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Personal and Contextual Factors in the Escalation of Driving after Drinking Across the College Years

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Abstract

College students continue to drive after drinking at alarmingly high rates. Age trends suggest that driving after drinking increases from late adolescence across the college years, largely mirroring trends in binge drinking. Relatively little research, however, has examined change over time in driving after drinking among college students or tested whether some students might be at greater risk of escalations in driving after drinking. Using a sample of 1,833 non-abstaining students who completed surveys for 7 semesters across the college years, we tested whether personal (i.e., age of drinking onset, gender, risk perceptions, and sensation seeking) and contextual (i.e., college residence) factors were associated with changes in driving after drinking. Using latent growth curve modeling, we found significant individual differences in rates of change in driving after drinking. Male students and students who began drinking earlier in life increased in driving after drinking more rapidly, whereas living in on-campus housing was associated with time-specific decreases in driving after drinking. These results demonstrate the value of considering driving after drinking from a longitudinal perspective and suggest possible avenues toward preventing the public health consequences of intoxicated driving.

Keywords

Driving after Drinking; Binge Drinking; Age of Drinking Onset; College Students; Latent Growth Curve Modeling

Of the public health consequences tied to college student alcohol consumption, driving after drinking is arguably the most immediately harmful. Approximately 30% of students report driving after consuming alcohol (Hingson, Zha, & Weitzman, 2009; Paschall, 2003; Wechsler, Dowdall, Maenner, Gledhill-Hoyt, & Lee, 1998), with its prevalence increasing from adolescence through the late college years (Beck et al., 2010; Chou et al., 2005; Fromme, Wetherill, & Neal, 2010). These high rates of college student driving after drinking are consistent with epidemiological findings that driving after drinking is most prevalent in early adulthood (Chou et al., 2006; Chou et al., 2005), in addition to evidence that college students drive after drinking more than do their age-peers who do not attend college (Paschall, 2003). The impact of college student driving after drinking is severe. Seventy-four

percent (approximately 1,400 annually) of all alcohol-related student injury deaths result from alcohol-related traffic accidents (Hingson et al., 2009).

In order to reduce the personal and social costs of alcohol consumption, it will therefore be vital to understand why driving after drinking reaches this peak prevalence during the college years. Binge drinking (defined as four or more drinks in a sitting for women and five or more drinks in a sitting for men) is consistently one of the strongest correlates of driving after drinking. Binge drinkers may account for more than 80% of driving after drinking incidents (Flowers et al., 2008; Quinlan et al., 2005), and the prevalence of driving after drinking follows a remarkably similar age-trend to that of binge drinking (Bachman, Wadsworth, O'Malley, & Johnston, 1997; B. F. Grant et al., 2004; Johnston, O'Malley, Bachman, & Schulenberg, 2009). It is important to note, however, that these links reflect person-level correspondences. That is, they show that students who binge drink also drive after drinking, but they do not necessarily imply that individuals are particularly likely to drive after the specific events in which they drink heavily. In fact, a student logistically need not reach the binge drinking criterion to drive after drinking, and prior research has found a relatively weak drinking-event-level association between alcohol use and driving after drinking (Neal & Fromme, 2007). Rather, these associations suggest that individuals who engage in one form of alcohol-related risk-taking (i.e., binge drinking) at one occasion may also be more likely to engage in other forms (e.g., driving after drinking) on that or other occasions (Shope & Bingham, 2002).

Given the behavioral similarity and strong person-level associations between driving after drinking and binge drinking, however, an important etiological issue is whether driving after drinking is influenced by individual difference factors independent of binge drinking. If, for example, rises in college student driving after drinking entirely overlap with concurrent escalations in binge drinking, intervention efforts to reduce the public health costs associated with intoxicated driving might be advised to focus largely on the reduction of drinking among binge drinkers (Quinlan et al., 2005). Alternatively, however, to the extent that driving after drinking is not purely a function of how much a student drinks but is also influenced by other personal factors, targeting binge drinking will not eliminate the public health threat of driving after drinking. Thus, research is needed examining whether additional factors differentiate students who will increase in driving after drinking from those who will not.

