The Effects of Binge Drinking and Socio-Economic Status on Sober Driving Behavior

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Objective: Drinking and driving is a primary cause of traffic fatalities and it has been suggested that binge drinkers comprise a major portion of those drivers involved in drinking and driving accidents. Although several experimental studies have investigated the driving behavior of binge drinkers (particularly college students and/or young adults) under the influence of alcohol, few studies have focused on a comparison of sober driving behavior of the general population between binge and non-binge drinkers with a consideration of drivers' income levels. In addition, these studies have not taken other potentially influential factors into account such as socio economic status.

Methods: A driving simulator study was conducted with a 2 × 2 factorial design (binge vs. non-binge drinker; low vs. high income). Sixty-two participants who were not under the influence of alcohol or drugs were asked to operate a driving simulator following traffic rules. Multiple aspects of participants' driving behaviors were measured in a sober driving situation. To control the potential effects of confounding factors, factors (e.g., age, gender, etc.) that were significantly correlated to the driving behavior were all entered into the multivariate analysis of variance (MANOVA) as covariates.

Results: Significant interaction effects were found between effects of binge drinking and income levels. Analyses indicated that binge drinkers—independent of their income levels—exhibited more speeding exceedances and longer speeding duration than those of non-binge drinkers with a high income. Individuals characterized as non-binge drinkers with a low income also exhibited more speeding behaviors.

Conclusion: Cognitive deficits and problems in vehicle control resulting from chronic alcohol consumption may impact binge drinkers' abilities to perform adequately, even in a sober driving situation. In addition, non-binge drinkers with a low income were more prone to make unsafe choices compared to non-binge drinkers with a high income. Further implications of the results in transportation safety and alcohol addiction were also discussed.

Keywords Binge drinker; Alcohol abuse; Driving behavior; Experiment; Driving simulator

INTRODUCTION

Drinking and driving is a major cause of traffic accidents and fatalities. The National Highway Traffic Safety Administration (NHTSA) considers a driver to be alcohol impaired when his/her blood alcohol concentration (BAC) is 0.08 g/dL or higher. In 2007, there were 12,998 fatalities in alcohol-impaired driving crashes, accounting for 32 percent of the total motor vehicle traffic fatalities in the United States (NHTSA 2007). More importantly, the majority of such driving fatalities were caused by individuals with a BAC level of 0.08 or greater. For example, in 2007, 12,068 (84%) of the 14,447 drivers with a BAC of 0.01 or higher who were involved in fatal crashes had BAC levels at or above 0.08, and 7,974 (55%) had BAC

levels at or above 0.15. The most frequently recorded BAC level among drinking drivers in fatal crashes was 0.16 (NHTSA 2007).

In general, a BAC level of 0.08 or greater corresponds to 5 drinks in a 2-h period for men and 4 drinks in a 2-h period for women, although clearly there is variability due to factors such as body mass, age, and recent drug and food ingestion (Jackson 2008). In research on alcoholism, binge drinkers are typically defined as individuals who consumed 5 or more drinks per occasion in the past month (Room 1972). Since then, the 5+ threshold has been proposed as a standard measure for heavy episodic drinking in general population alcohol surveys (Midanik 1999). More recently a gender-specific threshold (5 or more drinks for men; 4 or more drinks for women) has also been widely adopted (Wechsler and Austin 1998; Wechsler et al. 1994, 1995). As a result, binge drinkers appear to play an especially prominent role in alcohol-impaired driving fatalities (Quinlan et al. 2005).

Table I Comparisons of existing studies and current study on binge drinking and driving

Study	Sample	Condition	Types of drinkers	Factors considered	Types of studies
Flowers et al. (2008)	General population	Alcohol	Binge vs. non-binge drinker	Heavy vs. non-heavy drinker	Survey
Valencia-Martin et al. (2008)	General population	Alcohol	Binge vs. non-binge drinker	Heavy vs. moderate vs. non-drinker	Survey
Duncan (1997)	General population	Alcohol	Binge vs. non-binge drinker	Chronic heavy drinking	Survey
Duncan et al. (1999)	General population	Alcohol	Binge vs. non-binge drinker	Chronic heavy drinking	Survey
Naimi et al. (2003)	General population	Alcohol	Binge vs. non-binge drinker	N/A	Survey
Quinlan et al. (2005)	General population	Alcohol	Binge vs. non-binge drinker	N/A	Survey
Marczinski et al. (2008)	College students	Alcohol vs. placebo	Binge vs. non-binge drinker	Demographic variables, drinking habits, driving history, impulsivity	Simulated driving study
Marczinski and Fillmore (2009)	College students	Alcohol vs. placebo	Binge vs. non-binge drinker	Alcohol tolerance, demographic variables, drinking habits, driving history	Simulated driving study
Current study	General population	Sober	Binge vs. non-binge drinker	SES factors, demographic variables, drinking habits, driving history, anger/expression	Simulated driving study

Binge drinking has been widely investigated in epidemiological studies (e.g., Duncan 1997; Naimi et al. 2003; Quinlan et al. 2005; Wechsler and Austin 1998; Wechsler et al. 1994, 1995, 2000). For example, under the influence of alcohol, binge drinkers were 14 times more likely to drive than non-binge drinkers (Naimi et al. 2003). In addition, college students are prone to drive after drinking in the United States (Marczinski et al. 2008). Existing laboratory research on binge drinking has primarily investigated both acute alcohol and placebo effects on the driving behavior in a simulated driving environment (e.g., Marczinski and Fillmore 2009; Marczinski et al. 2008). A recent related study by Marczinski and colleagues (2008) examined both acute alcohol and placebo effects on simulated driving performance as well as subjective ratings of intoxication and driving ability in binge and non-binge drinkers. Interestingly, they reported that the driving performance of the binge and non-binge drinkers did not differ on any aspect of driving performance with either acute alcohol or placebo administration. They have extended this line of research to examine other factors such as acute tolerance (Marczinski and Fillmore 2009). Given these recent findings with regard to binge drinking (Table I), several important issues may need to be addressed in the future investigation.

