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Event-Level Associations between Objective and Subjective Alcohol Intoxication and Driving after Drinking across the College Years

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Abstract

Heavy episodic drinking is strongly associated with driving after drinking, yet there has been mixed evidence regarding whether the disinhibiting effects of alcohol intoxication contribute to the decision to drive after drinking. This investigation tested whether greater alcohol intoxication increased the probability of driving after drinking particularly during drinking episodes in which students experienced reduced subjective feelings of intoxication. A sample of 1,350 college students completed up to 30 days of Web-based daily diary monitoring in each of 4 consecutive years. Participants reported daily on their alcohol consumption, subjective intoxication, and whether they drove after drinking on the previous day or night. In generalized estimating equation models, daily estimated blood alcohol concentration (eBAC) was more strongly associated with driving after drinking during episodes in which subjective intoxication was lower. That is, students were most likely to drive after drinking when they were objectively more intoxicated but perceived themselves as less intoxicated. These event-level associations did not change over time nor did they differ as a function of gender. Further, the effects persisted when predicting driving at eBACs above the legal limit for operating a motor vehicle. Greater subjective intoxication may serve to inhibit driving after drinking, particularly when students are objectively more intoxicated. In the absence of subjective intoxication, however, other salient pressures might impel driving after drinking. Prevention efforts should incorporate the importance of variability in subjective intoxication.

Keywords

Driving after Drinking; Alcohol; Subjective Intoxication; College Students; Event-Level

Driving after drinking remains prevalent among U.S. college students. Approximately 30% of students self-report driving after drinking (Hingson, Zha, & Weitzman, 2009; Wechsler, Dowdall, Maenner, Gledhill-Hoyt, & Lee, 1998), with older students reporting higher rates (Beck et al., 2010; Fromme, Wetherill, & Neal, 2010). This high prevalence is alarming given the well-established detrimental effects of alcohol on driving. Alcohol impairs psychomotor performance (Harrison & Fillmore, 2005) and response inhibition (Fillmore, Blackburn, & Harrison, 2008; Schweitzer & Vogel-Sprott, 2008), decreasing drivers'

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capability to maintain lane position and constant speed (Marczinski & Fillmore, 2009; Marczinski, Harrison, & Fillmore, 2008). Unsurprisingly, then, drivers are at elevated risk of accidents and injuries when intoxicated, with the likelihood of a fatal traffic accident increasing exponentially with increasing blood alcohol concentrations (BACs; Keall, Frith, & Patterson, 2004). In 2005, approximately 1,400 college students died in alcohol-related traffic accidents, comprising 74% of all alcohol-related student injury deaths (Hingson et al., 2009).

Alcohol Use and Driving after Drinking

Research on the etiology of driving after drinking has primarily focused on identifying individual difference predictors (Nochajski & Stasiewicz, 2006), including male gender (Flowers et al., 2008), high trait-level sensation seeking (i.e., a preference for novelty and excitement; Jonah, 1997; Pedersen & McCarthy, 2008), and low perceptions of the dangerousness of intoxicated driving (McCarthy, Lynch, & Pedersen, 2007; McCarthy & Pedersen, 2009). Notably, one of the strongest individual-level predictors of driving after drinking is heavy alcohol use. Heavy episodic drinkers, in particular, account for over 80% of self-reported driving after drinking incidents (Flowers et al., 2008; Quinlan et al., 2005). This strong association has led some to propose that the disinhibiting effects of alcohol intoxication—particularly at the level of intoxication produced by heavy episodic drinking—may increase a student's propensity to decide to drive while impaired. Quinlan and colleagues (2005), for example, argued that "prevention efforts to reduce [driving after drinking] are likely to be of limited success unless they are coupled with efforts to also reduce the prevalence of binge drinking" (p. 349).

Importantly, however, the existing evidence has largely been at the global, or between-person, level. That is, these studies show that people who drive after drinking are also more likely to engage in heavy episodic drinking. These global associations are compelling, but they do not demonstrate that greater intoxication during a specific drinking episode (i.e., at the event level) increases the likelihood of a decision to drive while intoxicated. It could be that the same underlying personality factors, such as sensation seeking, contribute to both, producing a spurious global association between heavier drinking and more frequent driving after drinking (Hittner & Swickert, 2006; Jonah, 1997). Indeed, despite its theoretical appeal, evidence for the role of alcohol intoxication in decisions to drive after drinking has been mixed. A recent study, for example, found no event-level association between intoxication and self-reported driving among college students (Neal & Fromme, 2007). That is, independent of the finding that typically heavier-drinking students were more likely to drive after drinking on average, students were no more likely to drive during the specific drinking episodes in which their BACs were higher.

