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The Temporal "Pulse" of Drinking: Tracking Five Years of Binge Drinking in Emerging Adults

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Abstract

Binge drinking is associated with clinically significant individual-level and public health consequences. The topography of binge drinking may influence the emergence of consequences but studies of topography require a higher level of temporal resolution than is typically available in epidemiological research. To address topography across the five "peak" years of binge drinking (18 to 23 years), we assessed daily binge drinking via successive 90-day Timeline Follow back interviews of 645 young adults (resulting in almost 700,000 data points). Results showed a weekend "pulse" of binge drinking that remained consistent across the entire five year span, with occasional holiday-based perturbations. Two-part latent growth curve (LGC) modeling applied to this dataset showed that the often-observed decrease in drinking associated with "maturing out" was due more to decreased participation in binge drinking occasions, rather than to amounts consumed when drinking (intensity). Similarly, the number of binge drinkers varied by day of the week, but the intensity of binge drinking, for those drinking, varied little by day of the week. This approach also showed distinctive predictors for participation and intensity; baseline expectancies and sociability accounted for individual differences in participation, whereas impulsivity-sensation seeking predicted intensity. Individual patterns of binge drinking participation and intensity also predicted drinking consequences over the 5 years of the study. Given these results, binge drinking patterns may serve as a useful phenotype for future research on pathological drinking.

Keywords

binge drinking; day of the week; development; holidays; Time Line Follow Back

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In 2004, a task force from the National Institute on Alcohol Abuse and Alcoholism (NIAAA) established a blood alcohol concentration (BAC) of 0.08 grams % (a “binge” dose) to be “clearly dangerous for the drinker and for society” (NIAAA, 2004, p. 3). Among the many dangers that become more likely at or beyond this dose include alcohol poisoning, injury to self or others, crime, decreased productivity (Centers for Disease Control [CDC], 2013), and neurocognitive impairment (Zeigler et al., 2005). Relative to all alcohol-related problems, binge drinking is “responsible” for half of the 80,000 estimated deaths, two-thirds of the 2.3 million life years lost, and three-fourths of the $200+ billion economic costs annually. In addition to these hazards, binge drinking is concurrently related to prevalence of alcohol dependence at the population level (Esser et al., 2014), and, when measured in adolescence, has been predictive of later alcohol use disorders (AUDs; Jennison, 2004), and more generalized substance abuse diagnoses (Chassin, Pitts, & Prost, 2002).

Although formal diagnosis typically has been employed to demarcate the point at which the consequences of a behavioral pattern rise to clinical significance, these statistics clearly show that our concerns about the clinical consequences of alcohol use should not be restricted to those cases crossing the threshold for formal diagnosis. In fact, as few as 10% of binge drinkers meet criteria for alcohol dependence (Esser et al., 2014). In recognition of this disparity, the CDC has recommended physician screening and brief counseling for binge drinking (2014), and the United States Department of Health and Human Services (DHHS) has made reduction of binge drinking rates in young adults an objective in the Healthy People 2020 initiative (DHHS, 2011).

Complex interactions among individual and environmental factors are a likely source of both distinct individual patterns as well as emergent population-level patterns of binge drinking. Perhaps one of the most robust population-level patterns has been the temporal pattern day of the week, as revealed in studies of daily drinking over periods from 3 month (s) up to one year (Del Boca, Darkes, Greenbaum & Goldman, 2004; Neighbors et al., 2011). The relevant studies have highlighted weekends as much more common occasions for drinking than weekdays (Del Boca et al., 2004; Neighbors et al., 2011), irrespective of individual drinking patterns, personality characteristics, and demographics (Hoeppner et al., 2012). Other temporal drinking patterns were reflected in calendar events such as Halloween, New Year's Day, and Spring Break (for college students), which occur on a more intermittent basis. Such events, along with local holidays, have been shown to be markers of dramatically increased drinking relative to non-holiday weeks (Del Boca et al., 2004; Goldman, Greenbaum, Darkes, Brandon,& Del Boca, 2011) or typical (non-holiday) Saturdays (Neighbors et al., 2011).

Also of interest to binge drinking researchers is intensity. Binge drinking intensity is the degree to which BAC levels exceed the 0.08 grams % defined as the cutoff for binge drinking. Intensity is important because heavier binge drinking has been shown to increase binge-associated harm (Esser, Kanny, Brewer, & Naimi, 2012). Analytic techniques that independently modeled frequency and intensity values as separate distributions within the same analysis have demonstrated that the increased percentage of drinkers on high-prevalence drinking occasions (e.g., weekends and holidays) could obscure drinking

intensity in traditional statistical models (i.e., apparent increases in mean quantity as an artifact of fewer zero values; Gillespie, Lubke, Gardner, Neale, & Kendler, 2012; Walls, Fairlie, & Wood, 2009). Such modeling has revealed certain holidays (such as Thanks giving) in which the number of drinkers increased, but the intensity did not (Goldman et al., 2011).

Research focused on developmental changes in binge drinking across youth and young adulthood has revealed increases in binge drinking rates throughout adolescence, with rates peaking in the late teens and early twenties and then diminishing toward the mid-twenties ("maturing-out;" SAMHSA, 2012; Lee, Chassin, & Villalta, 2013). Like binge drinking frequency, binge drinking intensity (greatest BAC) is greatest during the late adolescent/emerging adulthood developmental period (CDC, 2013). When observed across this age group, changes in drinking patterns may be partially explained by individual factors such as alcohol expectancies (Del Boca et al., 2004), personality characteristics (Littlefield, Vergés, Wood, & Sher, 2012), or other psychosocial characteristics (Chassin et al., 2002; Wechsler, Dowdall, Davenport, & Castillo, 1995).

The present study was designed to re-examine the relationships described above at a relatively higher level of temporal resolution than explored in previous work, including at the level of daily drinking, and to carry out this more focused re-examination across the developmentally-relevant time frame of late adolescence through emerging adulthood (Arnett, 1992). This time frame is noteworthy because it captures the peak of drinking that previously has been observed at the population level using coarser estimates of drinking. The fine-grained reports on the topography of drinking over this extended developmental period were intended to contribute to the understanding of the contextual processes that influence drinking trajectories across this important time of life. In addition, the application of two-part modeling to this fine-grained data might help disaggregate the antecedents and consequences of binge drinking frequency from intensity over this 5-year period.

Toward this end, self-reports of daily drinking were used in this study to ascertain temporal, developmental, and individual binge-drinking patterns and their moderators across five years beginning at age 18 or 19. To further refine the assessment strategy, BAC estimates, rather than numbers of drinks, were used to define binge drinking (e.g., Neighbors et al., 2011). Most prior binge drinking studies have used a dichotomous measure based on gender-specific quantity per episode (e.g., Wechsler, Dowdall, Davenport, & Rimm, 1995). Although such approximations typically account for the key variables of quantity (number of standard drinks), and gender (males clear alcohol faster than females), they do not account for body weight or the number of hours constituting a drinking event. Additionally, the use of a binary threshold versus a continuous measure would preclude identifying individuals' binge drinking intensity (the magnitude of binge drinking exceeding a BAC of 0.08 grams %). To allow for the testing of complex prediction models of fine-grained drinking data, we also collected measures of possible moderators of drinking identified in prior work. These predictors were evaluated in the context of two-part latent growth curve (LGC) modeling, which permitted independent prediction of the probability of an individual engaging in a binge drinking episode and the intensity whenever binge drinking occurred.