As can be seen in Table I, although studies in the addictions literature have explored the characteristics of binge drinkers in general (e.g., their drinking patterns) with various surveys and questionnaires (e.g., Duncan 1997; Duncan et al. 1999; Flowers et al. 2008; Naimi et al. 2003; Quinlan et al. 2005; Toben and Wechsler 2005; Valencia-Martin et al. 2008), only 2 experimental studies have been conducted in binge drinkers, and these both examine the effects of alcohol administration on simulated driving. No experimental studies, to our knowledge, have been conducted to assess binge drinkers' driving behaviors in sober driving situations. In addition, some of the survey studies examined excessive intake of alcohol on the basis of both binge drinking (high per occasion consumption) and heavy drinking (high average consumption). For example, Flowers et al. (2008) defined binge drinking using the gender-specific threshold (e.g., 4+/5+) and determined heavy drinking based on an average consumption of more than 2 drinks per day among men and more than 1 drink per day among women during the past 30 days.

Another important aspect to consider about the prior literature on binge drinking and driving behavior is the research sample in these studies. College students have been studied in previous simulated driving experiments. Although informative, findings based on college samples may not always extrapolate to all drivers (Gordon et al. 1986). Thus, it is essential to examine the behavior of individuals in the general population because several major differences could impact drinking and driving behavior between college students and individuals recruited from the community. College students are usually ages 18 to 25 and thus are likely have shorter drinking histories, less driving experience, and different drinking motivations than the general population, which may include older individuals. Accordingly, binge-drinking college students might perform different driving behaviors (e.g., speed control) compared to older binge drinkers, either under the influence of alcohol or even in sober driving conditions. Moreover, it has been reported that 69 percent of binge-drinking episodes occur among those aged

26 years or older rather than the typical college student age range (18–25 years old, Naimi et al. 2003). Thus, it is imperative that research in this area explore driving behaviors among the general population and include older individuals with different drinking histories, demographic characteristics, and driving experience.

Finally, it is important to note that the aforementioned driving simulation studies examined placebo vs. alcohol effects rather than sober effects on simulated driving performance. Typically, the placebo in these studies involves a small amount of alcohol floated on the surface of the beverage and/or a glass sprayed with an alcohol mist to provide a strong alcoholic scent (Marczinski et al. 2008). This is obviously appropriate for the alcohol vs. placebo distinction and previous research has demonstrated that individuals report that they believe this beverage contains alcohol (Fillmore and Sprott 1998). Although placebo may not have direct physiological effects, it is clear that it can have indirect psychological or physiological effects on human behavior. Human behavior may change under a simple but wrong belief or misperception due to self-fulfilling prophecy or expectancy (Allport 1950; Merton 1957). Other researchers suggested that placebo may have a physiological effect: the placebo effect may be mediated through connections of the frontal cortex with the periaqueductal gray matter (e.g., Carlson 1994). Moreover, compared to the placebo condition, the inclusion of a sober condition without administration of placebo is closer to the reality in which individuals do not drink any alcohol and drive but may still engage in dangerous or impaired driving.

Previous research in the addictions literature has indicated that individuals with alcohol dependence and/or a pattern of binge drinking exhibit a number of cognitive deficits (e.g., visuospatial perception, processing speed and efficiency, attention, impulsivity; Moselhy et al. 2001; Oscar-Berman 1993; Oscar-Berman and Hutner 1993; Stephens and Duka 2008; Sullivan and Pfefferbaum 2005) and problems in inhibitory control (e.g., Thayer et al. 2006) that may affect driving performance. Sullivan and Pfefferbaum (2005) have suggested that chronic and excessive consumption of alcohol results in degradation of frontocerebellar circuitry, affecting widespread brain regions and contributing to alcoholism's salient, enduring, and debilitating cognitive and motor deficits. In addition, considering the characteristics of binge drinking–consumption of large amounts of alcohol within a limited time period as well as drinking followed by a period of abstinence–binge drinking has been argued to enhance the possibility of brain damage and cognitive deficits resulted from chronic alcohol consumption (Hunt 1993). Though the potential for driving under the influence is high for binge drinkers, it is also possible that deficits in neurocognitive processing may impact their ability to perform adequately even in sober driving situation.

Another factor that is gaining attention with regard to alcohol use and related behaviors, such as driving under the influence, is socioeconomic status (SES). SES is a multidimensional construct reflecting particular strata in society and is comprised of several socioeconomic characteristics (Oakes and Rossi 2003).

