Published in final edited form as:
Psychopharmacology (Berl). 2015 December ; 232(23): 4277–4284. doi:10.1007/s00213-015-4055-2.

Distraction produces over-additive increases in the degree to which alcohol impairs driving performance

Nicholas A. Van Dyke and **Mark T. Fillmore***
University of Kentucky, Department of Psychology, 171 Funkhouser Dr., Lexington KY 40506-0044, USA

Abstract

Rationale—Research indicates that alcohol intoxication and increased demands on drivers' attention from distractions (e.g. passengers and cell phones) contribute to poor driving performance and increased rates of traffic accidents and fatalities.

Objectives—The present study examined the separate and combined effects of alcohol and distraction on simulated driving performance at blood alcohol concentrations (BrACs) below the legal driving limit in the United States (i.e. 0.08%).

Methods—Fifty healthy adult drivers (36 men and 14 women) were tested in a driving simulator following a 0.65 g/kg dose of alcohol and a placebo. Drivers completed two drive tests; a distracted drive, which included a two-choice detection task, and an undistracted control drive. Multiple indicators of driving performance, such as drive speed, within-lane deviation, steering rate, and lane exceedances were measured.

Results—Alcohol and distraction each impaired measures of driving performance. Moreover, the magnitude of alcohol impairment was increased by at least two-fold when tested under the distracting versus the undistracted condition.

Conclusions—The findings highlight the need for a clearer understanding of how common distractions impact intoxicated drivers, especially at BrACs that are currently legal for driving in the United States.

Keywords

Alcohol; simulated driving; distraction; subjective intoxication; BrAC; traffic safety

*Correspondence concerning this article should be addressed to: Mark T. Fillmore, Department of Psychology, University of Kentucky, 171 Funkhouser Drive, Lexington, KY 40506. Tel.: +1 859 257 4728; fax: +1 859 323 1979. fillmore@uky.edu.

The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

Both authors designed the study, wrote the protocol, collected the data, and undertook the statistical analyses. All authors contributed to and have approved the final manuscript.

All authors declare that they have no conflicts of interest.

Introduction

Alcohol-related traffic crashes and fatalities are a continuing problem for society. In the United States, the most recent reports indicate that alcohol was a factor in 10,322 traffic fatalities annually; a number that equates to more than 28 alcohol-related deaths every day (National Highway Traffic Safety Administration 2013). One strategy to reduce harm has been to employ "per se" laws for blood alcohol concentrations (BrACs) at which drivers can legally operate a motor vehicle. In the United States, this BrAC limit has been set at 0.08% in all 50 states for the past 12 years (Mercer et al. 2010). However, many countries have adopted BrAC limits of 0.05% and lower in effort to further reduce injuries and fatalities associated with alcohol-related traffic accidents (Fell and Voas 2014). Recently, the National Transportation Safety Board proposed that the legal BrAC limit for driving a motor vehicle be lowered to 0.05% in the United States (NTSB 2013).

Determining a legal limit for driving is based on different types of evidence, including relative risk studies and controlled laboratory studies of the effects of alcohol on aspects of driving performance, using simulators or other tasks. One widely cited study of relative risk, the Grand Rapids study, showed that driver risk increases sharply at BrACs between 0.05% and 0.10% (Borkenstein et al. 1974). These findings are supported by other reports of increased risk for traffic accidents at BrACs below the current legal limit (e.g. Fell and Voas, 2014; Hurst 1973; Moskowitz et al. 1985; Zador 1991; Zador et al. 2000). Controlled laboratory studies of alcohol effects on simulated driving provide additional data to guide policy. However, most laboratory studies have utilized doses at or above 0.08% (for reviews see: Martin et al. 2013; Ogden and Moskowitz 2004), and data are lacking on impairments at lower doses, or effects of alcohol in the presence of distractors.

Alcohol impairs performance on simulated driving on three standardized outcome measures: the standard deviation of the vehicle's lane position (SDLP), steering rate, and lane exceedances (e.g. Martin et al. 2013). These measures are inter-related as successful operation of a motor vehicle involves making small, continuous manipulations to the steering wheel in order to maintain a constant position of the vehicle within the driver's own lane (i.e. SDLP) without crossing into other lanes or onto the edge of the road (i.e. lane exceedance). Alcohol impairs driving performance on each of these measures by increasing SDLP, steering rate, and the number of lane exceedances compared with sober driving performance (Marczinski et al. 2008; Fillmore 2007; Harrison and Fillmore 2008; Harrison and Fillmore 2005; Rakauskas et al. 2008; Shinar et al. 2005; Verster et al. 2009). These impairments are typically observed at BrACs at or above 0.08%.