Finally, binge drinking patterns were tested as predictors of clinically relevant drinking consequences independent of alcohol use disorder diagnosis.

Method

Participants

Six hundred and forty-five 18-19 year olds were recruited from the Tampa Bay area to participate in a longitudinal naturalistic study of young adult behavior. Participants were recruited if they reported drinking alcohol at least once per month. The sample was diverse, with demographic characteristics consistent with the Tampa Bay population (50% female; 60% non-Hispanic white, 21% Hispanic, 13% African American, 6% other).

Planned stratification produced participants who were nearly equally split between college students (48%; from multiple colleges in the area) and non-students (52%). College status was determined at baseline by full-time (9 or more college credits at the time of recruitment) enrollment, a conceptualization consistent with several studies (Barnes et al., 1992; O'Malley and Johnston, 2002; White et al., 2005). This distinction recognizes that full-time students may be more engaged in, and exposed to, academic pursuits than part-time equivalents (Carter, Brandon, & Goldman, 2010).

Missingness

The ongoing record of drinking across the five years represented, on average, the detailed reports of drinking for 382 participants (almost 60%) per day. Although the assessment schedule was rigorous for participants, 32% of participants completed 90% (18 out of 20) or more of their assessments, 50% completed 70% (14 out of 20) or more, and 78% completed more than half of their assessments. Our first pass at addressing potential problem of missingness involved excluding from analyses individuals who failed to participate beyond the baseline interview (n = 54; early in the study such individuals were replaced). To reassure ourselves that the loss of these individuals did not introduce any systematic bias in the sample, we compared these early attriters with those who remained in the study. These comparisons yielded no significant differences on gender or family history (ps > .28), but those who were lost to attrition were more likely not to be a college student (p< .001). To further refine our attrition check, therefore, noncollege students who dropped from the study then were compared with college students who remained in the study using the Wilcoxon rank sum test for continuous variables (e.g., personality characteristics and alcohol expectancies) and chi square for categorical variables (gender and family history). Because no statistically significant differences were observed between these two categories, it was unlikely that our final sample carried with it unintended distortions.

A more critical strategic decision for obtaining high-density information from this age group was to tolerate the absence of an individual from any particular assessment (i.e., missingness), as long as that individual remained with the study and completed other assessments over the full extended time period (i.e., keeping attrition to a minimum). This decision was predicated on modern statistical analyses for missingness. So, the data presented herein reflects some degree of missingness (Missing At Random [MAR]; see later

statistical analysis), but minimal attrition (less than 8%). Attrition was defined as participants who left the study at any point in the 5 years and provided no more drinking data. That is, although many participants completed less than the full set of assessments, most participants remained through the end of the study, and provided data on a large percentage of the days (*Mdn*=78%) for which they were enrolled.

Measures

Blood Alcohol Concentration—BAC was calculated from data collected as part of a Timeline-Follow back interview (Sobell and Sobell, 1992) using a Widmark-based formula established by the National Highway Traffic Safety Administration (1994). Key variables entered into the formula were number of standard drinks consumed, body weight, sex, and the number of hours[1] the drinking episode lasted. Body weight was assessed via physician's beam scale in the laboratory on an annual basis. Because drinking data was synchronized with calendar date, and body weight was not (it could have been measured at any calendar date), the body weight used to calculate BAC was the average weight across the participant's duration in the study; *M*(*SD*) = 161.66 lbs. (40.97), range = 93.50 to 376.67. In addition to allowing for a defined binge drinking intensity (0.08 grams %, established by NIAAA, 2004), estimating BAC in this way controlled for body weight, gender, and duration of a drinking episode. BAC was calculated for each participant for every day of his or her participation in the study.

Potential Moderators—The following antecedent factors were tested as moderators (covariates) of binge drinking rates: sex, college status at baseline, family history, personality characteristics, and alcohol expectancies at study entry. Each of these had been identified as moderators of drinking in previous studies. Participants were considered positive for family history of an Alcohol Use Disorder (AUD) if one or both of their biological parents had an AUD. This information was obtained from the Family History Assessment (taken from the Collaborative Study on the Genetics of Alcoholism, COGA; Rice et al., 1995).

The Zuckerman-Kuhlman Personality Questionnaire (ZKPQ; Zuckerman & Kuhlman, 1993) was used to assess multiple personality dimensions. Scores taken from the ZKPQ included Impulsivity-Sensation Seeking (with alcohol items removed), Sociability, Aggression-Hostility, Neuroticism-Anxiety, and Activity. Example items include, *I often do things on impulse* (Impulsivity-Sensation Seeking), *I never met a person I didn't like* (Sociability), *When I get mad, I say ugly things* (Aggression-Hostility), *I sometimes feel edgy and tense* (Neuroticism-Anxiety), and *I do not like to waste time just sitting around and relaxing* (Activity). This measure has demonstrated adequate internal consistency (α's for subscales ranging from .64 to .85; Gomà-i-Freixanet, Valero, Muro, & Albiol, 2008); the scale evidenced similar internal consistency in our sample (for all scales, α = .80).

Alcohol expectancies were computed as the total score from the 68-item Alcohol Expectancy Questionnaire (AEQ; Brown, Christiansen, & Goldman, 1987; Goldman,

[1]Due to data collection inconsistencies early in the study, a small portion (< 10%) of drinking data did not include the time span (hours) of a drinking episode.

Greenbaum, & Darkes, 1997). This measure has demonstrated adequate internal consistency (Rubio, Bucholz, Neuman, & Rauch, 2003); and had good internal consistency in our sample (α = .93).

Consequences of Alcohol Use—The Alcohol Experiences Form (AEF) used questions from widely used instruments tailored for our research program to assess: history of drinking (e.g., age of first use), typical patterns of alcohol use, consumption under risky circumstances (e.g., drinking in settings that may promote risky sexual activity), perceptions of peer and significant other alcohol use, and perceived harmfulness of drinking at different levels (e.g., regularly, to intoxication), and drinking consequences. These consequences included: Unhappiness, Physical health; Family relationships; Friendships; Accidents; Taken advantage of sexually; Took advantage of someone else sexually. Participants were considered to have experienced a consequence if they endorsed the consequence at any of the annual or quarterly assessments throughout the 5 years of the study. Internal consistency of these items was good (Cronbach's α = .70).