Prior research suggests several factors that might distinguish drinkers who drive after drinking. Perhaps the strongest evidence to date concerns age of alcohol use onset. Individuals who begin drinking earlier in childhood or adolescence are at risk for a variety of adverse alcohol-related outcomes, including alcohol use disorders (AUDs; B. F. Grant & Dawson, 1997). In addition, national surveys have found that an earlier age of drinking onset is associated with eventual driving after drinking (Hingson, Heeren, Levenson, Jamanka, & Voas, 2002). Similarly, the age at which youth first reach alcohol intoxication has also been linked to driving after drinking among college students (Hingson, Heeren, Zakocs, Winter, & Wechsler, 2003). Twin studies of the link between age of drinking onset and AUDs show that this association reflects, in large part, a genetically influenced predisposition toward problematic alcohol involvement (J. D. Grant et al., 2005; Prescott & Kendler, 1999; Sartor

et al., 2009). Consistent with these studies, the association between age of onset and driving after drinking might also reflect shared genetic contributions to both rather than any causal influence of early drinking. At least one study using a sibling-comparison design, however, has found an association between age of drinking onset and driving after drinking independent of familial liability to drive after drinking (Lynskey, Bucholz, Madden, & Heath, 2007). This finding suggests a potential environmentally mediated link between early drinking and driving after drinking. Exposure to deviant peers or poor social control, for example, might socialize individuals who begin drinking early toward problematic alcohol-related attitudes and behaviors (Hingson et al., 2002).

Notably, an early onset of alcohol use coincides with the adolescent developmental peak of a range of risk-taking behaviors (Harden & Tucker-Drob, 2011; Steinberg, 2008), and recent research has linked driving after drinking to a number of demographic, social-cognitive, and personality predictors of other risk-taking behaviors. There are robust gender differences in prevalence rates among the U.S. adult population, with men reporting more driving after drinking relative to women (Chou et al., 2006; Quinlan et al., 2005), although these differences have been less consistent among college students (Beck et al., 2010; Fairlie et al., 2010; Harford, Wechsler, & Muthén, 2002; LaBrie, Kenney, Mirza, & Lac, 2011). Further, students who hold higher perceptions of risks associated with intoxicated driving engage in driving after drinking less often (Fairlie et al., 2010; McCarthy, Lynch, & Pedersen, 2007), a finding which has been replicated among adolescents (McCarthy & Pedersen, 2009) and young adults (Bingham, Elliott, & Shope, 2007). Individual differences in adolescent sensation seeking, defined as a preference for novel, rewarding, or exciting stimuli, are final potential predictors of driving after drinking (Jonah, 1997; Zuckerman, 1994). Several studies have found that more sensation-seeking adolescents are more likely to drive after drinking, even controlling for alcohol use (Pedersen & McCarthy, 2008; van Beurden, Zask, Brooks, & Dight, 2005). In sum, an early alcohol use onset, in addition to other predictors of risk-taking behaviors, may help explain why some heavy-drinking college students will escalate in driving after drinking while others will not.

Contextual Factors and Driving after Drinking

An additional consideration in understanding driving after drinking is the crucial role of the context in which drinking occurs (Giancola, Josephs, Parrott, & Duke, 2010). Whether a student drives after leaving a party, for example, is necessarily dependent on whether that student has a car available as a means of transportation that night. More broadly, students will tend to be at greater risk for driving after drinking if they experience stronger pressures to use a car during or following drinking events. In particular, students who live on campus may have access to a variety of nearby social activities, in addition to university resources for transportation, and it may be more difficult (e.g., cost prohibitive) to keep cars on campus. As a result, these students should be less reliant on personal automotive transportation for social events where alcohol use might occur, meaning that they should be at reduced risk of driving after drinking. Consistent with this proposition, students who live on campus drive after drinking less than those who do not, even after controlling for recent binge drinking (Harford et al., 2002). This finding represents a valuable step in identifying a potentially protective role for living on campus, yet it is important to acknowledge that the

association could plausibly be explained by environment selection: The type of student who drives less frequently after drinking may also be more likely to live on campus. Establishing that living on campus exerts a protective causal influence will require further research to rule out this selection account.

The Current Study

In the present investigation, we followed a cohort of 1,833 non-abstaining students across the college years to enable a test of the roles of personal and contextual factors in the collegiate escalation of driving after drinking. We addressed the following specific research questions:

1. How closely are intra-individual increases in driving after drinking associated with concurrent binge drinking trajectories? The strong cross-sectional association, comparable age-trends, and conceptual and logistical relatedness of the two behaviors all suggest that their developmental trajectories would be closely linked.
2. Do personal correlates of driving after drinking (i.e., age of drinking onset, gender, perceived risk, and sensation seeking) differentiate students' rates of escalation in driving after drinking controlling for binge drinking? Given previous literature linking each factor to levels of driving after drinking, we expected that all might predict escalations over time.
3. Is living in on-campus housing associated with time-specific decreases in driving after drinking? Previous research suggests a protective influence (Harford et al., 2002), and our longitudinal, intra-individual approach enabled a stronger test free of confounding by stable individual differences.