Income reflects direct access to material goods, education reflects access to non material goods, and occupation reflects the power and prestige associated with specific jobs (van Oers et al. 1999). Because income (either personal or household income) might reflect an individual's economic ability to purchase alcohol-related product, it is often examined in research on alcoholism (e.g., Casswell et al. 2003; Khan 1998; Spijkerman et al. 2008). Epidemiological evidence indicates a positive relation between income and the prevalence of alcohol abuse in the general population but an inverse relation between income and alcohol dependence. Casswell et al. (2003) also reported that frequency of drinking was influenced by income with the higher income respondents drinking more often, an effect that was persistent over time. In the current study, a single cutoff point of income was used to categorize all participants into 2 groups. Similar methods for categorizing income levels using a single point have been reported in the previous studies (e.g., Keskinoglu et al. 2006; Yee and Niemeier 1998). Then, income group differences in terms of occupation and education were examined to make sure that people from 2 groups reflect different socioeconomic status.

A few studies have been conducted examining the relation between income and driving behavior, although the literature is equivocal. For example, several investigators have reported that unsafe driving behaviors, such as speeding, driving after drinking, and not using seat belt, are characteristic of a core group of low-income drivers (Haaga 1986; Helsing and Comstock 1977; NHTSA 2000; Shinar 1993). Yet, other studies reported a negative relationship between income and safe driving behavior (Golias and Karlaftis 2001; Traynor 1993; Shinar et al. 2001). For example, Golias and Karlaftis (2001) found that higher income led, in general, to less law-abiding driver behaviors. One possible explanation for this heterogeneity of findings is the self-report measure of driving behavior and lack of empirical evidence on the effect of income on driving behavior. Although self-reports are widely recognized as a valuable methodology in the social sciences, they are vulnerable to a number of biases that can lead to both under- and over reporting (Corbett 2001). In addition, self-reported behavior measures are potentially vulnerable to self-presentational biases such as self-deception and the tendency to give favorable self-descriptions (e.g., Lindeman and Verkasalo 1994; Paulhus 2002).

Although separate lines of research exist on driving behavior and its relation to either SES/income or alcohol consumption, it is not clear how income might influence or interact with drinking patterns (e.g., binge drinking) to influence driving behavior. Thus, the purpose of this study is to examine (1) whether drinking pattern (binge vs. non-binge drinkers) significantly interacts with income status to affect driving variables during sober performance of a driving simulation task and, if so; (2) whether there is any significant difference of driving behavior between non-binge drinkers with high income and those in other 3 categories; and (3) whether such significant difference exists among binge drinkers with high income, binge drinkers with low income, and non-binge drinkers with low income.

METHODS

Recruitment Procedures

Participants were recruited via newspaper and radio advertisements for participation in a study of driving behavior. Interested participants contacted an experimenter who explained the study and administered a brief set of screening questions over the phone to determine eligibility. This brief phone screen included questions regarding medical history, driving behavior, and drinking patterns.

Inclusion criteria for all participants included: age 22–45 years, English speaking, valid U.S. driver's license, and driven within the past 6 months. A number of strict exclusion criteria were used in the study to limit potential confounds on the behavioral/cognitive aspects of driving performance. Exclusion criteria included a history of seizures, neurosurgery, head injury with a loss of consciousness > 10 min, mental retardation, report of serious psychiatric disorder (i.e., schizophrenia or bipolar disorder), or serious medical disorders (e.g., neurological disorders, HIV/AIDS, etc.), drug dependence (excluding nicotine), and current use of psychoactive medications.

Participants

Sixty-four participants in the western New York area (25 males and 39 females) took part in the laboratory session, which involved a driving simulator. Two participants (1 male and 1 female) were eliminated from the analysis due to incomplete questionnaire data, resulting in a sample of 62 participants whose average age was 30.6 years (SD = 7.94) and average education level was 14.8 years (range from 12 to 18 years, SD = 1.92). The sample was 72.6 percent Caucasian, 22.6 percent African-American, 1.6 percent Native American, and 3.2 percent other. In addition, 4.8 percent of participants indicated they were also of Hispanic/Latino origin.

Self-Report Measures

All participants were asked to complete the following self-report measures on site before engaging in the driving task.

1. Demographic questionnaire—This questionnaire was designed to capture information about participants' demographic situations, such as age, gender, education level, and estimated annual household income.
2. Driving history survey—This measure contained questions regarding driving history such as estimated annual mileage, the year a U.S. driver's license was first issued, and prior crash or violation history as well as information on the participant's vehicle such as horsepower.
3. Alcohol Use Timeline Followback (TLFB; Sobell and Sobell 1992, 1995)—The timeline followback is a specialized interviewing procedure that uses a daily calendar method to gather retrospective reports of quantity and frequency of daily drinking for the period prior to assessment. Alcohol use is recorded in terms of the number of standard drinks consumed. The TLFB was administered to each participant to document alcohol consumption for the prior 30 days. The timeline permits derivation of drinking-related dimensions such as drinking days (DD) and binge drinking days (BDD). The reliability and validity of the measure have been consistently demonstrated among alcohol-dependent individuals (e.g., Sobell and Sobell 1992, 1995).
4. State Trait Anger Expression Inventory-2 (STAXI-2; Spielberger 1999)—provided an assessment of trait anger. The portion of the STAXI used in the current study (part 3) assessed four components: anger expression-in (AX/In), anger expression-out (AX/Out), anger control-in (AC/In), and anger control-out (AC/Out). These items are scored by participants' responses to statements on a 4-point scale (*almost never*, 1, *sometimes*, 2, *often*, 3, *almost always*, 4). The anger expression index (AX/Index) provided an overall estimate of the person's tendencies to express anger either outwardly toward other people or inwardly toward herself. It is based on the person's responses to the AX/In, AX/Out, AC/In, and AC/Out items and a higher score indicates greater anger expression or less anger control.