Indicators of AUD—The Semi-Structured Assessment for the Genetics of Alcoholism (SSAGA; Bucholz et al., 1994) originally was designed to permit diagnosis across multiple diagnostic schemes including DSM IIIR, and DSM IV, and so included a wide variety of typical diagnostic indicators. Even for DSM V (American Psychiatric Association, 2013), released after our study began, the SSAGA assesses 10 out of the 11 symptoms used to diagnose an AUD (only “craving” is not captured). Hence, the SSAGA indicators permitted us to closely approximate DSM V diagnosis by categorizing participants as having an AUD if they endorsed at least 2 of these symptoms. Although the absence of the single craving symptom created the potential for a slight underestimate of DSM V diagnosis, for the present exploratory purposes, the 10 SSAGA indicators were sufficient. The SSAGA interview was conducted at annual assessments, providing the possibility of a diagnosis for each year of the study.

Procedure

Data were collected over a five-year period, with drinking assessed for every calendar day [via a modified Timeline-Follow back interview over 90-day intervals (TLFB, Sobell & Sobell, 1992)] at three-month increments (see Goldman et al. 2011 for an earlier report). Recruitment for the study lasted approximately 18 months, leading to an overall data span of greater than five years; from 90-days before the study's inception, July 23, 2003, until the last day of the study, November 2, 2009. Each participant's five-year tenure in the study fell within these bounds. Five complete calendar years that fell within the full data collection period of this study (2004-2008) were selected for analyses. Data from 2003 (during recruitment) and from 2009 (as the study was nearing completion) were excluded due to limited sample size (< 200 participants). Because five complete calendar years were examined, data for holidays were repeated five times, providing data for the same holiday on different days of the week across calendar years (except for holidays like Thanksgiving, which are defined by a specific day of the week). For example, Halloween, 2004 was on a Sunday, then Monday, Tuesday, Wednesday, and Friday, in 2005, 2006, 2007, and 2008, respectively. Within the 2004-2008 time period, the number of individuals at each time point

ranged from 159 on January 1, 2004 to 557 on April 19, 2005. The varying *n* between calendar days was due to incomplete recruitment (early in the study period), missed assessments (as discussed earlier), 8% attrition, and the increasing number of participants who had completed five years of data collection toward the end of the total six year, three month, data collection period.

Data Analysis

Descriptives—Daily drinking data was summarized by creating percentages of the number of abstainers, the number of drinkers with BAC < 0.08 grams % (binge criteria), and the number of drinkers with BAC ≥ 0.08 grams %. When graphed, these percentages illustrated weekly waves of drinking. For these waves, period and amplitude of the waves were calculated. BAC also was characterized continuously and described using the median BAC for each day to assess the degree to which typical drinking exceeded the binge threshold (intensity).

Growth Curve Analyses—To assess the longitudinal change of both the percentage of binge drinkers and binge drinking intensity (BAC level in excess of 0.08 grams %), we used two-part LGC modeling (Muthén, 2001). This approach was chosen because of the semi-continuous distribution of binge drinking which contained an excessive number of non-binge events (i.e., we were interested in the percentage of participants who were drinking at levels equal to or exceeding BAC=0.08 grams %, and for those who did, to what extent BAC exceeded 0.08 grams %). Typically, two-part LGC approaches separate zero (non-binge) values from values greater than zero. Because we were interested in binge drinking specifically, rather than any drinking, zero values were given to BACs < 0.08 grams %.

To reduce model intractability due to the large number of drinking days (1,827), TLFB data were aggregated into 65 four-week estimates. The aggregating factor consisted of the peak BAC across the four week period. Peak BAC, rather than mean BAC, was chosen as a more accurate indicator of binge drinking intensity and prevalence across each four-week period. As an illustration of why *peak* was chosen rather the *mean*: a participant who drank to a 0.20 BAC (2.5 times the binge cutoff) on every Friday during the period, but did not drink on any other day, would have *averaged* 0.03 BAC and not been considered a binge drinker during that period. Using the peak BAC as the estimate during that period would identify that individual as a binge drinker with a relatively high intensity.

Although BAC data were skewed and kurtotic (4-week peak BAC> 5.0 on both skew and kurtosis), concerns about transformations' effects on our growth curve estimates directed our decision not to transform the data. Rather, we used Maximum Likelihood Robust (MLR) estimation which was developed for continuous variables with non-normal distributions. A series of unconditional growth models were fit to the data to select the form of the individual growth curve trajectories. Intercept (initial level of scores), slope (linear change), quadratic (non-linear change), and cubic (non-linear change) parameters were fit separately for the categorical and continuous data. Because initial level and change often are correlated, models included regression of the intercept on slope to statistically control for this

correlation. Both fixed and random estimates of the growth factor means and variances were tested. The model with the lowest Bayesian Information Criterion (BIC) was selected.

After selecting the linear growth model as the best fitting unconditional model, the model was expanded to include predictors of the growth parameters (i.e., sex, college status at baseline, family history, alcohol expectancies (AEQ), personality (ZKPQ scales), and study completion [to account for the effects of attrition]). Each predictor was first tested in a univariate model. Predictors with *p* values less than .01 were combined in a multivariate model. Model estimation was conducted in Mplusv. 7.1 (Muthén & Muthén, 1998-2013) using full information maximum likelihood estimation (FIML) to benefit from all available information in the data. That is, participants with missing information were included in the analyses under the assumption of missing at random (MAR, i.e., missingness conditional on observed variables).

Relationship Between Binge Drinking and Drinking Consequences—Binary logistic regression was used to examine whether information on binge drinking patterns was related to drinking consequences. The individual slope and intercept parameters (estimated from the LGC model) were used to predict whether drinking consequences had occurred over the five years of assessment. AUD diagnosis at baseline was entered as a covariate into statistically significant models to determine if binge drinking patterns provided independent prediction of drinking consequences.

Results

Because the graphed drinking records from this study were so informative in their own right, we first show these graphs in Figures 1-3. Given the richness of information in these figures, we describe at some length below what each figure depicted. We then move into statistical analysis of these longitudinal patterns using two-part growth modeling.

Collective Temporal Contingencies

Over the five years of drinking described in this study, 698,726 drinking data points were collected. These data represent drinking as reported by each participant for each day of the study (minus missing participant-days). For display purposes, these records were broken down into half-year segments in Figures 1.1 and 1.2. Each segment shows the percentage of individuals who were not drinking at all on any given day, the percentage who were drinking at less than a binge drinking level, and the percentage who were at or above the binge drinking threshold (summing to 100% of participants available for each study-day).

Examination of these figures reveals the periodicity of the daily drinking records (the period, often used to describe wave data, is the number of time units per wave). A drinking wave period of seven days (a standard calendar week) was evident across the entire span of the 1,827 days presented. The highest percentage of individuals for all drinking days were non-drinkers, with the percentage of non-drinkers approaching 100% for Sundays through Thursdays on most weeks. Toward the latter part of each week, though, the percentage of non-drinkers diminished, as many individuals moved into the drinker category. Evident from the pulsating records, those individuals who were included in the drinker categories were

more likely to represent a binge episode than a lighter drinking episode. Starting low on Sundays (*Mdn*=3%), the percentage of binge drinkers slowly escalated throughout the week until acceleration on Thursday (7%) and Friday (11%) peaked on Saturday (14%)(Figure 2). A smaller percentage shifted into drinking levels that fell below the binge cutoff. Because binge drinking tended to exceed non-binge drinking across all five years of the study even as the participants aged upwards, it appeared that they continued the binge-intensity drinking as they aged. Furthermore, and consistent with the work of White, Kraus, and Swartzwelder (2006), binge drinking demonstrably exceeded the binge threshold. Median binge drinking intensities among binge drinkers across the duration of the study (BAC = 0.12 grams %) were about 50% greater than the binge cutoff (Figure 2). These BAC levels varied little by day of the week.