Method

Participants and Procedures

The present investigation was drawn from a longitudinal study of alcohol use and other behavioral risks among students in the incoming class of 2004 at a large, public, southwestern university. Of the 6,391 eligible, first-time students between ages 17 – 19, seventy-six percent ($n = 4,832$) expressed interest in the longitudinal study and met the final participation criterion of being unmarried. Interested participants were randomized across 3 conditions: a longitudinal condition in which they completed a precollege survey, 2 assessments per academic year for 3 years, and 1 survey in year 4 ($n = 3,046$); a precollege and year-4 survey condition ($n = 976$); and a year-4 survey only condition ($n = 810$). For further information regarding participant recruitment and other procedures, see Corbin, Vaughan, & Fromme (2008) and Hatzenbuehler, Corbin, and Fromme (2008).

Participants for the current study were taken from the longitudinal condition. Via a secure website (DatStat, Seattle, WA), seventy-four percent ($N = 2,245$) of students randomized to this condition provided informed consent and responded to the precollege survey, which assessed behavior for the final 3 months of high school. After adjusting for the proportion of students randomized to the longitudinal condition used here, the response rate for the precollege survey was approximately 56% (Corbin et al., 2008). The seven Web-based

college surveys, which were included in the present investigation, were administered three weeks prior to the end of the fall and spring semesters through the fall of year 4. They each assessed behaviors for the preceding three months. Participant compensation ranged from \$20 to \$40 across the college surveys, and retention rates were 92%, 90%, 84%, 80%, 75%, 73%, and 69%, respectively. Relative to retained participants, those who did not complete surveys through year 4 were more likely to be male ($h = .24$) and White ($h = .06$) and to have lived off campus during the first semester of college, $h = .14$. These participants also reported lower perceived risk for driving after drinking ($d = .09$) and higher sensation seeking ($d = .19$) prior to college, in addition to higher first-semester binge drinking ($d = .16$) and driving after drinking, $d = .10$. Effect sizes for these differences were all trivial to small in magnitude (Cohen, 1988).

Because alcohol use is a logistically necessary precursor to driving after drinking, our analyses are limited to non-abstaining students ($N = 1,833$). We specifically excluded any students who reported no typical week alcohol consumption across all college assessments for which they provided data. The included sample was 61% female (58% White, 15% Asian, 16% Hispanic/Latino, 3% African-American, 8% multiethnic or other ethnicities).

Measures

Binge drinking—At each college assessment and in the precollege survey, participants reported the total number of times they binge drank during the past three months using the standard definition of binge drinking (i.e., four or more standard drinks in a sitting for women and five or more standard drinks for men). Average college binge drinking frequencies ranged from $M = 3.71$ ($SD = 6.83$) in the fall of year 1 to a peak of $M = 5.46$ ($SD = 7.82$) in the fall of year 4. Rates of binge drinking were lower at the precollege survey, $M = 2.61$, $SD = 5.88$.

Driving after drinking—We assessed driving after drinking with two indicators taken from each college survey. Participants reported how frequently they drove (1) *after having one to three alcoholic beverages* and (2) *after having four or more alcoholic beverages* during the past three months on a scale from 0 = *never* to 6 = *more than 20*. We summed responses to these items to create a single driving after drinking index. The past-3-month prevalence of driving after drinking (at least once) among non-abstainers ranged from 20% in the fall of year 1 to 49% in the fall of year 4. Inter-item correlations were high across all seven college assessments, average $r = .73$. See Table 1 for correlations between driving after drinking and binge drinking at each college assessment.

Campus residence—In each college survey, participants also reported whether they lived in an on-campus dormitory or off campus (e.g., in a private dormitory, apartment, house, or fraternity or sorority house). Although students at this university are not required to live in dormitories during the first year, participants were most likely to live in an on-campus dormitory (70%) during the first semester. Rates decreased across subsequent semesters, 69%, 29%, 28%, 6%, 6%, and 3%, respectively.