Although the causal role of intoxication in driving after drinking is therefore still unclear, it is possible that alcohol plays a more or less substantial role under specific conditions. In particular, the extent to which one *feels* intoxicated may serve to inhibit driving after drinking. Even at identical BACs, people respond to alcohol in varying degrees, in part as a function of family history of alcohol problems and drinking history (Morean & Corbin, 2010; Quinn & Fromme, in press; Ray, MacKillop, & Monti, 2010), and subjective intoxication may guide decision-making in driving contexts. When individuals are more objectively intoxicated, salient internal or behavioral cues that one is intoxicated might inhibit driving, whereas the absence of such cues might encourage driving. Laboratory-based studies have provided some evidence for the role of subjective intoxication in decisions to drive after drinking. Specifically, after consuming an intoxicating dose of alcohol, individuals who experience greater subjective intoxication have reported lower willingness to drive and a reduced confidence in their driving abilities (Beirness, 1987;

Marczinski & Fillmore, 2009; Marczinski, Harrison, & Fillmore, 2008). Although these studies have demonstrated the potential relevance of subjective intoxication to driving decisions, less research has tested whether subjective intoxication moderates the association between increasing BACs—and therefore increasing impairment—and risk for driving after drinking.

Importantly, subjective intoxication can vary not just across individuals but also across drinking episodes. Factors including drinking and absorption pace (Martin & Earleywine, 1990), social stimuli (Ray et al., 2010b), and co-ingestion of caffeine (Ferreira, de Mello, Pompeia, & de Souza-Formigoni, 2006; Marczinski & Fillmore, 2006) can all affect subjective intoxication. It is therefore possible that episode-to-episode variation in subjective intoxication could influence decisions to drive after drinking by moderating the association between objective intoxication and driving. Specifically, episodes in which BACs are higher (i.e., students are objectively more intoxicated and therefore more cognitively impaired) but subjective intoxication is lower (i.e., students are not experiencing the cues normally associated with intoxication) might increase risk for driving after drinking. To our knowledge, however, no study prior to the current investigation has tested this possibility.

BAC, Subjective Intoxication, and Driving after Drinking in the Natural Environment

In the present study, we followed a sample of college students who completed daily self-monitoring diaries in four consecutive years to test whether subjective intoxication influenced the event-level association between alcohol use and driving after drinking. Although laboratory-based experimental studies using reported intentions or behavioral analogues have important strengths for isolating causal effects, they cannot establish a relation between intoxication and driving after drinking as it actually occurs. Further, college student alcohol consumption varies in quantity, pace, and context across drinking episodes, and students often reach peak BACs that exceed those ethically permitted in laboratory-based alcohol challenge studies (e.g., Rutledge, Park, & Sher, 2008). Event-level approaches, in contrast, maximize ecological validity by capturing both alcohol use and driving after drinking in the natural environment.

Additionally, our daily diary methodology permitted the separation of between-person, global effects from within-person, event-level effects. Our hypotheses primarily concerned the within-person effects of alcohol consumption and subjective intoxication. Specifically, we predicted that the event-level association between BAC and driving would be stronger during drinking episodes when a given student felt less intoxicated than usual. It was thus essential that we distinguish the effects of within-person, episode-to-episode variability in BAC and subjective intoxication from the between-person effects of individual differences in typical drinking and subjective intoxication.

In summary, we conducted an event-level study to investigate the following research questions: (1) Are objective alcohol intoxication (i.e., BAC) and subjective intoxication associated with driving after drinking at the event level after accounting for demographics, family history of alcohol problems, and an established personality predictor of driving after drinking (i.e., sensation seeking; Pedersen & McCarthy, 2008)?, and (2) More importantly, is the event-level association between objective intoxication and driving after drinking stronger during episodes in which students experience lower subjective intoxication? Given the scope of our sample and the limited existing event-level research on driving after drinking, we also explored whether any of these associations changed over time or differed as a function of gender.

Method

Participants and Procedures

Participants in the current investigation were drawn from a larger longitudinal study of alcohol use and other behavioral risks among college students. In the summer prior to matriculation, first-time students between the ages of 17 and 19 in the incoming class of 2004 at a large southwestern university ($N = 6,391$; 94% of the incoming class) were invited to participate in the larger study. Of the 4,832 interested students who also met a final inclusion criterion of being unmarried, 3,046 were randomized to a longitudinal study condition in which they would complete a Web-based pre-college survey followed by semi-annual assessments. For further information regarding recruitment and procedures for the longitudinal study, see Corbin and colleagues (2008) and Hatzenbuehler and colleagues (2008).