Experimental Design

A 2 × 2 factorial design (binge vs. non-binge drinker; low vs. high income) was used to examine differences related to the types of drinkers and income levels. Participants who consumed 5 or more drinks (for male) or 4 or more drinks (for female) in at least one occasion in the past month were regarded as binge drinkers (Wechsler and Austin 1998; Wechsler et al. 1994, 1995). Non-binge drinkers were those individuals who consumed 4 or fewer drinks (for male) or 3 or fewer drinks (for female) per occasion in the past month. As a result, participants were categorized into 2 groups: binge drinkers ($n = 42$) and non-binge drinkers ($n = 20$).

All participants were asked to estimate their total household income last year before taxes including wages, pensions, and interest or dividends on savings and investments on a scale of 7 income categories (e.g., less than $5,000, $5,000 to $10,000, etc). Because some individuals may have access to resources provided by the household income, but may not have a personal income, household or family income was used in present study. The Department of Agriculture, U.S. General Service Administration, defines low income as between 50 and 80 percent of the area median income (AMI). In this study, the criterion was calculated by multiplying the median annual household income in the western New York area (around $30,000 in 2007; Bishaw and Semega 2008) by 65 percent (average boundary between 50 and 80%). Accordingly, an approximate cutoff income of $20,000 was used to categorize 62 Participants into 2 groups: low-income group (less than or equal to US $20,000, $n = 23$) and high-income group (greater than US $20,000, $n = 39$).

Apparatus

The driving task was completed using a STISIM® driving simulator (STISIMDRIVE M100K, Systems Technology Inc., Hawthorne, CA; See Figure 1). The STISIM simulator was installed on a Dell Workstation (Precision 490, Dual Core Intel

Figure 1   STISIM driving simulator.

Xeon Processor 5130 2GHz) with a 256MB PCIe×16 nVidia graphic card, Sound Blaster® X-Fi™system, and Dell A225 Stereo System. The driving scenario was presented on a 27-inch LCD with 1920 × 1200 pixels resolution. The driving simulator also included a Logitech Momo® steering wheel with force feedback and a gas and a brake pedal (Longitech Inc., Fremont, CA).

Experimental Procedures

Upon arrival, participants were asked to sign a consent document. Both urine and breath samples were collected and tested for recent alcohol/drug use. Urinalysis for benzodiazepines, opiates, amphetamine, cocaine, and cannabis were performed immediately. Any participant who tested positive for alcohol or drugs was not allowed to participate in the study that day ($n =$ 4), but was rescheduled for a different test date.

After filling out a set of questionnaires, all participants completed a practice block for the driving task. This session allowed them to become familiar with the driving simulator controls including steering wheel, speedometer, brake, and gas pedal. Participants were required to drive the simulator for a one-mile distance with normal road events so that they could manipulate the simulator smoothly and become familiar with the different road events. For example, when a participant approached a road barrier in the right lane, she or he had to enter the left lane to pass the barrier and then return to the right lane as soon as possible to avoid any approaching vehicles in the left lane.

Next, participants completed the test block (8 miles), a 2-lane (in each direction) local environment with normal road events. Four types of driving events were included.

Pedestrians crossing the road. Two types of pedestrians were designed: target and nontarget. Initially, pedestrians were displayed 2 ft from either the left or right roadway edge line. When the driver was within 200 ft of the pedestrian, the pedestrian (target) began to cross the road at a constant speed of 2 ft/s. To reduce learning effects, stationary pedestrians (nontarget) were also displayed with an exact ratio of 1:3 (target vs. nontarget).

Barriers in the road. Target and nontarget barriers were used. Target barriers were placed in the middle of the right lane and appeared 600 ft ahead of the driver. Participants had to change

from one lane to another and avoid any approaching vehicles when they passed the barriers. Nontarget barriers were placed on either side of the road with an exact ratio of 1:3 (target vs. nontarget).

Intersections with traffic lights. Two types of traffic lights were included: target and nontarget. Target traffic lights turned from green to yellow when the driver was within 200 ft of the intersection. The light then stayed yellow for a total of 2 s at which time it turned to red. Nontarget traffic lights remained green and occurred 3 times as often as target traffic lights.

Speed limit sign. Speed limit signs with different speed limits (ranging from 20 to 60) were displayed 1000 ft in front of the driver. Participants were instructed to adjust their speed and follow the speed limit throughout the task.

Each type of event occurred 15 times in the test block and was randomly distributed throughout the block without overlapping. Participants were asked to operate the driving simulator and follow the traffic laws as if they were driving a real vehicle on the road.

Measurement

Several behavioral measures from the driving simulator test block were examined: frequency of accidents, frequency of running a red light, speeding frequency, and duration of speeding.