Age of drinking onset—Age of drinking onset was assessed at the year-4 survey only. Participants reported the age at which they first took a *drink on [their] own rather than just a sip from an adult's glass, not including drinking as part of religious ceremonies* on a scale from 1 = 9 years old or younger to 8 = 20 years old or older. Similar measures have been used in numerous previous studies to retrospectively assess age of drinking onset (B. F. Grant & Dawson, 1997; Hingson et al., 2002). The average age of onset score was $M = 4.65$ ($SD = 1.82$), meaning that students began drinking at approximately age 17 on average. Of the included participants, 28 (1.5%) reported never having consumed alcohol in response to the age of drinking onset question despite endorsing some typical alcohol use in the college surveys. These participants' age of drinking onset scores were coded as missing. Because age of onset was not assessed until the fall of year 4, responses were available for 67% ($n = 1,219$) of participants.

Perceived risk—In the precollege survey, participants reported their perception of the likelihood of negative outcomes resulting from driving after drinking on a 5-point Likert-type scale where 1 = *not at all likely* and 5 = *very likely*. On average, perceived driving after drinking risk was relatively high, $M = 4.02$, $SD = 1.34$.

Sensation seeking—In the precollege survey, participants also completed a measure of sensation seeking taken from the Zuckerman-Kuhlman Personality Questionnaire (Zuckerman, Kuhlman, Joireman, Teta, & Kraft, 1993). The scale comprises 11 items on a dichotomous scale where 0 = *false* and 1 = *true*. It includes items such as *I like doing things just for the thrill of it*. No items refer to alcohol use or driving after drinking. In the current sample, the sensation-seeking scale demonstrated adequate internal consistency, $\alpha = .73$, $M = 5.78$, $SD = 2.69$. See Table 2 for correlations between personal predictor variables and driving after drinking.

Analytic Approach

We tested our research questions using Latent Growth Curve Modeling (LGM; McArdle & Nesselroade, 2003; Meredith & Tisak, 1990). This modeling strategy permits the examination of mean-level age trends and individual differences in intra-individual change in driving after drinking over time. We analyzed all models in MPlus version 5 (Muthén & Muthén, 1998-2007) using full-information maximum likelihood (FIML) estimation with robust standard errors. FIML has been recommended as the preferred method for accounting for missing data (Schafer & Graham, 2002). It relies on the assumption that all systematic patterns of missing data that relate to the dependent variables in the model can be explained by the independent variables in the model. Under this assumption, known as the Missing at Random assumption, all available data can be analyzed, including that from participants who did not provide data at all time points. We modeled binge drinking and driving after drinking as continuous variables but log-transformed scores prior to analysis to reduce skew and kurtosis (after adding 1 to all scores to permit transformation of zeros). Because the χ^2 test of model fit can be overly sensitive in large samples, we additionally evaluated model fit using the CFI (values greater than .90 indicate good fit) and RMSEA (values less than .05 indicate good fit and values less than .08 indicate adequate fit) (Kline, 2005).

Results

Latent Growth Curve Models of Driving after Drinking and Binge Drinking

We first used LGM to examine intra-individual change over time in driving after drinking and binge drinking. The LGM equation for individual n 's time t driving after drinking score ($Y[t]_n$) is as follows (McArdle & Nesselroade, 2003):

$$Y[t]_n = y_{In} + A[t] \cdot y_{Sn} + e[t]_n.$$

In this equation, the intercept, y_{In} , represents the initial level of driving after drinking (i.e., in the fall of year one), and the change (or slope) score, y_{Sn} , represents the magnitude of change over each time interval. As denoted by the subscript n , the intercept and change scores are both permitted to vary across individuals. $A[t]$ represents the time-specific basis coefficients that specify the shape of change over time (e.g., linear vs. non-linear). Finally, $e[t]_n$ represents each individual's time-specific residuals, or deviations from levels predicted by the LGM. We compared linear LGMs with non-linear, latent basis LGMs in order to determine which trajectory best described change over time in driving after drinking and binge drinking. The non-linear model does not specify a particular trajectory shape. Rather, after setting two basis coefficients to 0 and 1 for scaling purposes, the model estimates the other basis coefficients from the observed data. This approach yields an estimated change trajectory that can closely match the shape of the observed data when growth is not linear. In all models, we set the first basis coefficient to 0, meaning that the intercept represented the level of driving after drinking or binge drinking in the fall of the first year, and set the third basis coefficient to 1, meaning that the change score in the linear model represented the amount of change across 1 calendar year. In the linear model, basis coefficients were adjusted to reflect the differing time lags from fall to spring and spring to fall.