Of students randomized to the longitudinal survey condition, 75% ($N = 2,245$) provided informed consent and completed the pre-college survey. As described in detail by Neal and Fromme (2007), these participants were then invited to additionally provide, in each of the four years of college, the daily self-monitoring data of interest here. In August 2004, we began randomly assigning sets of participants to begin 30 consecutive days of Web-based daily monitoring each week. The initial set of invited participants ($n = 200$) was large enough to ensure sufficient monitoring in the first weeks. Between 40 and 43 participants were invited to participate in each subsequent week throughout the calendar year. Participants were enrolled during the same calendar period in each of the four years, with the exception that participants randomized to monitor during the summer months were not asked to provide monitoring in year four (i.e., after graduation). To complete the assessments, participants logged into a secure Web site (DatStat, Seattle, Washington), on which they viewed their 30-day monitoring period in calendar form. We encouraged participants to log into the site daily but permitted access to the previous seven days on the calendar to reduce missing data while minimizing retrospective bias. Participants received a compensation of \$1 per day of completed monitoring, plus a \$5 bonus for participating on all 30 days. All procedures were approved by the university's Institutional Review Board.

Of the students invited into the daily diary protocol, 2,016 participated in at least one year. To ensure reliable responding without introducing bias due to over-exclusion or inclusion of noncompliant participants, we included data in the current investigation from students who completed at least 14 days of monitoring within a given year ($N = 1,867$ students; 63% of the randomized sample). We also excluded 234 outlying observations (0.16% of all observations) on which estimated BACs (eBACs) exceeded .40 g/dl. These strategies for eliminating potentially unreliable responses have been used in previous event-level research (Neal & Fromme, 2007). Self-report data from the pre-college survey on family history of alcohol problems and sensation seeking was available for 95% of the included sample ($N = 1,778$). Because driving after drinking cannot occur in the absence of alcohol consumption, all analyses in the present investigation were limited to a final sample of $N = 1,350$ non-abstaining participants who additionally met the above criteria.

This final sample was 64% female and 60% White, 16% Asian or Asian-American, 13% Hispanic or Latino, 3% African-American, and 9% multi-ethnic or other ethnicities. In the summer prior to matriculation, the average age was 18.41 years ($SD = 0.35$). Included participants reported a total of 19,622 drinking days, with each participant contributing $M = 14.5$ total drinking days across all 4 monitoring periods, range = 2 – 86.

Measures

Demographics, sensation seeking, and family history of alcohol problems were assessed in the pre-college survey. All other measures were included in the daily diaries.

Sensation seeking—Participants completed a measure of sensation seeking taken from the Zuckerman-Kuhlman Personality Questionnaire-III (Zuckerman, Kuhlman, Joireman, Teta, & Kraft, 1993). Participants responded to the 11 sensation seeking items (e.g., *I like doing things just for the thrill of it*) on a dichotomous scale where 0 = *false* and 1 = *true*. No item referred to alcohol or other substance use. In the current sample, the scale demonstrated adequate internal consistency, $\alpha = .72$. The mean sensation seeking score was 5.69, $SD = 2.67$, range = 0 – 11.

Family history of alcohol problems—We assessed family history of alcohol problems with the Family History Tree questionnaire (Mann, Sobell, Sobell, & Pavan, 1985). Participants categorized siblings, parents, and grandparents under the following descriptions: *non-drinker*, *social drinker*, *possible problem drinker*, and *definite problem drinker*. Participants with at least one definite problem-drinking family member were classified as having a positive family history (23%; $n = 313$). All other participants were classified as having a negative family history.

Daily diaries—For each day, participants first reported time-varying demographic characteristics (e.g., weight) and then answered a series of questions regarding the previous day's behavior. Participants reported the number of discrete drinking occasions, number of standard drinks (i.e., 12 oz beer, 5 oz wine, or 1.5 oz liquor in a shot or mixed drink) consumed, and duration of the heaviest drinking occasion. Using self-reported gender, weight, and drinking quantity and duration, we calculated eBAC following Matthews and Miller's (1979) procedure. This method of estimating BAC has been recommended for use when breath alcohol concentrations (BrACs) are not available (Leeman et al., 2010). It has demonstrated validity as a measure of objective alcohol intoxication, including very strong associations with BrAC (Hustad & Carey, 2005). Participants also reported their subjective intoxication during the day's heaviest drinking episode on a visual analogue scale from 0 = *not at all drunk* to 100 = *extremely drunk*. This measure of subjective intoxication has demonstrated strong test-retest reliability and convergent validity with other indices of the sedative effects of alcohol (Quinn & Fromme, 2011), which is consistent with other commonly used measures of subjective intoxication (Ray, MacKillop, Leventhal, & Hutchison, 2009; Chung & Martin, 2009; Morean & Corbin, 2008). Finally, participants reported whether they drove after drinking on the previous day.

