Substance Use Trajectories From Early Adolescence Through the Transition to College

KAREN J. DEREFINKO, PH.D.,[a,b,*] RICHARD J. CHARNIGO, PH.D.,[c] JESSICA R. PETERS, PH.D.,[b,d] ZACHARY W. ADAMS, PH.D.,[e] RICHARD MILICH, PH.D.,[b] & DONALD R. LYNAM, PH.D.[f]

[a]*Department of Preventive Medicine, University of Tennessee Health Sciences Center, Memphis, Tennessee*
[b]*Department of Psychology, University of Kentucky, Lexington, Kentucky*
[c]*Department of Biostatistics and Statistics, University of Kentucky, Lexington, Kentucky*
[d]*Department of Psychiatry and Human Behavior, Alpert Medical School of Brown University, Providence, Rhode Island*
[e]*Department of Psychiatry, Medical University of South Carolina, Charleston, South Carolina*
[f]*Department of Psychological Sciences, Purdue University, West Lafayette, Indiana*

ABSTRACT. Objective: The transition to college is an important developmental period for the development of alcohol, marijuana, and hard drug (cocaine, opiates, inhalants, stimulants, hallucinogens, Ecstasy, club drugs) use. The current study explored specific changes in substance use patterns during and after the transition to college through the use of trajectory analyses. **Method:** Participants were 526 students who reported retrospectively and prospectively on their substance use from age 13 through the junior year of college. Group-based trajectory modeling was used to estimate developmental trajectory groups for alcohol, marijuana, and hard drug use during this period. **Results:** Results supported a five-group model of alcohol use, a four-group model of marijuana use, and a four-group model of hard drug use. Although three of the five alcohol trajectories indicated high escalation throughout adolescence, one of these groups decreased in alcohol use dramatically during the freshman and sophomore years, a trend also found for hard drug use. Trajectories demonstrated significant differences in terms of gender, race, and impulsive personality characteristics. **Conclusions:** These results indicate that the start of college is an important developmental transition in terms of polysubstance use, and that despite the homogeneity of this undergraduate sample, there is considerable divergence in trajectories during college. (*J. Stud. Alcohol Drugs, 77,* 924–935, 2016)

COLLEGE MATRICULATION REPRESENTS a time when multiple substance use risk factors converge (Mohler-Kuo et al., 2003; White et al., 2005). The period of "emerging adulthood" is a time of notable transitions, including changes in residence, reduced supervision of activities, changes in peer groups, movement toward adult responsibilities, and growing independence of decision-making, making this period one of the most critical for potential changes in substance use (Arnett, 2000). In addition to age-related risks, college environments normalize substance use and allow access to same-age peers and alcohol and other drugs, thereby providing considerable opportunity for substance use experiences (Arria et al., 2013; White et al., 2005). Research suggests that heavy drinking is more likely among college students than in their non–college-attending contemporaries (Slutske et al., 2004), as is diagnosis of an alcohol use disorder (Slutske, 2005). In addition to alcohol, the initiation and use of marijuana and other illicit substances is more likely during this transition (Garnier et al., 2009; Mohler-Kuo et al., 2003).

Despite the prevalence of substance use in late adolescence and young adulthood, previous work suggests wide divergence in individuals' substance use over time (Guo et al., 2002; Schulenberg et al., 2005). For example, many adolescents never begin to use substances, and some continue to abstain even into adulthood. In contrast, some develop heavy use habits at young ages, sometimes leading to substance abuse and dependence in adulthood (Schulenberg et al., 2003; Sher & Gotham, 1999). High rates of use and divergence in outcomes suggest that including adolescence and young adult years in substance use trajectories may provide valuable information about how and for whom use changes during this transition.

Several studies have sought to identify trajectories of substance use, although few have explored the entire risk period from early adolescence through emerging adulthood. The most widely explored substance in this age range is alcohol. Chassin et al. (2002) explored heavy episodic drinking trajectories in a community sample of children of alcoholics versus controls from age 12 to age 23. Four trajectory groups were identified: non–heavy episodic, infrequent, late-moderate, and early heavy use patterns. Tucker et al. (2005) explored heavy episodic drinking from ages 13 to 23 in a community sample. Four trajectories were also identified, but groups were calculated without abstainers, resulting in groups dissimilar to those reported by Chassin et al. (2002).

Received: June 17, 2015. Revision: June 6, 2016.