Although it is important to understand impaired driving in reference to specific BrACs, it is also important to understand how the driving context itself can contribute to this impairment. Of particular concern to impaired driving is the added problem of distraction or divided attention (Papantoniou et al. 2013; Papantoniou et al. 2013). Technology-based distractions (e.g. cell phones, handheld computers, GPS units) and distractions within the vehicle (e.g. temperature and radio controls) pose increasing demands on the driver's attention. Texting, talking on a cell phone or with passengers in the vehicle, and attention to numerous dashboard controls, pose risks that are likely to interact with the impairments produced by alcohol. Surprisingly little research has been conducted on the combined effects of alcohol and distraction. One study (Rakauskas et al. 2008) examined the separate and combined effects of distraction and alcohol at BrACs just below the legal limit (i.e. ~0.075%). Alcohol and distraction individually increased SDLP, and this impairment was greater when alcohol and distraction were combined. Harrison and Fillmore (2011) tested drivers with placebo or alcohol at BrACs just above the current legal limit (i.e. 0.09%) either with or without distraction. The combined effects of alcohol and distraction produced more than additive increases in SDLP. These findings raise the possibility that such distraction could interact with alcohol intoxication in a more than additive manner to exacerbate the impairing effects of alcohol, even at BrACs below the legal limit of 0.08%. The tacit assumption of the per se law is that BrACs below the legal limit are generally regarded as safe. However, such assumptions might not apply to our changing driving environment which is characterized by increasing sources of driver distraction.

The present study investigated the separate and combined impairing effects of distraction and alcohol at BrACs below the legal limit for driving in the United States. It was predicted that, compared with placebo, alcohol would increase drivers' SDLP, steering rate, and the number of lane exceedances. For the distraction condition, participants intermittently performed a simple two-choice detection task while driving. The distraction task was modest, and not expected to disrupt drivers' performance (Harrison and Fillmore 2011). However, we predicted that the combination of alcohol with the distraction task would more than additively impair driving performance.

Methods

Participants

Fifty licensed adult drivers (36 men and 14 women) between 21 and 34 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 consume alcohol at least once per week, and 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. Any volunteer who tested positive for the presence of any of these drugs was excluded from participation. No female volunteers who were pregnant or breast-feeding participated in the research. The University of Kentucky Medical Institutional Review Board approved the study, and participants received $110 for their participation.

Apparatus and materials

Simulated driving task (STISIM Drive, Systems Technology Inc., Hawthorne, CA)—A computerized driving simulator measured driving performance. In a small room, participants sat in front of a 19-inch computer display which presented the driving simulation at a 60 degree horizontal field of view. The simulation placed the participant in the driver seat of the vehicle which was controlled by steering wheel movements and manipulations of the accelerator and brake pedals. At all times, the participant had full view of the road (lane width = 12 ft) surroundings and instrument panel, which included an analog speedometer. Buildings, animals, and trees, in addition to other cars, which required no passing or slowing on the part of the participant, were present in each scenario. Crashes, either into another vehicle or off the road, resulted in the presentation and sound of a shattered windshield. The program then reset the driver in the center of the right lane at the point of the crash. Each drive test provided measurements of drivers' average speed, deviation of lane position, steering rate, and lane exceedances. The drive tests used in the study were of short duration (i.e. approximately 6 min) in order to prevent fatigue and minimize time for drivers' BrAC to change appreciably during testing.

Undistracted drive—This course consisted of 31,100 feet (5.9 miles) conducted during the daytime on a busy, urban street. Drivers were instructed to obey all traffic laws while driving through 20 intersections equipped with traffic lights. Red lights were present at five intersections requiring the driver to stop until the light turned green. At all of the other intersections the light was either green or yellow as the car passed and did not require any action on the part of the driver. Response conflict was present during the drive which provided monetary rewards for completing the drive in the shortest time and penalized drivers 50 cents for failing to stop at each red light. This was included in order to mimic everyday driving situations in which drivers are conflicted between the urge to speed to arrive at a desired destination on time at the risk of traffic tickets. Participants earned $5 for completing the drive in less than 5 minutes, $4 for finishing in 6–7 minutes, $3 for 7–8 minutes, $2 for 8–9 minutes, $1 for 9–10 minutes, and 50 cents if the driver finished in greater than 10 minutes. Drivers were informed of these incentives prior to completing the drive test and the rewards earned on the drive were revealed to the participants at the end of each session. A drive test took between 5 to 10 minutes to complete, depending on the speed of the driver. This drive scenario has been used in other research and has shown to be sensitive to alcohol's effects evidenced by impairments of critical aspects of driving behavior (e.g. Fillmore et al. 2008; Marczinski et al. 2008).