Data Analytic Strategy

The event-level reports of driving after drinking were non-normally distributed and nested within students. We therefore tested associations among eBAC, subjective intoxication, and driving after drinking using Generalized Estimating Equations (GEEs; Hardin & Hilbe, 2003) in Stata 10.1 (StataCorp, 2009). GEEs accommodate nested data by accounting for intra-individual correlations. Because driving after drinking was a dichotomous variable, we estimated all models using a GEE extension of binary logistic regression by specifying the binomial reference distribution and logit link. These models permit the use of odds ratios (i.e., exponentiated coefficients) as a measure of effect size. We estimated two-level models (monitoring days within individuals), with an autoregressive correlation structure to account for the multiple observations within students. GEE modeling in Stata is not well-suited to three-level data. We therefore treated monitoring year as a covariate—rather than an additional level of dependency in the data—to account for any within-person variation in driving after drinking across years. In preliminary analyses (the results of which are

available from the first author), we found little evidence of within-year dependency beyond within-individual dependency, which supports our use of two-level models. To account for day-to-day variation in eBAC, subjective intoxication, and driving after drinking, we included indicator variables for each day of the week with Sunday as the reference day. We also included within-year monitoring day to test and control for reactivity effects. Finally, all models included sensation seeking, family history of alcohol problems, gender, and ethnicity as between-person covariates.

We used a person-centered approach to distinguish the effects of within-person, episode-to-episode variation in subjective intoxication and eBAC from the effects of between-person individual differences in typical subjective intoxication and eBAC. We entered both daily deviations from average levels of subjective intoxication and eBAC *and* average levels across monitoring periods into the GEE models. The person-mean-centered daily subjective intoxication and eBAC variables represented the within-person, event-level effects of deviation from average levels of subjective intoxication or eBAC, whereas the person-average subjective intoxication and eBAC variables reflected the between-person, global-level effect of individual differences in subjective intoxication and alcohol consumption, respectively. To ease the interpretation of odds ratios, we multiplied average and daily eBAC by 100, meaning that odds ratios for these variables reflected the increase in odds of driving associated with a .01 g/dl increase in eBAC. Similarly, we divided daily and average subjective intoxication ratings by 10. Odds ratios for these variables reflected the increased odds of driving associated with a 10-point increase in subjective intoxication. We also standardized sensation seeking scores.

We first examined aggregate change and stability in alcohol use, subjective intoxication, and driving after drinking across the four college years represented in the sample. Next, we tested our research questions using GEE models. After testing the direct and moderated effects of eBAC and subjective intoxication, we tested whether these associations differed as a function of gender or changed across time. Finally, although alcohol-induced cognitive impairment has been demonstrated at BACs as low as .05 g/dl (Schweizer & Vogel-Sprott, 2008), we were interested in determining whether the effects of interest persisted when predicting the more stringent criterion of driving at eBACs above the legal limit for operating a motor vehicle in the U.S. (i.e., .08 g/dl). We therefore repeated the above analyses including only those observations (8,887 drinking days among 913 participants) where eBACs were equal to or greater than .08 g/dl.

Results

Inclusion Analyses

Included participants did not differ from participants in the longitudinal cohort who were excluded from the current analyses ($n = 895$; 40% of the longitudinal sample) on age, $t(2243) = 0.14$, $p = .89$, $d = .01$, or family history of alcohol problems, $\chi^2(1) = 0.60$, $p = .44$. Included participants were, however, modestly higher in sensation seeking, $t(2127) = 2.42$, $p = .02$, $d = .11$, and were more likely to be female, $\chi^2(1) = 27.12$, $p < .001$, and white, $\chi^2(4) = 52.78$, $p < .001$. Unsurprisingly, considering that we excluded abstainers, included students reported more heavy episodic drinking at the pre-college survey, although this effect was small in magnitude, $t(2236) = 3.91$, $p < .001$, $d = .17$.

Aggregate Summary Statistics

As shown in Table 1, approximately one quarter of included students (i.e., non-abstainers) reported driving after drinking at least once during their 30 days of monitoring in the first year of college. This prevalence increased to nearly one third by year four. Students

consumed alcohol approximately 1.22 days per week of monitoring in their first year, and they drank more frequently in each subsequent year. On average, eBACs on drinking days exceeded the legal limit for operating a motor vehicle during the first year, but students tended to reach lower eBACs in year four relative to the first two years of college. Concomitantly, students reported lower levels of subjective intoxication in year four.

Models Predicting Driving after Drinking

As shown in Table 2, we found event-level support for the roles of daily eBAC and subjective intoxication in driving after drinking. A .01 increase in daily eBAC was associated with a 2% increase in the odds of driving. As expected, however, this association was qualified by a significant daily eBAC $\times$ daily subjective intoxication interaction. The association between increasing eBAC and driving was greater on days when students reported lower-than-their-average subjective intoxication (see Figure 1). That is, risk for driving after drinking was greatest during drinking episodes when participants reached higher eBACs but experienced lower subjective intoxication.

Beyond the event-level effects of daily eBAC and subjective intoxication, we found several significant between-person associations. Heavier drinkers (i.e., those higher in average eBAC) were more likely to drive after drinking, with a .01 increase in average drinking-day eBAC associated with a 4% increase in the odds of driving. Moreover, a 10-point increase in (between-person) average subjective intoxication was associated with a 4% increase in the odds of driving after drinking. In addition, students higher in sensation seeking were more likely to drive after drinking, although students with a positive family history of alcohol problems were not. There was no main effect of gender. Finally, we found some evidence of a possible assessment reactivity effect in that the odds of driving after drinking decreased 1% with every additional monitoring day.