Accidents. Three types of accidents could occur during the driving simulation. First, pedestrian-related accidents included instances where drivers did not respond quickly enough and hit a pedestrian who was crossing the road. Next, vehicle-related accidents dealt with any collision with a vehicle on the road. The last type of accident was barrier-related accidents, which specified how many times drivers hit a barrier either in the middle or on either side of the road.

Running a red light. This reflected the number of times drivers crossed the limited line for a traffic light while the traffic light was red.

Speeding frequency. This indicated the number of times a vehicle's speed exceeded the posted speed limit.

Duration of speeding. The duration of speeding (in seconds) provided the percentage of time that a driver spent above the posted speed limit.

Data Analysis

Analysis of variance (ANOVA) was used to examine potential group differences in demographic factors (e.g., age, gender), socioeconomic status, and driving history. Chi square analyses were used for categorical variables such as gender and race. Pearson correlations were performed to investigate the bivariate relations between self-report variables and behavioral variables from the driving task. A multivariate analysis of covariance (MANCOVA) was then conducted with the driving behavior variables serving as dependent variables and drinking group (binge vs. non-binge) and income levels (high vs. low) serving as between-subjects factors. In addition, those factors significantly correlated with the dependent variables were entered as covariates (e.g., age, gender, number of years since obtaining

Table II Means and standard deviations for demographic and self-report measures and driving performance variables

	Binge drinkers		Non-binge drinkers	
	Low income ($n = 13$)	High income ($n = 29$)	Low income (n=10)	High income ($n = 10$)
Sociodemographic factors				
Age (years)[a]	25.2(5)	32.6(7.3)	26.3(7.5)	35.1(8.5)
Gender (% Male)	0.15	0.45	0.5	0.4
Race (% Caucasian)[b]	0.92	0.93	0.5	0.1
Education (years)	14.9(1.7)	14.6(1.9)	15.5(0.8)	14.3(2.1)
Employment status (% full Time)[a]	0.46	0.66	0.4	0.9
Driving history				
Year license (years)[a]	7.5(3.4)	15.7(8)	9.3(7)	17.7(8.4)
Annual mileage[a]	2.69 (1.4)	3.9(0.7)	2.4(1.1)	3.5(1.2)
Horsepower (hp)[a]	169.9(48.7)	207.9(64.3)	137.2(18.4)	241 (97.3)
Drinking history (past 30 days)				
Greatest number of drinks/day[b]	10.9(6)	8 (4.8)	2 (1.3)	1.4(1.4)
Number of heavy drinking days[b]	4.2(4.3)	3.8(3.5)	0	0
Number of drinking days[b]	7.5(6.4)	8.4(6.8)	3.1(3.8)	2.1(2.1)
Total number of drinks[b]	49.9(56.5)	39.4(38.7)	6 (7.9)	4.5(7.3)
STAXI anger expression index[a]	25.2(10.8)	34.6(11.9)	23.8(11.6)	27.4(16.6)
Driving performance				
Speeding frequency[c]	18.3(9.9)	18.7(8.7)	19.2(8.6)	11.3(9)
Duration of speeding (s)[c]	324.6(168.3)	390.9(227.9)	344.4(233.8)	197.1(205.7)
Frequency of running a red light	11.2(6.9)	11.6(6.9)	12 (7.3)	7.2(8.1)
Frequency of hitting a pedestrian	2.5(2.2)	2 (1.4)	2.6(2.1)	1.1(1.9)
Frequency of hitting a barrier	0.8(1)	1.2(1.5)	1.1(1.4)	1.4(1.1)
Frequency of colliding with a vehicle	0.4(0.5)	0.1(0.6)	1 (0.3)	1 (0.3)

Note: "Employment status is classified into three categories: full-time, part-time and unemployed; Year license refers to the number of years since a driver obtained his or her first valid U.S. driver license; Annual mileage is a self-reported measure on a scale of 5 categories (e.g., less than 5000 miles, 5000 to 7500 mile, etc.)

[a] Significant difference between high and low income groups ($ps < .05$).

[b] Significant difference between binge and non-binge drinker groups ($ps < .01$).

[c] Significant types of Drinkers × Income levels interaction ($ps < .05$).

a driver's license, etc.). Significance testing was set for an alpha level of .05. Finally, for significant interactions, planned contrasts were used to compare the 4 groups on the driving behavior variables. These 4 groups were binge drinker with high income (BH), binge drinker with low income (BL), non-binge drinker with high income (NH), and non-binge drinker with low income (NL). This approach was chosen given the prior literature on binge drinking effects on cognitive functioning and the equivocal literature on income and driving to ensure that the comparisons for each group were represented (Field 2009). Three hypotheses were stated: (1) $H_0 : 3\mu_{NH} = \mu_{NH} + \mu_{BH} + \mu_{NL}$(Contrast 1); (2)$H_0 : 2\mu_{NL} = \mu_{BH} + \mu_{BL}$(Contrast 2); (3) $H_0 : \mu_{BH} = \mu_{BL}$(Contrast 3).