Occasionally, the regular weekly rhythm of periods and peaks was perturbed by out-of-sequence (weekday) or amplified weekend peaks. These peaks occurred on consistent dates throughout the five years reported. Close examination of the specific calendar dates of these peaks in variably revealed them to be holidays/special events of some kind. Holidays evident in the drinking waves included Valentine's Day, Spring Break, St. Patrick's Day, Cinco de Mayo, Memorial Day, Independence Day, Labor Day, Halloween, Thanks giving, Christmas, and New Year's Eve (in calendar sequence). Holiday peaks were particularly steep when the holiday coincided with a weekend. Examples included New Year's Eve 2005, Saint Patrick's Day 2006 and 2007, Cinco de Mayo 2006 and 2007, and Halloween 2008. For a very few holidays, non-binge drinking was consistently more likely than binge drinking (Thanksgiving and Christmas).

Developmental Trends Across Five Years from 2003-2008

Also visually apparent in the figures was a decrease in the percentage of binge drinkers participating in each weekly pulse as participants aged throughout the study. Weekly binge drinking can be seen to regularly peak at close to 20% of participants on Saturdays in 2004 and 2005, when participants were 18-20 years of age. By 2008, when participants were aged 22-23, Saturday binge peaks appeared consistently confined to only about 10% of the sample. Holiday peaks also appear larger in 2004 and 2005 than in 2008. Notably, the figures consistently show New Year's Eve to be by far the greatest bingeing holiday. Binge rates approached or exceeded 50% of the sample for each year except 2008, when participants were oldest (another reason for this lower rate of binge drinking was that, in this particular year, this holiday fell on a Monday). New Year's Eve also was the only holiday in which the percentage of binge drinkers exceeded the percentage that remained abstinent. This crossover was observed in every year except 2008.

Individual Patterns

The pulsating weekly pattern seen in Figures 1.1 and 1.2 emerged from the collective drinking of all participants across the five years of the study. Within this collective pattern individual differences were evident.

To illustrate (a few) individual drinking patterns, the daily drinking data of four individuals (two frequent binge drinkers and two infrequent binge drinkers; all family history-negative

males) were charted for the year 2005 (again, the yearly records are split into two parts for display purposes). These data, presented in Figures 3.1 and 3.2, were chosen qualitatively because they represented polarized exemplars of how drinking was individualized for each person. For example, drinking occurred in regular weekly patterns on multiple weekend days (Frequent Drinker 1); or binging occurred in spindles of activity throughout the year (Frequent Drinker 2). Drinking also occurred in the form of sporadic binge or non-binge (Infrequent Drinker 2) or exclusively non-binge (Infrequent Drinker 1) activity. Predictors of individual patterns are statistically examined below.

Application of Growth Curve Models to 5-year Changes in Binge Drinking

As noted earlier, the apparent decline in binge drinking seen across the five years in Figures 1.1 and 1.2 was statistically evaluated using two-part LGC models. These models simultaneously examined, across calendar years, the percentage of binge drinkers (categorical) and the intensity of binge drinking (continuous). Four main parameters were estimated from these models: (a) the percentage of binge drinkers in our sample over the prior 4-weeks at baseline (categorical intercept);(b) the change in this percentage for each 4-week period over the time of the study (categorical slope); (c) the maximum intensity over the prior 4-weeks (peak BAC) at baseline (continuous intercept); and (d) the change in 4-week maximum intensity over the time of the study (continuous slope).

Categorical analysis (percentage of drinkers on given days)—The categorical portion of the two part analysis estimated the percentage of binge drinkers over the prior 4-weeks to be 58% at baseline. Across the study span, a decrease in the percentage of binge drinkers was observed (the slope revealed a 0.19% decrease every 4 weeks [*SE*=0.003]; $p<0.001$). At the 5-year (65^{th}) time point, the model estimate of the percentage of binge drinkers was 42%. Observed and model estimated percentages of 4-week binge drinkers are presented in Figure 4.

Continuous analysis (drinking intensity)—For continuous data in the two-part modeling process, no significant changes in slope were observed across the five years of the study. That is, although fewer individuals participated in binge-drinking occasions toward the end of the study, they tended to maintain the same drinking intensity whenever they did drink across the five years. The 4-week peak BAC during binge episodes (intercept) was 0.19 (*SE*= 0.003; $p<.001$). Again, these values did not decrease significantly over the course of the study. To rule out the possibility that the non-significant slope was a byproduct of eliminating BAC levels below the binge cutoff (0.08 grams %) from the two-part models (i.e., resulting in range restriction), we also analyzed the slope of BAC data with non-binge BACs included. The slope with all drinkers included remained non-significant ($p=.13$).

Individual differences (in antecedent factors) predicting growth parameters in drinking—Statistical examination of the variances in all growth parameters tested in the LGCs supported the individual variability in drinking patterns suggested descriptively in Figures 3.1 and 3.2. The statistically significant variances ($p<.001$) found in all of the growth parameters indicated that reliable individual differences were present in both participants' binge drinking at the beginning of the study and in the rate of decline in

participation in binge drinking episodes. As planned (see Methods), demographic, personality, and alcohol expectancy factors assessed at study entry were tested as possible predictors (covariates) of these differences. That is, we tested whether these individual difference characteristics might predict the extent of variation observed in the intercept and slope of the binge drinking participation levels. After combining any statistically significant univariate factors into a single multivariate model, the following pattern emerged: AEQ-measured total alcohol expectancies (b=2.60; SE=0.45; p<.001), and ZKPQ-measured sociability (b=1.51; SE=0.42; p<.001), both assessed at study entry, were the most robust predictors of 4-week binge drinking *participation* (categorical intercept). That is, the extent to which individuals held expectations of positive effects from alcohol, and were social in nature, predicted participation in drinking (understandable because most drinking occurred in group situations). Although statistically significant as univariate predictors, ZKPQ-measured impulsivity-sensation seeking and aggression-hostility, did not remain statistically significant when included in the multivariate model (see Table 1).

In contrast, ZKPQ-measured impulsivity-sensation seeking assessed at study entry was the only covariate that significantly predicted binge drinking *intensity* (continuous intercept) (b=0.24; SE=0.01; p=.001). Not surprisingly, individuals who characteristically seek exciting outcomes drank more. Demographic factors (e.g., gender, student status) did not significantly contribute to any of the categorical parameters in the models. None of the assessed factors accounted for change in binge drinking participation over time (slopes) in the 2-part analyses. Although we do not report on changes in life context here, we might anticipate that these kinds of changes were most associated with changes in binge drinking participation over time.