Effects of year in college and gender—We next tested whether the associations of interest changed across the college years. We added five terms representing interactions between monitoring year and daily eBAC, daily subjective intoxication, daily eBAC $\times$ daily subjective intoxication, average eBAC, and average subjective intoxication to the final model in Table 2. The inclusion of these interactions did not significantly improve model fit, $\Delta\chi^2(5) = 10.39$, $p = .06$, and no individual interaction reached significance, $ps > .06$. Further, the daily eBAC $\times$ daily subjective intoxication interaction remained significant, $b = -0.01$, $OR = 0.99$, $p = .05$. In sum, the main effects and interactions among within- and between-person variability in eBAC and subjective intoxication—including the hypothesized interaction between eBAC and subjective intoxication at the event level—did not appear to change across the college years.

In order to test whether gender moderated associations between eBAC and subjective intoxication and driving after drinking, we added five terms representing interactions between gender and daily eBAC, daily subjective intoxication, the daily eBAC $\times$ daily subjective intoxication interaction, average eBAC, and average subjective intoxication to the final model presented in Table 2. This expanded model demonstrated improved fit to the data, $\Delta\chi^2(5) = 13.76$, $p = .02$. Gender significantly moderated the effect of daily eBAC, $b = 0.02$, $OR = 1.02$, $p = .03$. Specifically, a .01 increase in daily eBAC was associated with a 4% increase in the odds of driving among men ($b = 0.04$, $OR = 1.04$, $p < .001$) but a 2% increase among women, $b = 0.02$, $OR = 1.02$, $p = .01$. Gender did not, however, moderate the daily eBAC $\times$ daily subjective intoxication interaction, $b = -0.003$, $OR = 1.00$, $p = .20$. There were no other interactions ($ps > .20$), and all other associations demonstrated in Table 2, including the hypothesized daily eBAC $\times$ daily subjective intoxication interaction ($b = -0.003$, $OR = 0.997$, $p = .03$), remained significant.

Models Predicting Driving at eBACs Above the Legal Limit

Our final analytic step was to determine whether event-level predictors of driving after drinking additionally predicted the more restrictive criterion of driving at eBACs above the legal limit for operating a motor vehicle (see Table 3). The association between daily eBAC and driving after drinking did not reach significance, likely reflecting the reduced range of eBACs (i.e., greater than or equal to .08 g/dl). As expected, however, we found a significant daily eBAC $\times$ daily subjective intoxication interaction, replicating our central initial finding. As shown in Figure 2, greater daily eBAC was associated with an increased likelihood of driving above the legal limit during episodes when participants reported lower subjective intoxication, but this association was attenuated considerably during episodes when participants reported greater subjective intoxication. Additionally, heavier drinkers were more likely to drive above the legal limit, as were students higher in sensation seeking. In contrast, individual differences in neither average subjective intoxication nor family history were associated with driving in these analyses.

Effects of year in college and gender—Including the five monitoring-year interactions did not significantly improve model fit, $\Delta\chi^2(5) = 5.82$, $p = .32$, and no monitoring-year interaction term reached significance, $ps > .05$. Further, the daily eBAC $\times$ daily subjective intoxication interaction remained significant, $b = -0.02$, $OR = 0.98$, $p = .01$. Similarly, adding the five gender interactions produced no improvement in fit, $\Delta\chi^2(5) = 0.83$, $p = .98$, with no individual gender interaction term reaching significance, $ps > .56$, and the daily eBAC $\times$ daily subjective intoxication interaction again remaining significant, $b = -0.01$, $OR = 0.99$, $p = .04$. In sum, when predicting driving above the legal limit, the hypothesized associations did not change across the four years of monitoring, and they were not influenced by gender.

Discussion

This investigation found event-level support for the relevance of objective and subjective alcohol intoxication to driving after drinking. Daily deviations from average eBACs were associated with increases in the likelihood of driving after drinking, although the magnitude of this relation was relatively small. More importantly, the association was moderated by daily subjective intoxication: Greater eBAC predicted driving after drinking more strongly on days when students felt less intoxicated than usual. Although patterns of alcohol use and subjective intoxication changed over time, the moderating effect of daily subjective intoxication was robust across the college years, and it did not appear to differ as a function of gender. Moreover, the effect persisted when predicting driving at eBACs exceeding the legal limit for operating a motor vehicle. This pattern of findings replicates and extends prior laboratory-based evidence (Marczinski et al., 2008; Marczinski & Fillmore, 2009) and suggests that students are more likely to drive after drinking when they have consumed more alcohol but feel less intoxicated than usual. That is, risk is highest when students are intoxicated but are not aware of the extent of their intoxication.