Distracted drive—The distracted drive was identical to the undistracted drive except that subjects also performed a two-choice detection task while they drove. Small red circles appeared near the top left or top right corners of windshield throughout the drive, and participants were instructed to respond to the distractors as quickly as possible by pressing one of two buttons on the dashboard of the simulator (left button for the left distractor and the right button for the right distractor). Each distractor was visible for a maximum of 5 seconds. If participants failed to respond to a distractor within 5 seconds or incorrectly identified a distractor (e.g. left distractor and right button) a "no response" or "incorrect response" was recorded, respectively. Distractors appeared randomly throughout the drive test and drivers encountered between 45 and 50 distractors, depending on the time it took to complete the drive. Participants' mean reaction time and response accuracy to the distractors across the drive were recorded. This form of modest distraction is similar to the distraction experienced while making adjustments to dashboard controls in a vehicle (e.g. Harrison and Fillmore 2011).

Perceived intoxication—Drivers provided a rating of their level of intoxication following completion of both drive tests 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).

Driving History Questionnaire – DHQ (Harrison and Fillmore 2005)—This self-report questionnaire assessed driving experience in terms of length of time holding a driver's license, number of days and miles driven per week, as well as involvements in traffic accidents and receipt of traffic tickets.

Recent drinking habits (TLFB; Sobell and Sobell 1992)—The TLFB assessed daily patterns of alcohol consumption over the past 3 months. Measures included the number of drinking days and the number of drinks consumed.

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

Procedure

The study was conducted in the Behavioral Pharmacology Laboratory of the Department of Psychology at the University of Kentucky and all volunteers provided informed consent. Participants were tested individually and completed an initial familiarization session to become acquainted with laboratory procedures, gather background information, and practice the simulated driving tests.

Participants' driving performance was tested under 0.65 g/kg alcohol and a placebo on separate days in counterbalanced order. In order to achieve equivalent BrACs for men and women, doses given to women were reduced to 87% of the doses given to men (Fillmore 2001; Mulvihill et al. 1997). Sessions were separated by a minimum of one day and a maximum of one week. All participants were required to abstain from alcohol for 24 hours and food for 4 hours prior to each session. The alcohol dose was calculated based on body weight and administered as absolute alcohol mixed with three parts carbonated soda. Participants consumed the dose in six minutes. The dose produces an average peak BrAC between 70 and 80 mg/100 ml approximately 70 minutes after consumption. The placebo consisted of a volume of carbonated mix that matched the total volume of the 0.65 g/kg alcohol drink. A small amount (i.e. 3 ml) of alcohol was floated on the top of the beverage and each glass was sprayed with an alcohol mist that provided a strong alcoholic scent as the beverage was consumed.

Testing began 60 minutes following alcohol consumption. Drivers first completed the undistracted drive and after a 5 min break they completed the distracted drive scenario, with all testing completed by 80 minutes post beverage. After completion of the drives, participants rated their level of intoxication and then relaxed in a lounge area where they remained until their BrAC reached 20 mg/100 ml upon which they were paid and debriefed. Transportation home was provided after the sessions.

Criterion measures

Measures of driving performance were intended to provide a profile of the driving behaviors typically impaired as a result of alcohol intoxication and were chosen on the basis of their established sensitivity to the disruptive effects of alcohol as demonstrated in previous research (e.g. Harrison and Fillmore 2005).

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

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

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

Drive speed and time to finish—Drive speed was measured in terms of miles per hour (mph) and speed was measured as the average mph of the vehicle during a test. The length of time it took drivers to complete a drive test was measured in minutes.

Failures to stop and traffic accidents—The total number of instances in which a driver failed to stop at red traffic lights or crashed, either into another vehicle or by going off road, was recorded for each drive test.

Accuracy and reaction time to distractors—Drivers' accuracy and mean reaction time to distractors on the distracted drive test were recorded.