Driving after drinking—The non-linear driving after drinking LGM fit the data better than did the linear model, $\chi^2(18) = 135.73, p < .001$, CFI = .95, RMSEA = .06, Satorra-Bentler scaled $\chi^2(5) = 21.28, p < .001$. As shown in Figure 1, Panel A, the non-linear model demonstrated close fit to the mean-level trajectory of driving after drinking. We therefore selected the non-linear model for all subsequent analyses. In this model, as in the observed data, students increased in driving after drinking across the college years on average, with more dramatic increases in the later years. Moreover, there were significant individual differences in both initial levels of driving after drinking in the fall of the first year and rates of change over time (see Table 3). This variation is illustrated in Figure 2, which displays the model-estimated driving after drinking trajectories of a random subset of 300 students. Additionally, students who drove after drinking more upon entering college increased in driving less across the college years, $r = -.28, p < .001$.

Binge drinking—Similar to the driving after drinking model, the non-linear binge drinking LGM fit the data better than did the linear model, $\chi^2(18) = 199.25, p < .001$, CFI = .96, RMSEA = .08, scaled $\chi^2(5) = 22.70, p < .001$, and the non-linear model approximated the mean-level binge drinking trajectory well (see Figure 1, Panel B). We

therefore again selected the non-linear model for all subsequent analyses. On average, students increased in binge drinking across the college years, although these increases appeared to attenuate by year 4. There were significant individual differences in both initial levels of and changes in binge drinking (see Table 3). Students who binge drank more often upon entering college increased in drinking less across the college years, $r = -.34$, $p < .001$.

Parallel Process Models

Our next analytic step was to combine the binge drinking and driving after drinking models into a parallel process LGM to test how strongly changes in binge drinking were associated with changes in driving after drinking. In the parallel process model, we regressed the driving after drinking and binge drinking change factors onto their respective intercept factors. We also regressed the driving after drinking change factor onto the binge drinking intercept and vice versa. Doing so ensured that any association between change factors would not be confounded by associations with intercepts. See Figure 3 for an illustration of the model. We also permitted time-specific residual covariation between binge drinking and driving after drinking, although for clarity these paths are not shown in the model diagram.

The parallel process LGM fit the data well, $\chi^2(74) = 341.16$, $p < .001$, CFI = .97, RMSEA = .05. As expected, changes in binge drinking were strongly associated with rates of change in driving after drinking (see Figure 4). Similarly, binge drinking in the first semester was strongly associated with initial levels of driving after drinking. Additionally, students who entered college binge drinking more frequently went on to increase in driving after drinking more rapidly. Initial levels of driving after drinking were not associated with changes in binge drinking.

Personal and Contextual Predictors of Driving after Drinking

We next tested whether time-invariant personal (i.e., age of drinking onset, gender, risk perceptions, and sensation seeking) and time-varying contextual (i.e., on-campus residence) variables predicted trajectories of driving after drinking over and beyond binge drinking. We added the explanatory variables—in addition to precollege binge drinking, to ensure that any associations with explanatory variables were not confounded by prior drinking—to the parallel process model described above. Specifically, after re-specifying the covariances between the respective binge drinking and driving after drinking intercept and change factors as regression paths, we regressed all four intercept and change factors onto the personal explanatory variables. These paths tested whether personal variables predicted intercepts and changes in binge drinking and, more importantly, intercepts and changes in driving after drinking *over and beyond* variance shared with trajectories of binge drinking. All personal variables were controlled for gender and were permitted to covary among each other.

Additionally, we regressed the driving after drinking and binge drinking indicators at each college assessment onto time-specific variables reflecting whether or not students lived in on-campus dormitories. These paths tested whether living on campus during a given semester was associated with deviations from the trajectories predicted by the LGM. We also permitted college residence to covary over time. See Figure 5 for an illustration of the

final model with personal and contextual predictors. This final model fit the data well, $\chi^2(243) = 751.76, p < .001$, CFI = .96, RMSEA = .03. Associations among driving after drinking and binge drinking intercept and change factors were comparable in magnitude and significance to those estimated in the initial parallel process model.

