, is an important step to improving traffic safety.

Contributors

Nicholas Van Dyke and Mark Fillmore designed the study and wrote the protocol. Nicholas Van Dyke managed the literature searches and summaries of previous related work. Nicholas Van Dyke undertook the statistical analyses, and Nicholas Van Dyke and Mark Fillmore wrote the first draft of the manuscript. All authors contributed to and have approved the final manuscript.

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Highlights

- Analysis of risky driving behaviors at 0.05% versus 0.08% blood alcohol concentration (BAC) in a driving simulator
- Risk-taking at 0.05% was significantly lower than risk-taking at 0.08%
- Reducing the legal driving limit from 0.08% to 0.05% could reduce risky driving

Figure 1.
The mean time-to-collision values (TTC) from the risk-based driving scenario under placebo, 0.50 g/kg (0.05% target), and 0.70 g/kg (0.08% target) alcohol. Capped vertical lines indicate standard error of the mean.

Table 1

Background characteristics.

	M	*SD*
Age	24.0	3.0
AUDIT	8.80	4.35
DAST	2.60	2.66
DHEQ		
Months driving	104.40	45.97
Driving frequency	5.00	2.10
Miles per day	27.65	27.40
Traffic citations	1.65	1.69
Traffic crashes	1.85	4.26
TLFB		
Drinking days	27.26	17.92
Total drinks	126.32	86.68
Binge days	9.11	9.45
Drunk days	9.11	7.00

Age = subjects' age in years at time of participation; AUDIT = Alcohol Use Disorders Identification Test scores; DAST = Drug Abuse Screening Test scores; Months driving = total months of licensed driving; Driving frequency = total number of driving days per week; Miles per day = total number of miles driven per driving day; Traffic tickets = total number of traffic citations; Traffic crashes = total number of motor vehicle crashes in which the participant was the driver of the vehicle; Drinking days = total drinking days in the past 3 months; Total drinks = total number of drinks consumed in the past 3 months; Binge days = total number of drinking episodes in which the participant drank to the legal limit of 0.08%; Drunk days = total number of drinking days in which the participant self-reported feeling drunk.

Table 2

BACs by sex

	Men	Women
	***M* (*SD*)**	***M* (*SD*)**
0.50 g/kg alcohol		
Pre-test BAC	46.9 (6.8)	59.2 (7.1)
Post-test BAC	48.1 (5.1)	55.9 (7.4)
Avg. BAC	47.5 (4.7)	57.6 (7.1)
0.70 g/kg alcohol		
Pre-test BAC	77.2 (12.7)	86.5 (12.5)
Post-test BAC	80.0 (10.5)	88.2 (11.8)
Avg. BAC	78.6 (10.6)	87.4 (10.5)

Pre-test BAC = BAC immediately prior to risky drive test; Post-test BAC = BAC immediately following risky drive test; Avg. BAC = average BAC across the drive test, calculated by the average of pre- and post-drive test BAC readings. All BACs reported in mg/100 ml.

Table 3

Behavioral measures of driving performance under alcohol

	0.0 g/kg	0.50 g/kg	0.70 g/kg
	M (*SD*)	*M* (*SD*)	*M* (*SD*)
Drive speed	51.3 (10.0)	51.6 (8.1)	51.4 (9.0)
Motor vehicle crashes	0.20 (0.41)	0.45 (0.83)	0.70 (0.92)
Monetary incentive	3.53 (0.99)	3.50 (0.87)	3.25 (1.03)

Drive speed = average drive speed throughout the drive (mph); Motor vehicle crashes = mean number of traffic crashes; Monetary incentive = mean rewards (US dollars) earned on the risky drive scenario, determined by time to completion and motor vehicle crashes (see methods).