Data analyses—Performance measures on the simulated drive tests were each analyzed individually using a 2 dose (0.0 g/kg vs. 0.65 g/kg) X 2 distraction (undistracted vs. distracted) within-subjects ANOVA. Participants' ratings of subjective intoxication following the drive tests were analyzed by t test.

Results

Demographics, drinking history, and drug use

Participants identified their racial group as Caucasian (n = 41), African-American (n = 6), Asian (n = 1), Hispanic/Latino (n = 1), and “other” (n = 1). In terms of driving history, the sample reported an average of 9.5 (*SD* = 4.1) years driving experience and reported driving an average of 6.0 (*SD* = 1.7) days per week. The sample reported receiving an average of 2.0 (*SD* = 3.8) traffic tickets and being involved in an average of 1.3 (*SD* = 1.3) traffic crashes in which the participant was the driver. With regard to recent drinking habits, the sample reported consuming alcoholic beverages an average of 29.9 (*SD* = 17.2) days and consumed an average of 136.4 (*SD* = 104.3) standard drinks in the past 3 months. The sample reported an average of 8.9 (*SD* = 9.7) binge drinking episodes and self-reported feeling drunk during drinking episodes an average of 10.4 (*SD* = 9.1) times over that same time period. Nine participants reported using marijuana an average of 2 times in the past month. However, no participant tested positive for THC at testing. No other drug use was reported.

Blood alcohol concentrations

Breath samples were taken at 60, 70 and 80 minutes post-drinking so that BrACs were measured immediately before and after each drive: 60 min and 70 min for the undistracted drive and 70 and 80 min for the distracted drive. The mean BrAC (mg/100 ml) at each time point was: 60 min (M = 64.6; *SD* = 15.3); 70 min (M = 69.5; *SD* = 21.5); 80 min (M = 65.1; *SD* = 19.0). Thus, it was evident that the drive tests occurred at comparable BrACs near the peak of the BrAC curve. A single average BrAC over the time course of each drive was calculated by averaging drivers’ BrAC at the beginning of the drive and at the completion of the drive. The average BrAC obtained for the undistracted drive and the distracted drive tests was nearly identical: 67.0 (*SD* = 17.4) and 67.3 (*SD* = 19.0), respectively. No detectable BrACs were observed in the placebo condition.

Simulated driving performance

Figure 1 plots the simulated driving performance means on the undistracted and distracted drives following alcohol and placebo. The figure shows that alcohol and distraction each impaired driving performance. For example, SDLP increased in response to alcohol versus placebo and was greater in the distracted compared with the undistracted condition. Moreover, the magnitude by which alcohol increased SDLP compared with placebo was greater during the distracted versus undistracted drive. The same pattern of over-additive impairment by the combination of alcohol and distraction is also evident for the measures of drivers’ steering rates and lane exceedances. Each measure of driving performance was analyzed using a 2 dose (0.0 g/kg vs. 0.65 g/kg) X 2 distraction (undistracted vs. distracted) within-subjects ANOVA. The ANOVAs revealed significant main effects of dose on SDLP, $F(1, 49) = 80.01$, $p < .001$, $\eta_p^2 = .62$, steering rate, $F(1, 49) = 19.34$, $p < .001$, $\eta_p^2 = .28$, and lane exceedances, $F(1, 49) = 37.38$, $p < .001$, $\eta_p^2 = .43$, and significant main effects of distraction on SDLP, $F(1, 49) = 94.96$, $p < .001$, $\eta_p^2 = .66$, steering rate, $F(1, 49) = 132.37$, $p < .001$, $\eta_p^2 = .73$, and lane exceedances, $F(1, 49) = 29.52$, $p < .001$, $\eta_p^2 = .38$. These effects were qualified by significant dose X distraction interactions on each of these measures: SDLP, $F(1, 49) = 24.22$, $p < .001$, $\eta_p^2 = .33$, steering rate, $F(1, 49) = 11.46$, $p = .001$, $\eta_p^2 = .19$, and lane exceedances, $F(1, 49) = 18.80$, $p < .001$, $\eta_p^2 = .28$.