Personal predictors—Table 4 displays the associations between personal predictors and latent growth factors. As expected, age of drinking onset and male gender predicted variance in driving after drinking changes that was not shared with trajectories of binge drinking. That is, students who began drinking earlier increased in driving after drinking more rapidly, controlling for first-semester levels of and changes in binge drinking, as did male students. No other variables predicted changes in driving after drinking. There were, however, several associations with initial levels of driving after drinking: Male students and students who perceived driving after drinking as less dangerous drove after drinking more in the fall of the first year.

In addition to these associations with driving after drinking, students who initiated drinking earlier had higher initial levels of binge drinking and greater rates of increase in binge drinking. Further, male students increased in binge drinking more rapidly across the college years, and sensation-seeking students binge drank more during the first semester but increased *less* rapidly over time.

Campus residence—Living in on-campus dormitories was associated with decreases in driving after drinking. Although paths predicting time-specific deviations from expected driving after drinking levels from campus residence could not be constrained to be equal across time without worsening model fit, scaled $\chi^2(6) = 18.54, p = .005$, students living on campus drove after drinking significantly less across all seven semesters, Cohen's *ds* ranging from $-.04$ to $-.09, ps < .05$. That is, a given student drove after drinking less often than would be expected by his or her longitudinal trajectory specifically during the semesters in which he or she lived on campus. In contrast, living on campus was more weakly and inconsistently associated with deviations from predicted levels of binge drinking. Students living on campus binge drank significantly less in the spring of year 2 ($d = -.06, p < .001$) but not during any other semesters, $ps > .10$. Paths predicting binge drinking also could not be constrained to be equal across time, scaled $\chi^2(6) = 23.00, p < .001$.

Discussion

Heavy drinking among college students remains both prevalent and harmful, with driving after drinking accounting for a sizeable proportion of the most severe alcohol-related harms. In the current study, we expanded upon prior work by testing the contributions of binge drinking and other personal and contextual predictors to escalations in driving after drinking across the college years. In doing so, we generated three major conclusions. First, there was a strong link between binge drinking and driving after drinking over time. Replicating prior findings (Beck et al., 2010; Fromme et al., 2010), college students increased on average in both binge drinking and driving after drinking from year one through year four. Moreover,

students who increased more rapidly in binge drinking also increased more intensely in driving after drinking.

This strong association extends prior studies demonstrating a between-persons link between levels of binge drinking and driving after drinking (e.g., Flowers et al., 2008). The present study and others examining associations between driving after drinking and person-level factors such as binge drinking frequency are limited, however, in the information they can provide regarding the event-level timing of driving after drinking. Indeed, considered with prior research showing a weak event-level association between alcohol use and driving after drinking (Neal & Fromme, 2007), the currently findings suggest that these between-persons, longitudinal associations may in part result from common underlying personal or environmental factors—perhaps including those that promote other adolescent externalizing behaviors (Zhang, Wieczorek, Welte, Colder, & Nochajski, 2010)—which might contribute to increases in the frequency of both binge drinking and driving after drinking.

Second, prior longitudinal research on driving after drinking has largely focused on change at the mean level. Building upon these findings, this study found significant individual differences in driving after drinking change across the college years. Some students increased dramatically in driving after drinking, whereas others actually decreased from year one onward. Moreover, we also found several individual-difference predictors of variation in driving after drinking trajectories not shared with binge drinking. Male students and students who initiated alcohol use earlier in youth increased in driving after drinking more rapidly, even when controlling for binge drinking. This result can be interpreted as meaning that gender and age of drinking onset increased in importance as predictors across the later college years, during which mean-level rates of driving after drinking reached their peak.

Both male gender and age of drinking onset are relatively distal to driving after drinking, and the potential causal relations underlying their associations therefore remain unclear. The existing literature does, however, point to several potential mechanisms through which earlier drinking might differentiate those with greater rates of growth in driving after drinking from those with less problematic trajectories. In particular, given the common genetic contributions to age of drinking onset and other alcohol-related outcomes (Prescott & Kendler, 1999), it is possible that the association may reflect shared genetic influences on age of initiation and driving after drinking. An early age of onset has long been linked with the inheritance of a variety of antisocial or externalizing tendencies (Cloninger, Bohman, & Sigvardsson, 1981; Sher & Gotham, 1999; Zucker, 1994), and driving after drinking may be an expression of this broad disposition as well (Bingham et al., 2007; Shope & Bingham, 2002; Zhang et al., 2010). Given evidence that an early age of onset predicts higher levels of driving after drinking independent of family liability (Lynskey et al., 2007), however, this association may also be partially environmentally mediated. Further research using within-family designs is needed to determine the extent to which genetic and environmental pathways explain why earlier drinking may help differentiate drinkers who increase more steeply in collegiate driving after drinking from those who do not.