Individual growth parameters (in drinking) predicting Drinking Consequences—After examining the relationship of early antecedents to later drinking, we evaluated the effects of drinking on later consequences. Of the drinking consequences measured in this study, Unhappiness was reported most prevalently (64%). Harm to physical health (39%); Harm to friendship (33%); Being taken advantage of sexually (26%); Harm to family (21%); Having had an accident (20%); and Taking advantage of someone else sexually (14%); followed in prevalence. Individual growth parameters (categorical intercept and slope estimated from LGC model) were used to predict 5-year prevalence of these consequences using binary logistic regression. The binge drinking intercepts (likelihood of binge drinking at baseline and peak 4-week BAC [intensity] at baseline), but not slopes, emerged as statistically significant predictors of consequences. Binge drinking likelihood was a predictor of 6 out of 7 of the consequences tested (Odds Ratios ranged between 1.11 and 1.40; p<.05; see Table 2); binge drinking likelihood did not significantly predict Taking Advantage of Someone Else Sexually. Binge drinking intensity (peak 4-week BAC) was a statistically significant predictor of all 7 drinking consequences (Odds Ratios ranged between 5.60 and 17.65; p<.05; see Table 2). When Time 1 AUD was entered as a covariate into the logistic regression models (to control for entry point AUDs), both AUD and binge drinking intensity remained statistically significant predictors (p<.05) in all models except Being Taken Advantage of Sexually, and Taking Advantage of Someone Else Sexually,

where only AUD was a statistically significant predictor. Binge drinking likelihood remained a statistically significant predictor in the model predicting Physical Harm ($p<.05$).

Discussion

The nearly 700,000 drinking data points collected for this study across the years 2004-2008 represent (to our knowledge) the longest time frame over which daily drinking assessments have been reported. By applying two-part modeling to this detailed database, we were able to separate binge participation rate from intensity (level of consumption above the binge threshold) over an important developmental period. (Commonly used measures such as quantity/frequency and frequency of binge drinking do not provide information on dose at each binge-drinking occasion). This separation showed for the first time that the well-known population-level decrease in drinking in early adulthood ("maturing-out") was due to decreasing *participation* in binge-drinking, rather than to diminished binge drinking *intensity*. This more fine-grained analysis did confirm, however, the rates and decline of binge drinking participation observed in studies taking broader brush (e.g., yearly) approaches (SAMHSA, 2012; CDC, 2013). Lee et al. (2013) found that when frequent binge drinkers reduced their drinking with age, they typically transitioned into less frequent binge patterns, but not patterns of abstinence or low-risk drinking. Such a result is explicated by the binge participation/binge intensity dichotomy observed here, where binge frequency, but not intensity, decreased with age. Particularly alarming was the observation that 4-week peak intensity levels began, and remained across the entire 5 years, more than double (> 0.19 grams %) the binge drinking threshold. This observation is important because, consistent with these results, previous work (Esser et al., 2012) has shown that binge drinking intensity is linked to increased drinking related harms, in some cases quite severe.

The two-part latent growth curve approach also allowed us for the first time to evaluate covariates of binge drinking participation and intensity independently; that is, we were able to show that different antecedent characteristics predicted different aspects of binge drinking. Specifically, binge drinking participation was predicted by alcohol expectancies and sociability measured at study entry. In contrast, binge-drinking intensity was predicted by impulsivity-sensation seeking. It appears that, although expectations for rewarding effects from alcohol use and sociability induce individuals to engage (participate) in a binge-drinking episode, their self-dosing regime seems influenced more by their characteristic level of impulsivity and sensation seeking. Perhaps prevention/intervention efforts might be usefully tailored to address these antecedents separately.

It is important to note that substantial adverse consequences of a kind that might trigger clinical interventions were predicted by binge drinking participation and intensity. These consequences included the likelihood of becoming unhappy, experiencing physical harm, or having an accident while drinking. In particular, binge-drinking intensity remained a statistically significant predictor for most of the studied consequences even after including Time 1 AUD in logistic regression models. As recently suggested, binge drinking and AUD are not necessarily overlapping phenotypes (Esser et al., 2014). It is increasingly evident that binge-drinking as a phenotype should receive clinical attention in its own right, independent of AUD diagnosis.

Temporal Patterns

The weekly “pulsing” of drinking in young adults, waxing during the weekend's approach and waning as it passed, was observed with remarkable consistency over the years of emerging adulthood. Unlike sleep (circadian), the menstrual cycle (circa-lunar), or calorie intake (circa-annual), no human research has uncovered circa-weekly rhythms that would provide a biological mechanism for this effect. Seemingly, this weekly pattern was purely the result of external contingencies that pertained to cultural practices and perhaps based on a kind of implicit “agreement” made among youthful drinkers as to when a community of drinkers would form. Although high-participation binge drinking occasions typically fell on Friday and Saturday (and sometimes Thursday) and appeared synchronized with school and work schedules, they could be shifted periodically. Some holidays, such as Independence Day, Halloween, and New Year's Eve, on years they occurred on weekdays, were illustrative of such shifts. If the holidays were in “phase” with the typical weekend drinking pattern, drinking peaks were notably amplified, especially for holidays not associated with days off from school or work (e.g., Cinco de Mayo and Halloween). Because of the high resolution of the current data (daily observations), even holidays with small perturbations of the weekly drinking rhythm could be observed. These holidays included Memorial Day, Labor Day, and Valentine's Day. With the exception of Valentine's Day, Thanksgiving and Christmas, drinking peaks always were characterized by a greater percentage of binge than non-binge drinkers. The greater binge drinking than non-binge drinking observed in these holidays and most other days of the study is consistent with previous epidemiological studies (e.g., SAMSHA, 2012), demonstrating that binge drinking is the modal style of drinking in this age group.

Individual Differences

The incessant pulse of weekly binge drinking characterized the alcohol consumption patterns of the entire sample, but individual variability in binge drinking frequency was observed in all binge drinking parameters. Two other indicators of individual differences in binge drinking patterns were the qualitatively different plots of selected individuals, and the observation that 4-week binge percentages were greater than most daily estimates, indicating that the constituency of binge drinkers differed each day. These results were consistent with a study by Schulenberg, O'Malley, Bachman, Wadworth, and Johnston (1996), which demonstrated different subtypes of binge drinking frequency across a similar age range. Future studies using mixture modeling-type approaches can be used to determine if the individual patterns inferred from this dataset fall into reliable classes.

Variability in binge drinking was not accounted for by gender or college status. That is, both males and females, and young adults both in, and out of, college showed similar rates of participation and intensity in drinking occasions. The lack of gender effect was likely the result of using a BAC estimate that accounted for gender. The lack of a student effect was somewhat surprising because previous studies have generally shown college students to drink more heavily than their non-college peers (e.g., White et al., 2005). Although these effects may be the result of other factors such as where the participant lived (e.g., with or without family; Carter et al., 2010), students moving into and out of student status across the five years of the study also may have obscured student status effects.