The over-additive impairing effects of combining alcohol and distraction were further quantified by determining the factor by which distraction augmented the magnitude of alcohol impairment in each measure of driving performance. The magnitude of alcohol impairment in each drive (i.e. impairment score) was calculated as the difference in performance between alcohol and placebo. In order to determine the factor by which alcohol impairment was augmented by distraction, the impairment score for the distracted drive test was divided by the impairment score for the undistracted drive for each measure. The factor by which distraction increased the magnitude of alcohol impairment for each measure was as follows: SDLP = 2.1; steering rate = 3.5; lane exceedances = 2.6. Thus, at a minimum, distraction was shown to double the magnitude by which alcohol impaired drivers' performance.

Drive speed and time to completion

A 2 dose X 2 distraction ANOVA of drive speed revealed a significant main effect of distraction, $F(1, 49) = 4.86$, $p = .032$, $\eta_p^2 = .15$. Examination of the means indicate that drive speed was slightly faster under distraction ($M = 59.64$, $SD = 6.28$) compared with no distraction ($M = 58.89$, $SD = 6.21$). There were no significant effects of dose or interactions (ps > .21). With regards to time to completion, a 2 dose X 2 distraction ANOVA found no significant effects or interactions (ps > .13). Time to completion was averaged across both drive tests and doses and found to be 5.9 minutes.

Failures to stop at red lights and traffic crashes

A 2 dose X 2 distraction ANOVA of failures to stop at red traffic lights revealed a significant main effect of dose, $F(1, 49) = 24.68$, $p < .001$, $\eta_p^2 = .33$. Examination of the mean number of stopping failures indicated that alcohol increased failures to stop on the undistracted (alcohol: $M = 0.92$, $SD = 1.00$; placebo: $M = 0.38$, $SD = 0.70$) and distracted (alcohol: $M = 1.24$, $SD = 1.12$; placebo: $M = 0.52$, $SD = 0.71$) drive tests (ps < .001). No main effect of distraction or interaction was found (ps > .06). A 2 dose X 2 distraction ANOVA of traffic crashes found no significant main effects or interaction (ps > .10).

Two-choice detection task

With regard to performance on the two-choice detection task, reaction time to the distractors was significantly slower under alcohol ($M = 1{,}134.4$ ms; $SD = 202.9$) compared with placebo ($M = 1{,}074.6$ ms; $SD = 210.2$), $t(49) = 2.36$, $p = .022$, and response accuracy declined slightly under alcohol ($M = 0.97$; $SD = 0.04$) compared with placebo ($M = 0.98$; $SD = 0.04$), $t(49) = 2.04$, $p = .048$. There was no difference in the total number of distractors drivers encountered under alcohol ($M = 48.6$; $SD = 2.0$) and placebo ($M = 49.0$; $SD = 2.8$), $t(49) = 0.93$ $p = .36$.

Subjective intoxication

Examination of self-reported levels of intoxication, measured at the completion of the drive tests, indicated that drivers felt more intoxicated under alcohol ($M = 33.7$, $SD = 21.8$)

compared with placebo (*M* = 4.9, *SD* = 6.1). This was confirmed by a significant within-subjects t test, $t(49) = 9.88$, $p < .001$.

Discussion

The present study examined the separate and combined effects of alcohol and distraction on simulated driving performance in a sample of healthy, licensed adult drivers who consumed alcohol on a regular basis. Alcohol and distraction were found to individually impair key aspects of driving performance. Compared with placebo, alcohol produced significant impairments in drivers' SDLP, steering rate, and lane exceedances. With regard to distraction, relative to the undistracted drive, the presence of distraction also produced significant impairments in drivers' SDLP, steering rate, and lane exceedances. In terms of the combined effects, drivers were most impaired when driving under alcohol in the presence of distraction, with the combined impairing effects being over-additive.

The finding that distraction interacted with alcohol to produce over-additive impairments in driving performance extends upon the limited evidence of an interactive relationship between the two factors. As mentioned in the introduction, only two previous studies have reported an interaction between alcohol and distraction on the SDLP measure of driving performance (Harrison and Fillmore 2011; Rakauskas et al. 2008). Not only did the current study find interactive effects on all three critical measures of driving performance, but to our knowledge this research represents the first attempt at quantifying the degree to which the impairing effects of alcohol can be exacerbated by distraction. Indeed, we report pronounced over-additive effects whereby the degree to which distraction increased alcohol impairment was no less than two-fold in all measures of driving performance. Moreover, the over-additive impairments of drivers' performance were evident at BrACs below the current legal limit for driving in the United States. The possibility that distractions can exacerbate alcohol impairment at even lower BrACs remains to determined, but would be important to test given current NTSB recommendations for lowering the legal driving limit to 0.05% in the United States.