The other previously identified correlates of driving after drinking and other risk-taking behaviors (i.e., perceived risk and sensation seeking) did not predict changes in driving after

drinking over and beyond changes in binge drinking. Students who perceived driving after drinking as less dangerous were, however, more likely to drive after drinking in the fall of the first year. This association is in concert with previous research showing that perceived risk is associated with levels of driving after drinking (McCarthy et al., 2007). In contrast, precollege sensation seeking did not predict driving after drinking intercept or change factors. Given the association between sensation seeking and initial levels of binge drinking, these results suggest that more sensation-seeking students may drive after drinking more frequently because they binge drink more frequently. That is, in the present sample, the association between sensation seeking and driving after drinking found in prior studies (see Jonah, 1997, for a review) may have been largely mediated by trajectories of binge drinking.

Finally, we also found support that living on campus serves as a contextual protective factor. Extending prior evidence of a negative relation between on-campus residence and driving after drinking (Harford et al., 2002), two aspects of the present study argue against a social-environment selection account for this association (e.g., that students who are less likely to drive after drinking might opt to live on campus). First, the paths linking on-campus residence to reduced driving after drinking in this study represented time-specific, intra-individual decreases in driving after drinking from levels predicted by the LGM, meaning that selection on stable individual differences would be unlikely to produce these associations. Second, there was less evidence for time-specific campus residence effects on binge drinking, suggesting specificity for driving after drinking. Thus, there may be protective aspects of living on campus. Students may find using a car less necessary or more difficult when living on campus, and the ample social events and resources provided on or very near campus may reduce students' motivation to drive to parties or other social activities elsewhere. Future research assessing access to personal automotive transportation among students living on and off campus will help elucidate this potential protective mechanism.

Limitations

The results of this study should be interpreted with an understanding of its methodological constraints and limitations. The included sample was drawn from a single university, limiting the generalizability of the findings presented here in relation to other universities and to the population of emerging adults who do not attend college. Additionally, attrition reduced the number of participants providing data at assessments in the later college years, although our use of FIML enabled the inclusion of all available data.

Our conclusions are also constrained by the measurement of several study variables. Notably, our measure of driving after drinking did not assess driving above the legal intoxication limit for operating a motor vehicle in the U.S. Further, it did not ascertain how quickly driving followed drinking temporally, precluding an assessment of the actual level of impairment reached when driving. Although alcohol-induced impairment of capacities necessary for driving have been demonstrated at levels of intoxication below the legal limit (Schweizer & Vogel-Sprott, 2008), future research should test whether our conclusions generalize to stricter definitions of intoxicated drinking. Further, age of drinking onset was not assessed until the fourth year of college and was therefore unavailable for one-third of

the sample. Concerns about any reduced validity of the drinking onset measure should be considered in light of the fact that age of drinking onset is commonly assessed retrospectively (e.g., B. F. Grant & Dawson, 1998; Hingson et al., 2002) and that, for more than half of participating students, this measure would have been retrospective even had it been included in the precollege survey. Finally, sensation seeking and perceived risk were assessed in late adolescence and modeled as time-invariant covariates. Both personal factors, however, likely change across development (Harden & Tucker-Drob, 2011). Whether these changes correspond with changes in driving after drinking is an important question for future research.

Implications

If the current findings are replicated at other universities, they suggest several avenues toward the prevention of accidents, injuries, and deaths resulting from driving after drinking among college students. At the individual level, men and students who initiate drinking earlier may benefit most from targeted prevention programs early in their college careers. Although the present findings additionally support efforts at the university policy level to amplify the potential protective effects associated with living on campus (e.g., reduced reliance on personal transportation for social activities), we note that the constraints of our non-experimental research design prohibit us from drawing strong causal conclusions. Randomized studies in which incentives for living on campus are increased could provide even stronger evidence that living arrangements influence rates of driving after drinking. Nevertheless, the results of the current study demonstrate that approaching the collegiate escalation of driving after drinking from a developmental change perspective may offer new insights into means of preventing driving after drinking before it exerts its worst effects.