Instead, variability in the rate of participation in binge drinking occasions was partially accounted for by personality characteristics and positive alcohol expectancies. As noted earlier, and consistent with previous research, participants who began the study with greater positive expectancies or sociability were more likely to be binge drinkers than those who started lower on these characteristics.

None of the measured participant factors was related to the rate of change (slope) in binge drinking over time. The rate of change also was not related to consequences of drinking. Although visually apparent and statistically significant, it is important to keep in mind that the 5-year slope in this study which dropped binge prevalence by about 3.2% each year starting at age 18 was paltry compared to the ascending slope during the 5 years leading up to age 18. Epidemiological studies have shown this slope to be at least 3 times greater, starting from less than 5% prevalence at age 13 (e.g., SAMSHA, 2012). It is likely that prediction of risky drinking and risky consequences would be stronger by using this ascending slope or, as captured in this study, the peak of the adolescent-adult drinking trajectory.

Regarding the descending slope observed in this study: It may be possible that these declines are entirely a function of changing external contingencies (i.e., life circumstances/ transitions) as individuals age (e.g., assumption of familial roles; Vergés et al., 2012). In the present context, the best predictor of this decrease simply seemed to be maturation/ development, which might be manifesting itself either in the form of changes within the individual, or in terms of changing life demands. In addition, the use of age as a proxy for development always is imperfect because neither neurobiological maturation, nor specific life demands, has a one to one correspondence with age. For example, neurobiological maturation has been shown to play a key role in decision making (Blakemore & Robbins, 2012), but is only loosely related to age.

Study Limitations

As with any longitudinal observational study, a potential concern was biased data due to selective attrition. The use of Mplus v. 7.1 (Muthén & Muthén, 1998-2013) full information maximum likelihood estimation (FIML) under the missing at random (MAR) assumption, along with an attrition analysis, reduce these concerns, however. Very little difference was found between completers and non-completers. Although student status was the single variable found to differ between these two groups, no influence of student status was observed on any component of the statistical models of binge drinking over time when entered as a covariate (please see caveats to the lack of student status effects mentioned above).

For three reasons, population-level estimates of binge drinking frequency may have been somewhat imprecise: First, because we were interested in studying patterns of binge drinking, we targeted only individuals who were fairly regular drinkers. Another potential source of bias in the BAC estimates came from the method of reporting drinking. Previous work has suggested that BAC levels may be overestimated when comparing BACs estimated with the modified Widmark formula vs. direct assessments with a Breathalyzer because of misconceptions about alcohol content in drinks (Kraus et al. 2005). A final

source of potential bias in BAC estimates came from body weight. Average 5-year body weight was used to calculate BAC. Because body weight tended to increase throughout the study, use of average body weight would tend to overestimate BAC toward the end of the study period (and underestimate BAC at the beginning). To put this potential bias into perspective, 1.2% of all BAC measurements were 0.07 or 0.08 grams %, just below or above the binge drinking threshold, respectively. To move these threshold doses by 0.01 grams % would have taken close to a 2 standard deviation change (16 lbs.) in body weight from the average weight (162 lbs.) of study participants. About 5% of participants had such a change. So, the potential limitation of using average body weight only would have affected approximately 0.06% of BAC measurements. Although all three of these factors may have been related to binge drinking proportions, only the latter two would be related to intensity. Because the median BAC level of all binge episodes was 0.12 grams % and mean 4-week *peak* BAC was 0.16 grams % (SE=.005), the majority of binge events likely still would have been categorized as such, however. Furthermore, this bias would affect the percentages of binge drinkers, but not the temporal and developmental patterns, or their moderators.

One explanation for the absence of a predictor of binge drinking slope was that we only included predictors from the study's entry point, and not time-varying estimates of predictors. Future analyses using time-varying covariates may be helpful in determining what individual difference factors influence the choice to participate/not participate in binge drinking occasions as emerging adulthood progresses.

The validity of this study of binge drinking is predicated on the representativeness of this sample. The sample was representative of drinkers in the geographic area from which it was taken (i.e., Tampa Bay), but is not guaranteed to match this age range throughout the United States. It is important to point out that the kind of detailed observation used in this study would not have been feasible using a typical epidemiological sample with tens of thousands of participants from various geographic regions. The similarity of the current data to the data emerging from large epidemiological samples (e.g., SAMSHA, 2012), however, reduces this concern to some degree, and provides confidence in generalizing to other geographic regions. Although other nations have different legal restrictions, societal norms, and familial norms which may alter drinking probabilities, the same patterns may generalize beyond this country. Specifically, drinking in other countries likely follows similar temporal (day of the week, holiday) and developmental patterns to those reported in the present study.

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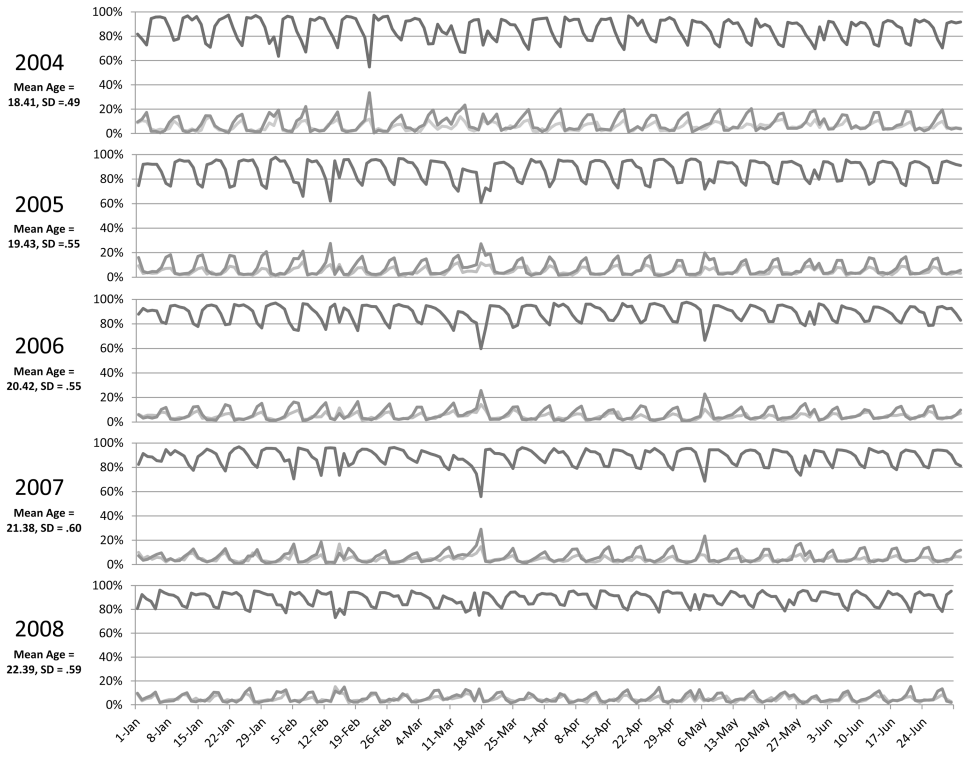

Figure 1.1.