The two-choice detection task used as a method of delivering driver distraction in the current study was chosen based on its use in previous research (e.g. Harrison and Fillmore 2011; Patten et al. 2004), and its relative simplicity and apparent balance between generality and specificity. The distraction task was simple and not likely any more difficult than what drivers encounter on a daily basis while tending to text messages and the numerous and increasingly complex dashboard controls of today's vehicles. This is corroborated by drivers' high response accuracy on the task, which approximated to one error per 50 distractors encountered during the drive test. It is also important to note that the distraction task was visual in nature. Distracting information is often auditory, such as cell phone conversations or discussions with other passengers in the vehicle. It will be important for future studies to examine the effects of other such forms of driver distraction on simulated driving performance. The inclusion of more tasks requiring greater attentional resources, such as texting while driving, also might be found to produce even greater impairments of basic driving behaviors while intoxicated.

Another factor that is important to consider is the nature of the driving behaviors assessed in the current study. Each critical driving behavior (i.e. SDLP, steering rate, and lane exceedances) emphasized aspects of driving often considered non-demanding and reflective of largely automatic skill. Driving behaviors are often classified on the basis of representing either automatic or controlled modes of cognitive processing (e.g. Michon 1985; Salvucci 2006). Behaviors governed by automatic processes tend to be well learned actions that require little conscious effort and can be conducted in parallel with other activities, such as tests of distraction (Fisk and Schneider, 1984). By contrast, controlled actions are effortful, demanding greater cognitive resources, and are often disrupted by a secondary activity (Shiffrin and Dumais 1981). The measures of driving performance in the present study emphasized the ability to maintain the vehicle's lane position on a straight stretch of road by executing only minor steering adjustments and, as such, are likely reflective of automatic processes that require minimal effort to execute. It is noteworthy that distraction was capable of producing two- to three-fold increases of alcohol-induced impairment of such low effort, automatic aspects of driving behaviors. It is important to determine how such controlled, effortful aspects of driving (e.g. over-taking vehicles, lane changing/turning) is disrupted by alcohol and distraction, separately and in combination. Indeed, the degree to which distraction exacerbates alcohol impairment could be much greater for such, controlled, effortful actions of the driver.

A potential limitation of the current study was the drive conditions were not counterbalanced over the two dose sessions leading to the possibility that fatigue could have contributed to the poorer performance during the distraction drive. The study was designed to prevent fatigue by measuring performance using brief driving tests (approximately 6 min) separated by rest periods to further prevent any fatigue. We conducted supplemental analyses which further indicate that fatigue was not likely an issue. Because fatigue would most likely accrue within the course of a single test (i.e., rather than after a rest period), we compared performance of the first half of the test to the second half to determine if performance was generally poorer on the second half. Within-subjects t tests of drivers' SDLP showed no significant change from the first to second halves of the distracted drive test under alcohol, $t(49) = 1.21$, $p = .23$, or placebo, $t(49) = 0.59$, $p = .56$. Thus, it does not appear that fatigue was an issue for drivers in the current study.

In conclusion, the findings from the present study provide some of the first pieces of evidence on the degree to which distractions can severely disrupt intoxicated drivers' ability to maintain proper control of their vehicle on the road by impacting even the most basic aspects of driving behavior. With continuing advancements in technology and the omnipresence of distractions while driving, it is becoming increasingly important to study the interaction between alcohol and distraction on driving. A clearer understanding of how common distractions impact intoxicated drivers, especially at BrACs that are currently legal for driving in the United States, is an important step to reducing traffic accidents and fatalities and improving overall traffic safety.

Acknowledgments

This research was supported by National Institute on Alcohol Abuse and Alcoholism Grant R01 AA021722 and National Institute on Drug Abuse Grant T32 DA035200.

References

Borkenstein RF, Crowther RF, Shumate RP. The role of the drinking driver in traffic accidents (The Grand Rapids Study). Blutalkohol. 1974; 11(Suppl 1):131.

Fell JC, Voas RB. The effectiveness of a 0.05 blood alcohol concentration (BAC) limit for driving in the United States. Addiction. 2014; 109:869–874. [PubMed: 24898061]

Fillmore MT. Acute alcohol-induced impairment of cognitive functions: Past and present findings. Int J Dis Hum Dev. 2007; 6:115–126.