These findings can be interpreted in terms of Alcohol Myopia (or “Attention Allocation”) Theory, which proposes that alcohol impairs controlled processing, a consequence of which is that intoxicated individuals are able to attend to only the most salient environmental or internal stimuli (Casbon, Curtin, Lang, & Patrick, 2003; Curtin & Fairchild, 2003; Giancola, Josephs, Parrott, & Duke, 2010; Moss & Albery, 2009; Steele & Josephs, 1990). Under response conflict (i.e., when there are roughly equivalent pressures to engage or not engage in a behavior), intoxicated individuals will be strongly influenced by these salient cues. The presence of salient impelling cues—or the absence of inhibiting cues—may therefore be necessary for alcohol intoxication to lead to intoxicated driving (e.g., MacDonald, Zanna, &

Fong, 1995). In contrast to other behavioral risks that have been associated with alcohol use (e.g., aggression, unsafe sex), driving is most problematic if the individual is intoxicated and therefore impaired. Thus, consistent with alcohol myopia, internal sensations of greater intoxication may serve as an important signal that one should not drive. We concur with Moss and Albery (2009) that experiencing subjective sensations associated with intoxication might inhibit driving after drinking by activating mental representations of clumsiness or potential negative consequences, which could be highly salient and therefore influential to intoxicated students who might be conflicted about whether or not to drive. In the absence of these internal cues of impairment, however, other pressures, including the desire to get home quickly and with one's car (Giancola et al., 2010), might hold sway over intoxicated students' decisions to drive.

Beyond the event-level effects of alcohol use and subjective intoxication, we additionally found several notable global (between-person) associations. Replicating several larger-scale studies, heavier drinkers (i.e., those with higher average eBACs) were more likely to drive after drinking (Flowers et al., 2008; Quinlan et al., 2005). This global association may reflect the fact that those who consume alcohol more frequently have more opportunities to drive after drinking. Additionally, a broad, genetically influenced predisposition appears to underlie a spectrum of problem behaviors, including alcohol and other substance use, risky sexual behaviors, poor academic performance, and delinquency (Cooper, Wood, Orcutt, & Albino, 2003; Krueger et al., 2002), and it may also increase individuals' propensity to drive after drinking. This externalizing predisposition might result from differences in personality, and higher sensation seeking—a robust predictor of alcohol use (Hittner & Swickert, 2006)—was associated with driving after drinking in our sample.

Finally, we found some evidence that average subjective intoxication (i.e., between-person individual differences in typical subjective intoxication) was *positively* associated with driving after drinking. That is, students who tended to experience greater subjective intoxication on average endorsed more driving after drinking. This result is consistent with previous results from the current sample, in which greater average subjective intoxication predicted a variety of other negative outcomes after accounting for typical alcohol use (Quinn & Fromme, 2011). Although preliminary, these findings suggest that average subjective intoxication may reflect individual differences in alcohol's hedonic effects or cognitive impairments (Assaad et al., 2006), which could contribute to greater behavioral risk-taking or other negative consequences.

Strengths and Limitations

Methodological strengths of the current investigation included its large, diverse sample, which was followed across four years. We note that modest selection bias regarding sensation seeking, gender, and ethnicity may have affected the present results. Our hypotheses, however, concerned within-person relations, and our use of person-centering reduced the impact of any individual-difference factors on event-level associations. Further, we were able to account for sensation seeking and demographics in all analyses, which increases our confidence that they did not unduly influence our individual-difference results. Nevertheless, range restriction may have attenuated their associations with driving after drinking, suggesting that effect sizes reported here may represent lower-bound estimates of the true magnitudes of the effects of sensation seeking and demographics.

Additionally, this study is among the first investigations of driving after drinking at the event level and is, to our knowledge, the first to do so longitudinally. Despite considerable methodological advantages, our event-level design was retrospective, if only over brief periods. It is therefore possible that retrospective bias may have influenced results. For example, participants could have under-reported their subjective intoxication as a *post-hoc*

rationalization for their having driven after drinking. Although this possibility could offer an alternative explanation for an inverse main effect of daily subjective intoxication—with drivers reporting feeling less intoxicated—it importantly would not explain the moderating effect of daily subjective intoxication on the association between daily eBAC and driving demonstrated here.

Finally, our measure of objective intoxication (eBAC) relied upon self-report of alcohol consumption. Shared method variance between eBAC and subjective intoxication may have resulted in an overestimation of their association, which we have described in previous work (Quinn & Fromme, 2011), although it would be unlikely to inflate the magnitude of the moderation effect demonstrated here. Further, the eBAC measure has demonstrated validity and is commonly used, but our finding that a very slight proportion of eBACs (0.16%) exceeded .40 g/dl illustrates that it, like all measures, is imperfect. The Matthews and Miller (1979) formula may overestimate BAC if drinking duration is under-reported or quantity over-reported, and we cannot account for the possibility that, in some rare cases, alcohol was consumed and then lost through vomiting prior to absorption. Although BACs in excess of .40 g/dl have been documented in other research among college students (Rutledge et al., 2008) and are not necessarily fatal (Brick & Erickson, 2009), we nevertheless excluded these observations to decrease the likelihood that reduced reliability due to memory or other cognitive impairment may have affected our results.