The percentage of participants who reported binge drinking, moderate drinking, or no drinking for each day of January through June in 2004 through 2008. The black line indicates participants who did not drink, the darkest gray line indicates participants who binge drank, and the lightest gray line indicates participants who moderately drank on a given day.

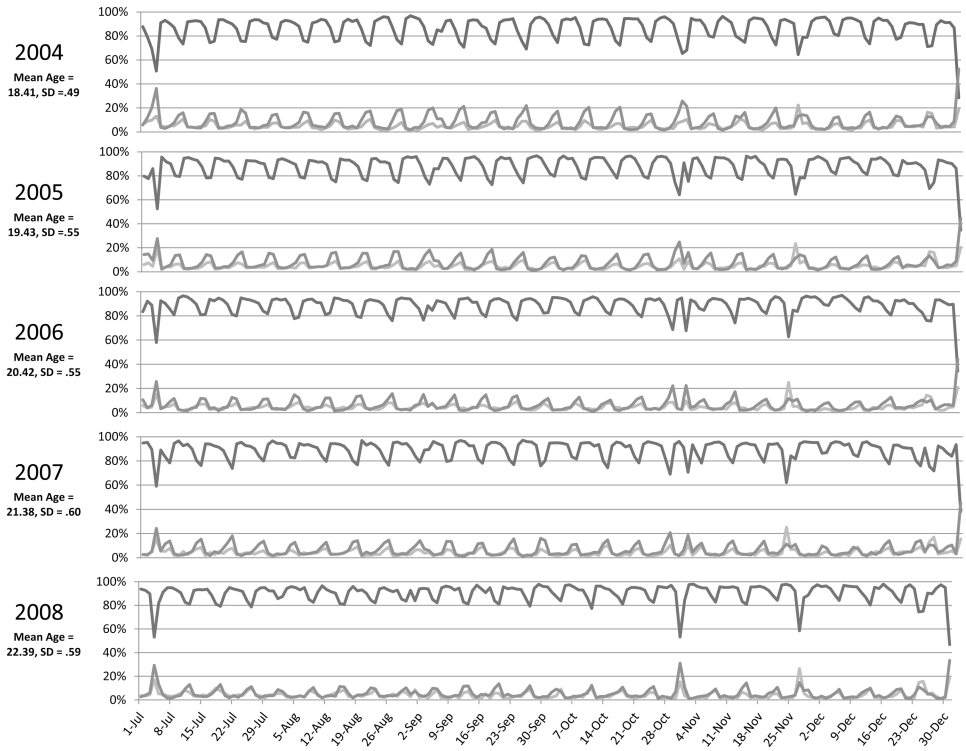

Figure 1.2.

The percentage of participants who evidenced binge drinking, moderate drinking, or no drinking for each day of July 1st through December 31st in 2004 through 2008. The black line indicates participants who did not drink, the darkest gray line indicates participants who binge drank, and the lightest gray line indicates participants who moderately drank on a given day.

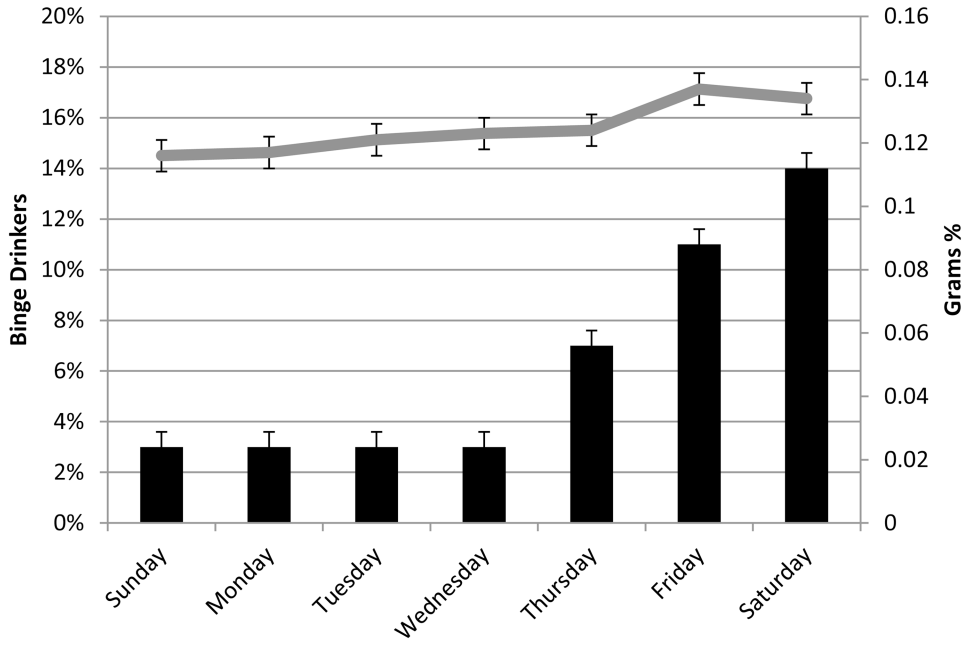

Figure 2.

Percentage of binge drinkers (bars) and median BAC (line) for binge episodes (with 95% confidence intervals) for each day of the week aggregated across all five years of the study.

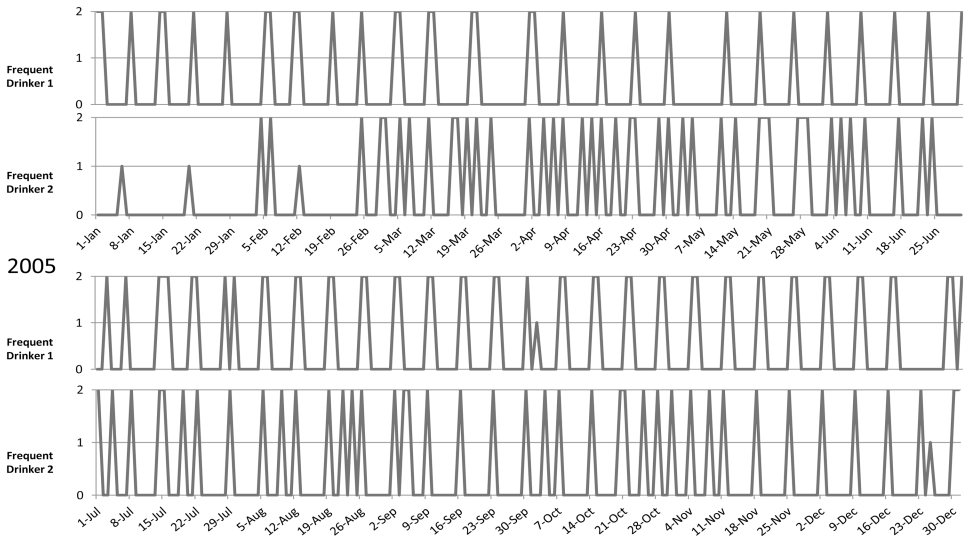

Figure 3.1.