Fillmore MT. Cognitive preoccupation with alcohol and binge drinking in college students: Alcohol-induced priming of the motivation to drink. Psyc Add Beh. 2001; 15:325–332.

Fillmore MT, Blackburn JS, Harrison EL. Acute disinhibiting effects of alcohol as a factor in risky driving behavior. Drug Alcohol Depend. 2008; 95:97–106. [PubMed: 18325693]

Fisk AD, Schneider W. Task versus component consistency in automatic process development: Consistent attending versus consistent responding. Bulletin of the Psychonomic Soc. 1984; 22:330–332.

Harrison EL, Fillmore MT. Alcohol and distraction interact to impair driving performance. Drug Alcohol Depend. 2011; 117:31–37. [PubMed: 21277119]

Harrison EL, Fillmore MT. Are bad drivers more impaired by alcohol?: Sober driving precision predicts impairment from alcohol in a simulated driving task. Accid Anal Prev. 2005; 7:882–889. [PubMed: 15907777]

Harrison EL, Marczinski CA, Fillmore MT. Driver training conditions affect sensitivity to the impairing effects of alcohol on a simulated driving test to the impairing effects of alcohol on a simulated driving test. Ex Clin Psychopharmacol. 2007; 15:588–598.

Hurst PM. Epidemiological aspects of alcohol in driver crashes and citations. J Saf Res. 1973; 5:130–148.

Marczinski CA, Harrison EL, Fillmore MT. Effects of alcohol on simulated driving and perceived driving impairment in binge drinkers. Alcohol Clin Exp Res. 2008; 32:1329–1337. [PubMed: 18540907]

Martin TL, Solbeck PA, Mayers DJ, Langille RM, Buczek Y, Pelletier MR. A Review of Alcohol-Impaired Driving: The Role of Blood Alcohol Concentration and Complexity of the Driving Task. J Forensic Sci. 2013; 58:1238–1250. [PubMed: 23879433]

Mercer SL, Sleet DA, Elder RW, Cole KH, Shults RA, Nichols JL. Translating evidence into policy: lessons learned from the case of lowering the legal blood alcohol limit for drivers. Annals Epidemiol. 2010; 20:412–420.

Michon, JA. A critical view of driver behavior models: what do we know, what should we do?. In: Evans, L.; Schwing, RC., editors. Hum Beh Traffic Saf. Plenum Press; New York, NY: 1985. p. 485-520.

Moskowitz H, Burns MM, Williams AF. Skills performance at low blood alcohol levels. J Stud Alcohol. 1985; 46:482–485. [PubMed: 4087910]

Mulvihill LE, Skilling TA, Vogel-Sprott M. Alcohol and the ability to inhibit behavior in men and women. J Stud Alcohol. 1997; 58:600–605. [PubMed: 9391919]

National Highway Traffic Safety Administration. Traffic safety facts 2012 data: Alcohol-impaired driving. DOT HS 811 870. U.S. Department of Transportation, National Highway Traffic Safety Administration; Washington, D.C: 2013.

National Transportation Safety Board, Bureau of Safety Programs, & United States of America. Reaching Zero: Actions to Eliminate Alcohol-Impaired Driving. 2013

Ogden EJD, Moskowitz H. Effects of alcohol and other drugs on driver performance. Traffic Inj Prev. 2004; 5:185–198. [PubMed: 15276919]

Patten CJ, Kircher A, Östlund J, Nilsson L. Using mobile telephones: Cognitive workload and attention resource allocation. Accid Anal Prev. 2004; 36:341–350. [PubMed: 15003578]

Rakauskas ME, Ward NJ, Boer ER, Bernat EM, Cadwallader M, Patrick CJ. Combined effects of alcohol and distraction on driving performance. Accid Anal Prev. 2008; 40:1742–1749. [PubMed: 18760103]

Salvucci DD. Modeling driver behavior in a cognitive architecture. Hum Factors. 2006; 48:362–380. [PubMed: 16884055]

Shiffrin, RW.; Dumais, ST. The development of automatism. In: Anderson, JR., editor. Cognitive Skills and their Acquisition. Lawrence Erlbaum Associates; Hillsdale, NJ: 1981. p. 111-140.