This research was supported by National Institute on Drug Abuse Grants DA007304 and T32DA035200 and National Institute of Mental Health Grants T32 MH18869 and T32MH019927. The content is solely the responsibility of the authors and does not necessarily reflect the official views of the National Institutes of Health.

*Correspondence may be sent to Karen J. Derefinko at the Department of Preventive Medicine, University of Tennessee Health Sciences Center, 66 N. Pauline St., Memphis, TN 38163-2181, or via email at: kderefin@uthsc.edu.

Flory et al. (2004) explored alcohol use trajectories from age 11 to age 21 in a community sample but, in contrast to previous work, found only three groups for alcohol use: nonusers, late onset, and early onset.

Fewer studies examine marijuana or hard drug use trajectories over the course of adolescence through emerging adulthood. Tucker et al.'s (2005) community-based study found four marijuana groups, including early-onset heavy use, steady increasers, stable light users, and occasional light users, but analyses did not include abstainers. Results from Flory et al. (2004) found only three groups for marijuana use. Only one trajectory study has explored hard drug use. Guo and colleagues (2002) found that among adolescents, three trajectories emerged for poly-illicit hard drug use (including crack, cocaine, amphetamines, tranquilizers, sedatives, psychedelics, and narcotics): nonusers, early onset, and late onset. However, these findings only used data from ages 13 to 16, thereby limiting the degree to which these trajectories reflect use into adulthood.

Although some work has examined prevalence across the college years (Arria et al., 2013; Garnier et al., 2009; Kasperski et al., 2011), no studies have used trajectory analyses to explore multiple substance use patterns across the transition to college. This is important, given that trajectories provide information on the progression of use that is not available in static rates. Greenbaum et al. (2005) examined alcohol trajectories during the freshman year of college among students already using alcohol. Five groups were identified, including light-stable, light-stable plus "high holiday" use, medium-increasing, high-decreasing, and heavy-stable. These findings differ from other work in community samples, which found fewer trajectory groups for alcohol use (Chassin et al., 2002; Flory et al. 2004; Tucker et al., 2005). The discrepancies between the number and type of groups suggest that college trajectories may differ from community trajectories. Of note, no marijuana or hard drug use trajectory work has been conducted in college samples, thereby leaving unanswered questions about how illicit substance use develops during this important period.

Covariates of substance use

Trajectory analyses not only provide information on the specific patterns of use over time, but also allow for the examination of factors that may differentiate trajectories. Although some differences are intuitive, others may provide important points of divergence. For example, hard drug abstainers are likely to be significantly lower on sensation seeking than those who frequently use hard drugs (Robbins & Bryan, 2004). However, little is known about groups that are less clearly distinct; for instance, how do experimenters (time-limited use) and moderate users (who maintain use) differ with regard to impulsive personality and externalizing behaviors?

Several impulsive personality characteristics have been identified as key factors in substance use development and maintenance, including urgency and sensation seeking (e.g., Dick et al., 2010; Kaiser et al., 2012). In addition to personality characteristics, delinquency and violent behaviors are robust correlates of substance use (e.g., McAdams et al., 2012; McGue et al., 2006). Several trajectory studies have used these factors to examine differences in substance use trajectory groups, although results are not consistent and are restricted with regard to the broad spectrum of available impulsivity traits (Whiteside & Lynam, 2001). Flory et al. (2004) found that alcohol and marijuana users were higher in sensation seeking and antisocial personality than those who fall into light-use or abstainer categories. Similarly, Chassin et al. (2002) found that those with heavy episodic drinking behaviors were higher on externalizing symptoms than were those who drink less frequently, and Guo et al. (2002) found that early- and late-onset heavy episodic drinkers and marijuana users were more likely to participate in risky sexual activities than were those who use alcohol or marijuana less. In contrast, Greenbaum et al. (2005) did not find that those in the heaviest alcohol-use trajectories differed in sensation seeking from the nil to low-use group, and Tucker et al. (2005) did not find differences in stealing across alcohol or marijuana trajectory groups.