The pattern of drinking for two participants (who evidenced frequent binge drinking) for each day in 2005. 0 represents no drinking for the given day, 1 represents moderate drinking for the given day, and 2 represents binge drinking for the given day.

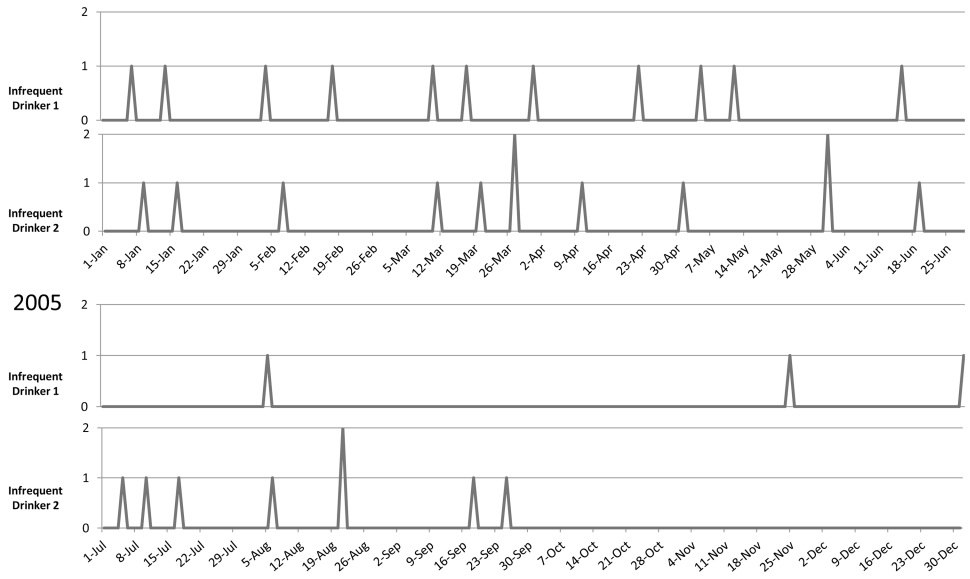

Figure 3.2.

The pattern of drinking for two participants (who evidenced infrequent binge drinking) for each day in 2005. 0 represents no drinking for the given day, 1 represents moderate drinking for the given day, and 2 represents binge drinking for the given day.

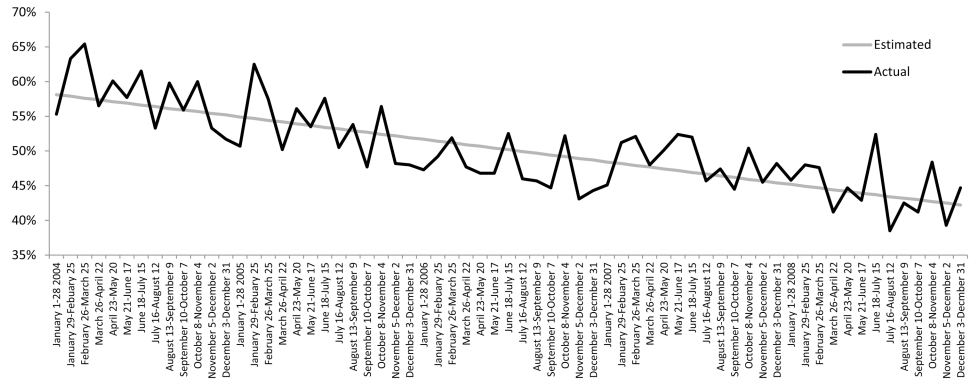

Figure 4.

The percentage of participants having at least one binge drinking episode during 4-week segments across 2004-2008. The dark gray line represents actual data. The light gray line represents the LGC model estimates for this trajectory.

Table 1
2-part Latent Growth Curve Model Results: Univariate and Multivariate Prediction

Predictors	Binge Frequency		Binge Intensity
Univariate Models	**Intercept (S.E.)**	**Slope (S.E.)**	**Intercept (S.E.)**
Gender	-0.088 (0.178)	-0.007 (0.005)	-0.005 (0.005)
Family History	0.072 (0.200)	-0.003 (0.005)	0.012 (0.006)
Student Status	-0.091 (0.202)	-0.003 (0.006)	0.009 (0.006)
AEQ Total	3.196** (0.426)	0.018 (0.013)	0.030 (0.014)
ZKPQ Impulsivity-Sensation Seeking	0.909** (0.194)	0.002 (0.006)	0.030** (0.006)
ZKPQ Neuroticism-Anxiety	0.068 (0.367)	0.001 (0.009)	-0.001 (0.012)
ZKPQ Aggression-Hostility	1.394* (0.412)	0.001 (0.011)	0.030 (0.012)
ZKPQ Sociability	1.964** (0.419)	0.018 (0.012)	0.042* (0.013)
ZKPQ Activity	-0.042 (0.419)	-0.008 (0.011)	0.024 (0.013)
Multivariate Model			
AEQ Total	2.596** (0.449)	0.016 (0.013)	0.011 (0.015)
ZKPQ Impulsivity-Sensation Seeking	0.338 (0.208)	-0.001 (0.006)	0.024* (0.007)
ZKPQ Aggression-Hostility	0.541 (0.406)	0.000 (0.012)	0.013 (0.013)
ZKPQ Sociability	1.505** (0.423)	0.018 (0.012)	0.026 (0.014)

Notes. Intercept and slope estimates are unstandardized with standard errors in parentheses. Univariate analyses refer to each predictor separately. The multivariate analysis included all predictors simultaneously ($p<.01$). S.E.=standard error; AEQ=Alcohol Expectancy Questionnaire; ZKPQ=Zuckerman Kuhlman Personality Questionnaire.

* $p<.01$;

** $p<.001$.

Table 2
Consequences of Drinking Predicted by Binge Frequency and Binge Intensity Intercepts

Consequence	Binge Frequency Odds Ratios (95% C.I.)	Binge Intensity Odds Ratios (95% C.I.)
Unhappiness	1.23*** (1.10-1.39)	5.60*** (2.49-12.57)
Harm to self (physically)	1.40*** (1.24-1.58)	17.65*** (7.37-42.28)
Harm to family	1.17* (1.02-1.34)	6.52*** (2.41-17.65)
Harm to friendship	1.25*** (1.11-1.41)	10.45*** (4.38-25.16)
Taken advantage of sexually	1.22*** (1.07-1.39)	3.41** (1.39-8.34)
Taking advantage of other sexually	1.13 (0.96-1.32)	3.90* (1.25-12.15)
Accident	1.39 (1.20-1.61)	16.51*** (5.67-48.11)

Notes. 95% C.I.=95% confidence interval for the odds ratio.

* $p<.05$;

** $p<.01$;

*** $p<.001$