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Figure 1. Observed and estimated mean-level trajectories of driving after drinking (Panel A) and binge drinking (Panel B) across the college years. Assessment semesters ranged from 1 = fall of the first year through 7 = fall of year 4.

Figure 2.

Estimated driving after drinking trajectories of 300 randomly selected students across the college years. Assessment semesters ranged from 1 = fall of the first year through 7 = fall of year 4.

Figure 3.

Path diagram of parallel process latent growth curve model of binge drinking and driving after drinking. Curved paths represent variances and covariances. Time-specific residual variances and covariances between binge drinking and driving after drinking indicators are not shown. Assessment semesters ranged from 1 = fall of the first year through 7 = fall of year 4.

Figure 4.

Associations among intercept and change factors from parallel process latent growth curve model of binge drinking and driving after drinking. Values are correlation and standardized regression coefficients. Curved paths represent variances and covariances. * $p < .05$.

Figure 5.

Path diagram of parallel process latent growth curve model including personal and time-varying campus residence predictors. Variances, covariances among personal predictors and among campus residence indicators, and time-specific residual variances and covariances between driving after drinking and binge drinking are not shown. Assessment semesters ranged from 1 = fall of the first year through 7 = fall of year 4.

Table 1
Zero-Order Correlations between Driving after Drinking and Binge Drinking

Driving after Drinking	Binge Drinking							
	Year 1 fall	Year 1 spring	Year 2 fall	Year 2 spring	Year 3 fall	Year 3 spring	Year 4 fall	
Year 1 fall	.39	.35	.32	.32	.29	.28	.26	
Year 1 spring	.41	.46	.38	.38	.33	.34	.28	
Year 2 fall	.42	.44	.52	.47	.41	.40	.35	
Year 2 spring	.40	.44	.47	.55	.46	.44	.38	
Year 3 fall	.39	.44	.46	.50	.54	.50	.45	
Year 3 spring	.35	.37	.40	.45	.44	.48	.42	
Year 4 fall	.26	.33	.35	.37	.41	.42	.50	

Note. All correlations significant, $p < .05$.

Table 2
Zero-Order Correlations between Driving after Drinking and Individual Difference Predictors

Driving after Drinking	Age of Drinking Onset	Male Gender	Perceived Risk	Sensation Seeking
Year 1 fall	-.22	.11	-.15	.11
Year 1 spring	-.26	.11	-.16	.11
Year 2 fall	-.28	.11	-.13	.12
Year 2 spring	-.28	.10	-.12	.12
Year 3 fall	-.27	.16	-.12	.10
Year 3 spring	-.25	.11	-.11	.11
Year 4 fall	-.22	.13	-.05 ^a	.08

Note. All correlations significant ($p < .05$) unless otherwise noted.

^a $p > .05$.

Table 3
Unstandardized Parameter Estimates from Univariate Latent Growth Curve Models

Parameter	Driving after Drinking	Binge Drinking
	Estimate [95% C.I.]	Estimate [95% C.I.]
Intercept		
Mean	.22 [.20, .25]	.93 [.87, .98]
Variance	.18 [.15, .21]	.86 [.79, .92]
Change		
Mean	.16 [.13, .19]	.13 [.08, .18]
Variance	.06 [.04, .08]	.08 [.03, .13]

Note. Driving after drinking and binge drinking were natural-log transformed prior to analyses. All mean and variance estimates were significantly different from zero, $p < .05$. Time-specific residual variances in driving after drinking, scaled $\chi^2(6) = 129.85$, $p < .001$, and binge drinking, scaled $\chi^2(6) = 17.69$, $p = .007$, could not be constrained to equality across assessments without significantly worsening model fit.

Table 4
Standardized Regression Coefficients Predicting Latent Intercept and Change Factors in
Final Parallel Process LGM

Predictor	Driving after Drinking		Binge Drinking	
	Intercept	Change	Intercept	Change
Precollege binge drinking	.27*	.03	.66*	-.03
Age of drinking onset	-.03	-.09*	-.15*	-.10*
Male gender ^a	.20*	.16*	.08	.20*
Perceived risk	-.10*	.01	.00	.01
Sensation seeking	-.04	.01	.09*	-.07*

^a Because gender was a dichotomous variable, gender effect sizes are presented as Cohen's *d* values (i.e., the standardized mean difference between scores for male and female participants).

* $p < .05$.