Implications

We conclude by noting that the current investigation suggests several strategies to reduce intoxicated driving. Although current public health campaigns include information regarding the dangers of so-called buzzed driving (i.e., driving when BACs are elevated but below colloquial thresholds for “drunkenness”), educational programs that convey the distinction between subjective intoxication and objective alcohol-induced impairments may help reinforce the message that feeling less intoxicated does not guarantee objective sobriety (Ad Council, 2008). Additionally, efforts to caution against drinking practices that reduce subjective intoxication might help students maintain awareness of their impairment levels. For example, co-ingestion of caffeine and alcohol decreases subjective intoxication without alleviating cognitive impairments (Ferreira et al., 2006; Marczyński & Fillmore, 2006), which might contribute to driving after drinking (Thombs et al., 2009). Our findings suggest that, whatever their implementation strategy, interventions should target the fact that how drunk a student feels is not always a sound indicator of whether or not he or she should get behind the wheel.

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Figure 1. Probability of driving after drinking as a function of daily estimated BAC (eBAC) and subjective intoxication. Low and high subjective intoxication refer to drinking episodes in which participants were one standard deviation below or above, respectively, their average level of subjective intoxication.

Figure 2. Probability of driving above the legal limit (i.e., BAC $\geq .08$ g/dl) as a function of daily estimated BAC (eBAC) and subjective intoxication. Low and high subjective intoxication refer to drinking episodes in which participants were one standard deviation below or above, respectively, their average level of subjective intoxication.

Table 1

Aggregate Summary Statistics by Year of Daily Monitoring

Variable	Possible Range	Observed Range	Year 1 (<i>n</i> = 847) <i>M</i> (<i>SD</i>)	Year 2 (<i>n</i> = 859) <i>M</i> (<i>SD</i>)	Year 3 (<i>n</i> = 924) <i>M</i> (<i>SD</i>)	Year 4 (<i>n</i> = 681) <i>M</i> (<i>SD</i>)
Monitoring days per year ^a	14 – 30	14 – 30	27.96 (3.55)	28.23 (3.48)	28.06 (3.76)	28.03 (3.69)
Drinking days per monitoring period	1 – 30	1 – 29	4.86 _a (3.99)	5.63 _b (4.73)	6.90 _c (5.23)	7.33 _d (5.10)
eBAC per drinking day (g/dl)	.00 – .40	.0003 – .40	.089 _a (.06)	.090 _a (.06)	.084 _{ab} (.06)	.074 _b (.05)
Subjective intoxication per drinking day	0 – 100	0 – 100	28.11 _a (23.38)	28.36 _a (22.78)	25.33 _a (21.09)	21.86 _b (19.78)
Prevalence of driving after drinking	--	--	26.6% _a	27.7% _a	31.5% _b	32.7% _c

Note. Means and prevalence estimates with differing subscripts within rows significantly differ, $p < .05$. eBAC= estimated blood alcohol concentration.

^aParticipants completing fewer than 14 monitoring days within a year were excluded from this investigation.

Table 2

Summary of Generalized Estimating Equation Models Predicting Driving after Drinking