RESULTS

Descriptive Statistics

One-way ANOVAs were conducted comparing the drinking and income groups on demographic variables, driving history and drinking history (Table II). There was significant difference between high and low-income group for age ($F(1, 60) = 16.411$, $p < .001$); employment status (Pearson's $\chi^2 (2) = 5.425$, $p = .012$); years since license was obtained ($F(1, 60) = 18.035$, $p < .001$); annual mileage (Pearson $\chi^2 (4) = 19.498$, $p < .001$); horsepower ($F(1, 60) = 12.989$, $p = .001$), and STAXI anger expression index ($F(1, 60) = 6.172$, $p = .016$). It was indicated

that the high-income group tended to be older, have a full-time employment status, have more years of driving experience, drive a vehicle with a higher horsepower, and have a higher score on the anger/expression index. Moreover, no significant differences between high and low-income groups were observed for gender, education level, race, or any drinking history variable.

On the other hand, there were significant differences between binge and non-binge drinkers in terms of race (Pearson's $\chi^2 (1) = 33.334$, $p < .001$), indicating that a greater proportion of binge drinkers were Caucasian as compared to the non-binge drinker group. Compared with non-binge drinkers, binge drinkers reported more binge drinking days ($F(1, 60) = 22.372$, $p < .001$); more drinking days ($F(1, 60) = 12.77$, $p = .001$), consuming a greater number of drinks per drinking day, ($F(1, 60) = 35.632$, $p < .001$) and consuming a greater total number of drinks in the prior month ($F(1, 60) = 13.856$, $p < .001$). Additionally, there were no significant differences between binge and non-binge drinkers for age, gender, education level, employment status, STAXI anger/expression index, or any driving history variable.

Bivariate Correlations

Pearson correlation coefficients (Table III) were calculated between variables derived from the self-report measures and simulation driving behaviors. The 6 driving behavior variables

Table III Pearson correlation coefficients

	Speeding frequency	Duration of speeding	Run a red light	Hit a pedestrian	Hit a barrier	Collide with a vehicle
1. Age	−.43**	−.41**	−.36**	−.38**	.01	−.09
2. Gender	−.06	−.33**	−.21*	.06	.16	.09
3. Year license	−.33**	−.33**	−.32**	−.40**	−.01	−.16
4. Marital status	−.20	−.22*	−.23*	−.28*	−.03	−.14
5. Anger Expression Index	.21	.35**	.23*	.21	.01	−.19
6. Annual mileage	−.05	.03	.04	−.21*	.02	−.05
7. Horsepower	.04	.10	.08	−.24*	−.24*	−.01

Note: Year license" refers to the number of years since a driver obtained his/her first valid U.S. driver license.

*Correlation is significant at the 0.05 level ($N = 62$).

**Correlation is significant at the 0.01 level.

were speeding frequency, duration of speeding, frequency of running a red light, frequency of hitting a pedestrian, frequency of hitting a barrier, and frequency of colliding with a vehicle.

Speeding frequency. For speeding frequency, there were significant negative correlations with age and number of years since driving license was obtained. This indicated that young drivers and those who had a driver's license for a shorter time exceeded the speed limit more often.

Duration of speeding. Similarly, young drivers and those who had a driver's license for a shorter time sped for a longer duration. There were also significant negative correlations with gender and marital status for this measure, indicating that drivers who are male and single exceeded the speed limit for longer time. In addition, the anger expression index was positively correlated with duration of speeding, indicating that drivers with higher anger expression scores were more likely to speed for longer periods of time.

Frequency of running a red light. Young drivers and those who had a driver's license for a shorter time ran red lights more frequently. Significant negative correlations were also observed between gender, marital status, and this variable, indicating that drivers who are male and single ran red lights more frequently. In addition, there was a positive correlation between the anger expression index score and frequency of running a red light. This indicated that drivers with higher anger expression scores were more likely to run red lights.

Frequency of hitting a pedestrian and others. Five variables were significantly negatively correlated with frequency of hitting a pedestrian. Single and young drivers, as well as those who had a driver's license for a shorter time, exhibited more instances of hitting a pedestrian. Moreover, people who reported lower annual mileage and a vehicle with lower horsepower exhibited more instances of hitting a pedestrian.

MANCOVA

In the third step of data analysis, a MANCOVA was conducted with the types of drinkers and income levels as between-subjects factors and 4 of the driving behavioral variables serving as dependent variables: speeding frequency, duration of speeding, frequency of running a red light and frequency of hitting a pedestrian. Frequency of hitting a barrier and colliding with another vehicle were dropped from further analysis because they were not strongly correlated with the effects of drinking or

income. In addition, age, gender, number of years since obtaining a driver's license, current marital status, the STAXI Anger Expression Index score, reported annual mileage, and vehicle horsepower were all entered into the MANCOVA as covariates to control the potential effects of these confounding factors. The overall MANCOVA was significant (Wilks's $\lambda = 0.821$, $p = .047$). Follow-up comparisons for each dependent variable are discussed below.

Speeding frequency. A significant types of Drinkers × Income levels interaction was revealed for speeding frequency (Figure 2; $F(1, 51) = 6.522$, $p = .014$). Planned contrasts indicated that non-binge drinkers with high income had significantly fewer speeding exceedances, compared to those in the other three groups (Contrast 1; $t(58) = −2.366$, $p = .021$). In other words, binge drinkers, independent of their income levels, exhibited more speeding exceedances than non-binge drinkers with high income. No significant difference was found between binge drinkers with high income and those with low income (Contrast 3; $t(58) = 0.139$, $p = .89$). There were no significant difference among binge drinkers with high income, binge drinkers with low income, and non-binge drinkers with low income (Contrast 2; $t(58) = 0.214$, $p = .83$).