Shinar D, Tractinsky N, Compton R. Effects of practice, age, and task demands, on interference from a phone task while driving. Accid Anal Prev. 2005; 37:315–326. [PubMed: 15667818]

Sobell, LC.; Sobell, MB. Timeline followback: A technique for assessing self-reported alcohol consumption. In: Litten, RZ.; Allen, J., editors. Measuring alcohol consumption: Psychosocial and biological methods. New Jersey: Humana Press; 1992. p. 41-72.

Verster JC, Wester AE, Goorden M, Van Wieringen JP, Olivier B, Volkerts ER. Novice drivers' performance after different alcohol dosages and placebo in the divided-attention steering simulator (DASS). Psychopharmacology. 2009; 204:127–133. [PubMed: 19125236]

Papantoniou P, Papadimitriou E, Yannis G. Assessment of driving simulator studies on driver distraction. Adv in Trans Stud. 2013; 35:129.

Papantoniou, P.; Papadimitriou, E.; Yannis, G. Assessment of driving simulator studies on driver distraction. Road safety and simulation international conference; 2013. p. 22-25.

Zador PL. Alcohol-related relative risk of fatal driver injuries in relation to driver age and sex. J Stud Alcohol Drugs. 1991; 52:302.

Zador PL, Krawchuk SA, Voas RB. Alcohol-related relative risk of driver fatalities and driver involvement in fatal crashes in relation to driver age and gender: an update using 1996 data. J Stud Alcohol Drugs. 2000; 61:387.

Author Manuscript

Author Manuscript

Author Manuscript

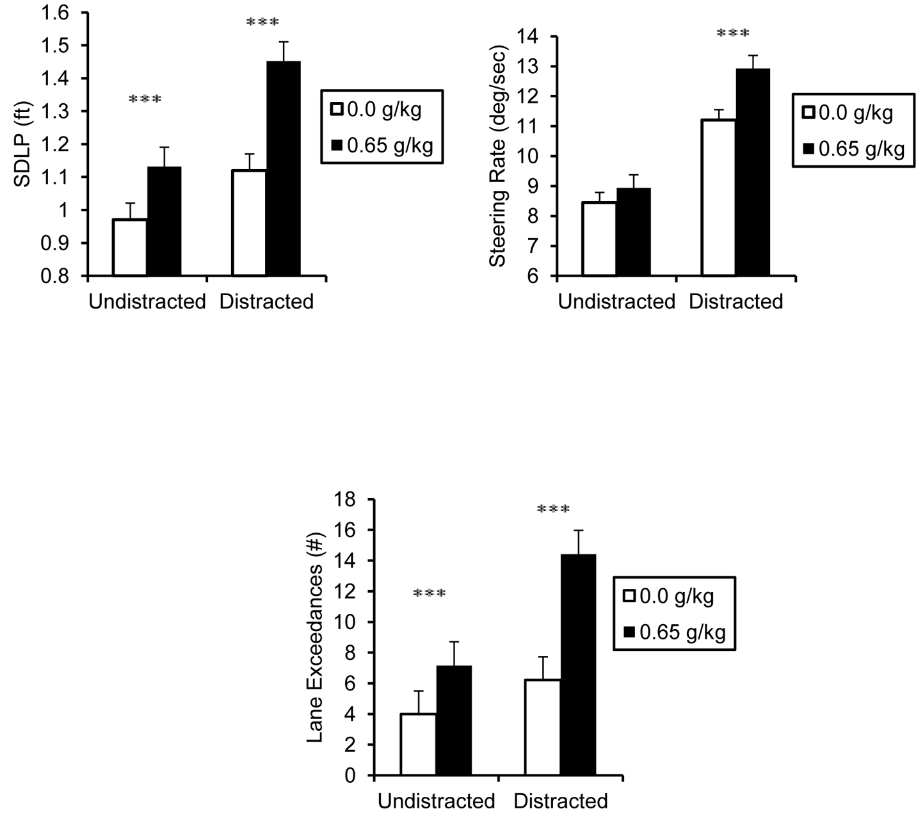

Fig. 1.

Left panel = mean standard deviation of lane position (SDLP) following 0.0 g/kg and 0.65 g/kg alcohol. Right panel = mean steering rate in degrees/sec following 0.0 g/kg and 0.65 g/kg alcohol. Lower panel = mean number of lane exceedances following 0.0 g/kg and 0.65 g/kg alcohol. Error bars indicate standard error of the mean. *** indicate significant pairwise comparison at $p < .001$, based on paired-sample t tests.