Variable	Step 1		Step 2		Step 3	
	Odds Ratio (OR)	95% C.I.	OR	95% C.I.	OR	95% C.I.
Day of week						
Monday	1.15	[0.91, 1.44]	1.14	[0.91, 1.44]	1.14	[0.91, 1.44]
Tuesday	1.10	[0.88, 1.38]	1.09	[0.86, 1.37]	1.07	[0.85, 1.35]
Wednesday	1.44**	[1.16, 1.79]	1.43**	[1.15, 1.79]	1.43**	[1.15, 1.79]
Thursday	1.42***	[1.17, 1.71]	1.34**	[1.11, 1.63]	1.32**	[1.09, 1.61]
Friday	1.37***	[1.14, 1.64]	1.28**	[1.06, 1.53]	1.26*	[1.05, 1.52]
Saturday	1.33**	[1.11, 1.59]	1.24*	[1.03, 1.49]	1.23*	[1.02, 1.47]
Monitoring day	0.99**	[0.995, 0.996]	0.99**	[0.99, 0.996]	0.99**	[0.99, 0.997]
Monitoring year	0.99	[0.94, 1.05]	1.04	[0.98, 1.09]	1.04	[0.98, 1.09]
Male gender	0.98	[0.87, 1.10]	1.03	[0.92, 1.16]	1.04	[0.92, 1.17]
Ethnicity						
African-American	1.48*	[1.02, 2.14]	1.63**	[1.13, 2.36]	1.60*	[1.11, 2.32]
Asian-American	0.80*	[0.65, 0.98]	0.79*	[0.65, 0.97]	0.78*	[0.64, 0.96]
Hispanic/Latino	1.29**	[1.09, 1.53]	1.35***	[1.14, 1.59]	1.34***	[1.13, 1.58]
Multieethnic/other	1.53***	[1.28, 1.84]	1.51***	[1.26, 1.81]	1.51***	[1.26, 1.81]
Family history positive	0.99	[0.87, 1.13]	0.95	[0.83, 1.08]	0.95	[0.83, 1.08]
Sensation seeking	1.13***	[1.07, 1.20]	1.10**	[1.04, 1.17]	1.10**	[1.04, 1.17]
Alcohol intoxication						
Average eBAC			1.04***	[1.03, 1.05]	1.04***	[1.03, 1.06]
Daily eBAC			1.02***	[1.01, 1.03]	1.02***	[1.01, 1.03]
Average SI			1.05**	[1.02, 1.09]	1.05**	[1.02, 1.09]
Daily SI			0.99	[0.96, 1.01]	0.99	[0.96, 1.01]
Daily eBAC×Daily SI					0.996***	[0.99, 0.998]
$\Delta\chi^2$ (df)		90.53*** (15)		133.72*** (4)		14.48*** (1)

Note: eBAC = estimated blood alcohol concentration. SI = subjective intoxication. White was the reference ethnicity, and Sunday was the reference day of the week.

* $p < .05$.
** $p < .01$.
*** $p < .001$.

Table 3
Summary of Generalized Estimating Equation Models Predicting Driving above the Legal Limit (eBAC .08 g/dl)

Variable	Step 1		Step 2		Step 3	
	Odds Ratio (OR)	95% C.I.	OR	95% C.I.	OR	95% C.I.
Day of week						
Monday	1.23	[0.87, 1.73]	1.23	[0.87, 1.73]	1.23	[0.87, 1.74]
Tuesday	1.23	[0.88, 1.72]	1.23	[0.88, 1.73]	1.23	[0.88, 1.72]
Wednesday	1.48*	[1.06, 2.06]	1.48*	[1.06, 2.07]	1.49*	[1.06, 2.08]
Thursday	1.23	[0.92, 1.63]	1.25	[0.94, 1.67]	1.25	[0.94, 1.66]
Friday	1.26	[0.96, 1.65]	1.30	[0.99, 1.71]	1.30	[0.99, 1.71]
Saturday	1.27	[0.97, 1.66]	1.30	[0.97, 1.71]	1.30	[0.99, 1.71]
Monitoring day	0.99	[0.99, 1.00]	0.99	[0.99, 1.00]	0.99	[0.99, 1.00]
Monitoring year	1.06	[0.99, 1.13]	1.06	[0.99, 1.14]	1.06	[0.99, 1.14]
Male gender	1.08	[0.92, 1.27]	1.10	[0.94, 1.30]	1.10	[0.94, 1.30]
Ethnicity						
African-American	1.25	[0.76, 2.40]	1.42	[0.80, 2.53]	1.41	[0.79, 2.52]
Asian-American	0.78	[0.59, 1.03]	0.78	[0.59, 1.03]	0.78	[0.59, 1.02]
Hispanic/Latino	1.32*	[1.04, 1.66]	1.33*	[1.05, 1.68]	1.32*	[1.05, 1.67]
Multiethnic/other	1.70***	[1.34, 2.17]	1.70***	[1.34, 2.17]	1.71***	[1.35, 2.17]
Family history positive	1.09	[0.92, 1.30]	1.07	[0.90, 1.28]	1.08	[0.91, 1.28]
Sensation seeking	1.11*	[1.02, 1.20]	1.08	[1.00, 1.18]	1.09*	[1.002, 1.18]
Alcohol intoxication						
Average eBAC			1.03***	[1.01, 1.05]	1.04***	[1.02, 1.06]
Daily eBAC			1.00	[0.99, 1.02]	1.01	[0.99, 1.02]
Average SI			1.00	[0.96, 1.04]	1.00	[0.96, 1.04]
Daily SI			0.94***	[0.91, 0.97]	0.94***	[0.91, 0.97]
Daily eBAC × Daily SI					0.99*	[0.99, 0.999]
$\Delta\chi^2 (df)$	50.62*** (15)		28.73*** (4)		4.76* (1)	

Note. Models include only those observations (8,887 days among $n = 913$ participants) on which eBACs were greater than or equal to .08 g/dl. eBAC = estimated blood alcohol concentration. SI = subjective intoxication. White was the reference ethnicity, and Sunday was the reference day of the week.

*
 $p < .05$.
**
 $p < .01$.

 $p < .001$.