There were no significant main effects for speeding frequency for types of drinkers or income levels.

Duration of speeding. The interaction effect of types of Drinkers × Income levels for duration of speeding was significant ($F(1, 51) = 7.897$, $p < .01$; Figure 3). Planned contrasts indicated that non- binge drinkers with high income significantly
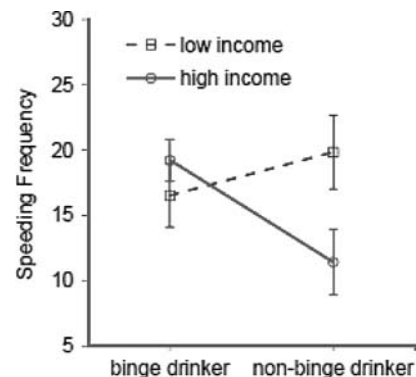

Figure 2 A significant interaction between types of drinkers and income levels on speeding frequency.
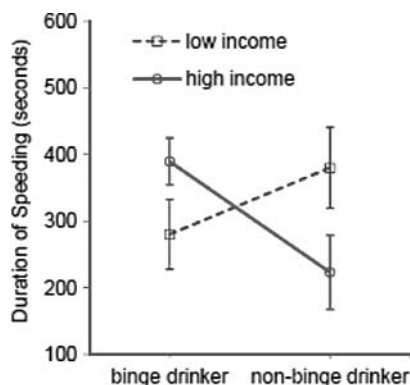
Figure 3 A significant interaction between types of drinkers and income levels on duration of speeding.

sped for a shorter time period than those in the other 3 groups (Contrast 1; $t(58) = -2.073$, $p = .043$). In other words, binge drinkers, independent of their income levels, exhibited longer speeding duration than non-binge drinkers with high income. However, no significant difference was shown between binge drinkers with high income and those with low income (Contrast 3; $t(58) = 0.927$, $p = .36$). There were no significant difference among binge drinkers with high income, binge drinkers with low income, and non-binge drinkers with low income, (Contrast 2; $t(58) = -0.175$, $p = .86$).

There were no significant main effects for types of drinkers or income levels on duration of speeding. No significant effects were observed for frequency of running a red light or frequency of hitting a pedestrian.

DISCUSSION

The current study found that even when sober, binge drinkers, regardless of income level, exhibited more speeding exceedances and longer speeding duration than those of high-income non-binge drinkers. In addition, individuals characterized as non-binge drinkers with low income also exhibited more speeding behaviors compared to high-income non-binge drinkers. Possible explanations for this effect include cognitive deficits and problems in vehicle control resulting from chronic alcohol consumption and/or a pattern of binge drinking and the negative relationship between income and unsafe driving behaviors.

A growing number of longitudinal neuropsychological studies reported that individuals with chronic and excessive alcohol consumption exhibit a number of cognitive deficits and problems in inhibitory control. Typically, these cognitive deficits include increased impulsivity, impaired working memory, judgment disability, response disinhibition, poor insight, reduced motivation, and attentional deficits (Moselhy et al. 2001; Nixon et al. 2002; Oscar-Berman and Hutner 1993; Parsons et al. 1987; Stephens and Duka 2008; Sullivan 2000). With chronic and excessive alcohol consumption, it has been found that both cortical gray matter and white matter sustain widespread volume loss (e.g., Fein et al. 2002), and degradation of frontocerebellar neuronal nodes and connecting circuitry lead to brain structural and functional compromise (Sullivan and Pfefferbaum 2005). Because binge drinkers consume larger amounts of alcohol than non-binge drinkers within a limited time period, it has been argued that the possibility of brain compromise and cognitive deficits may be magnified in this group (Hunt 1993). Based on the current findings, it is possible that such deficits in neurocognitive processing may have impacted participants' abilities to adequately perform a driving task (e.g., to inhibit or prevent speeding of the car), even in a sober driving situation. Moreover, chronic alcohol consumption has been associated with a lack of impulse control (Rubio et al. 2008), which may be related to a decrease in focused attention and a greater disregard for future consequences (e.g., risk perception). Because the influence of drinking pattern on cognitive deficits was not examined directly in present study, it was impossible to determine whether potential cognitive deficits were a result of a binge drinking pattern or contributing factors to a binge drinking pattern. Further research is needed to pinpoint the possible role of alcohol-related neurocognitive deficits and their effects on driving behavior.

The current study showed a significant interaction of types of drinkers versus income levels for both speeding frequency and duration of speeding. The STISIM records speeding frequency as any time the vehicle's speed exceeds the posted speed limit while duration of speeding as the time period a driver spent above the speed limit. Both measures, in nature, capture different features of speeding. For example, a driver may speed for a long time period, which does not necessarily mean that she or he has frequent speeding exceedances. Moreover, validity of the driving simulator for real-life relevance in evaluating speeding countermeasures has been previously demonstrated (e.g., Godley et al. 2002; Harms 1996; Tornros 1998). For example, Godley et al. (2002) conducted both a real road and the same road implemented in the driving simulator to validate driving behaviors in a simulated environment. It was found that drivers' speed control behavior in the simulated environment was a good predictor of their driving behavior on the real road, establishing the relative validities (significant correlation $r = 0.40$–0.52). Another measure in the current study, frequency of running a red light, revealed a similar and marginally significant pattern of the interaction effect of types of Drinkers × Income levels, indicating that it might also be a useful indicator of risky driving behavior. On the other hand, 3 collision-related measures were less sensitive to identify any group difference compared to speeding ones. One possible explanation is that in reality individuals are more aware of the potential for severe consequences resulting from collision rather than speeding and likely pay more attention in the presence of a pedestrian, vehicle, or obstacle on the road. Accordingly, the current findings showed that binge drinkers, regardless of income, differed from non-binge drinkers with high income, primarily in speeding during routine driving rather than loss of control in an emergency.

Although we anticipated that income levels may influence driving behavior, the interaction with types of drinkers is a unique finding. It has been well established that higher

income is associated with healthier behavior choices, such as health food purchasing, regular physician visits, and medical care (Kenkel 1991; Rosner et al. 1988; Yung et al. 1984). Individuals with a higher income seem to be more aware of the consequences of their behavior and therefore more prone to make healthier choices (Kenkel 1991). Particularly, previous research in the driving literature revealed that there was a negative relationship between income and unsafe driving behaviors, such as speeding, driving after drinking, and not using a seat belt (Haaga 1986; Helsing and Comstock 1977; NHTSA 2000; Shinar 1993). In the current study, non-binge drinkers with a high income exhibited fewer speed exceedances and sped for a shorter time, indicating a positive effect of income levels on the safe driving behavior, consistent with the aforementioned findings. However, binge drinkers in the high-income group engaged in more speeding behavior, likely due to the effects of a history of binge drinking. In addition, although income levels showed differences on some demographic and driving experience variables, several relevant factors were included as covariates in the main analysis, providing strong support for the income finding.

Despite studies that have specifically shown a negative relation between income and unsafe driving behaviors, the overall literature on this relation is relatively inconsistent and some researchers argue that higher income can lead to unsafe driving behaviors (Golias and Karlaftis 2001; Shinar et al. 2001; Traynor 1993). For example, Traynor (1993) found that high income was related to increased safety-enhancing purchases, such as anti-lock brakes. Although the usage of such advanced safety devices may decrease the likelihood that an accident will result in severe injury or fatality, at the same time it may lead to increased assertiveness and decreased risk perception, encouraging the prevalence of unsafe driving behaviors. Several possible explanations could be applied for the inconsistent findings regarding income and unsafe driving behaviors. First, there is very little empirical evidence (such as real road or simulator study) on the relation between income and driving performance variables. Self-report measures of driving behaviors derived from questionnaires or surveys are vulnerable to a number of biases that can lead to both under- and overreporting (Corbett 2001; Lindeman and Verkasalo 1994; Paulhus 2002). Second, income is not an independent indicator of driving behaviors and is correlated with a number of factors, such as region, culture, occupation, etc, For example, low income defined in one area might be classified as moderate or even high income in another area. As a result, the classification of income might be different and result in inconsistent findings in relation to the effect of income on driving behaviors (van Oers et al. 1999). Although the current income groups are related to the Western New York region and might not be generalizable to all areas, cultures, etc it may be important to consider income in conjunction with drinking patterns given the interactive effect that we found.

In practice, this study has value for reducing the risk of alcohol-related traffic crashes. First, several driving behavioral variables, such as speeding-related measures (speeding frequency and duration of speeding), might be helpful to identify those most at risk for alcohol abuse and aggressive driving. Marczinski et al. (2008) found that binge and nonbinge drinkers did not differ on any aspect of driving performance in either alcohol or placebo condition. In other words, under the influence of alcohol, binge drinkers did not have obviously significant difference of driving behavior than non-binge drinkers. In this study, however, it is suggested that speeding-related measures might serve as important considerations related to drinking even in a sober driving situation.

Second, the interaction of types of drinkers and income levels may help to identify individuals at higher risk for hazardous driving behaviors. These findings may have implications for determining appropriate treatment, intervention, and rehabilitation options for individuals with a history of drinking and driving. Namely, it may be important to take into account both the offender's drinking history and socioeconomic status in the course of rehabilitation and driver educational achievement in order to effectively reduce the risk of alcohol-related traffic crashes.

Despite these intriguing findings, it is necessary to consider the limitations of this study to be addressed in future work. For example, the study was conducted using a driving simulator, which may produce different risk perceptions for subjects compared with real-road driving. Real road tests may be needed in future studies to validate these findings. In spite of the small sample size, the observed power (β) for the types of Drinkers × Income levels interaction was at least 0.8 in the current study, but future studies should benefit from a larger sample size. Future studies should also consider other internal and external factors that might influence driving behavior such as impulsivity and the availability of safety-enhancing features on the participants' own vehicles. Furthermore, it may be useful to determine whether history of drinking and income levels have an impact on driving behavior while under the acute influence of alcohol as well. Finally, in addition to experimental research methods, computational modeling approaches could also be used to capture the effects of alcohol on human perceptual, cognitive, and motor control functions (Wu and Liu 2007; Wu et al. 2008). In sum, the current study reinforces prior evidence suggesting that binge drinkers represent a special group of interest with regard to dangerous driving behaviors and also highlights the importance of considering other factors that might help identify at-risk drivers, such as the potential interaction between drinking and SES status. Future studies are necessary to better define the factors that are most important with regard to rehabilitation and prevention.

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