Current study

The current work extends previous work by simultaneously examining the development of three different forms of substance use across the entire college transition. Specifically, we used trajectory analyses to define the progression of alcohol, marijuana, and hard drug use from age 13 through the junior year of college. To date, no study has examined trajectories across all three classes of substances within the same sample, and no study has explored use across the transition from high school to college. We hypothesized that the transition to college would reflect general increases in substance use trajectories, particularly for those with high substance use before college entry. In addition to describing the development of substance use, we examined gender and racial differences in the composition of trajectory groups, overlap among the substance classes (alcohol, marijuana, and hard drugs), and relations between trajectories and covariates linked with the development and maintenance of substance use, including impulsivity and delinquent and violent behaviors.

Method

Participants

Participants (N = 526, 48% male) were assessed yearly for 3 years starting freshman year of college. Recruitment

occurred across 2 years. Average age of participants at assessment was 18.95 years (range: 18.00–26.33 years old), and most were under 21 years of age (99%). Participants were recruited from introductory psychology courses and received course credit and monetary incentives for participation. Approximately 81% of participants identified as White, 12% African American, and 6% as other.

"High-risk" participants were identified via pre-study screening and were sent email invitations to enroll. The goal of this screening was to ensure that the sample contained enough participants at risk for escalating substance use in order to have sufficient variability to address the questions of interest. Students in introductory psychology courses were administered a screening questionnaire during the first 2 weeks of the semester. This questionnaire was developed by the study team and assessed the presence of conduct problem behaviors that occurred before age 18, such as stealing, lying, and fighting (12 items, $\alpha = .75$), based on the *Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition* (DSM-IV; American Psychiatric Association, 1994), conduct disorder criteria. A composite score determined the distribution of scores for predicted substance use risk (calculated separately by gender). Those whose scores fell within the top 25% for their gender were specifically invited to participate through email. High-risk participants identified via this method made up 23.1% of the final sample.

Measures

Substance use was assessed during all 3 years of the study. Impulsive personality and delinquency and violence variables were assessed in the third year of the study.

Substance use. The Life History Calendar is a retrospective interview method for collecting data on life events and behaviors (Caspi et al., 1996). Information was obtained regarding alcohol, marijuana, and hard drug use. Tobacco use was collected but is not reported in this article as it is a topic of a different study under review.

For the first assessment, participants reported retrospectively on their substance use from age 13 to the present. Each year was divided into three, 4-month periods that corresponded to the two semesters of the school year and the summer starting at age 13. The Year 2 and Year 3 interviews assessed only the past year of use (divided by 12 months). For alcohol and marijuana use, participants selected from seven choices describing the average amount they used per occasion during each period (e.g., for alcohol, 1 = *1 drink,* 2 = *2 drinks, . . .* 6 = *6–10 drinks,* and 7 = *10 or more drinks.* One drink means 1 beer, 1 shot of distilled spirits, or one glass of wine. For marijuana, 1 = *1–2 hits,* 2 = *3–4 hits, . . .* 6 = *17 or more hits.* One hit is equal to 1 joint, bong, or pipe hit). These categories were transformed to represent actual numbers of drinks/hits per occasion before trajectory analyses.

For hard drug use, participants indicated their use during each assessment period among seven different substance categories: cocaine, opiates (e.g., codeine), inhalants (e.g., paint), stimulants (e.g., methamphetamine), hallucinogens (e.g., LSD [lysergic acid diethylamide]), Ecstasy [3,4-methylenedioxymethamphetamine; MDMA], and club drugs [e.g., ketamine]). Counts of the different types of hard drugs endorsed during each assessment period were used (e.g., endorsement of cocaine, MDMA, and stimulants would result in a score of 3 for that period).

Impulsive personality traits. The UPPS Impulsive Behavior Scale (Whiteside & Lynam, 2001) is a 45-item self-report inventory measuring four personality trait pathways to impulsive behavior: Urgency, (lack of) perseverance, (lack of) premeditation, and sensation seeking. Each item on the UPPS was rated on a 4-point scale (ranging from 1 = *strongly disagree* to 4 = *strongly agree*), and mean scores were calculated for each trait. All dimensions demonstrated good internal consistency ($\alpha = .82–.88$).

Delinquency and violence. The Crime and Analogous Behavior Scale (Lynam et al., 1999) is a 49-item self-report inventory that asks the participant about violence (e.g., fighting, use of weapons) and delinquency (e.g., breaking into a house or building, theft). Items were scored yes/no. Items were combined into two summary variables based on similarity in item content. Delinquency was calculated as the sum endorsement of 6 items (e.g., have you ever taken a car without the owner's permission?). Violence was calculated as the sum endorsement of 4 items (e.g., have you ever been in a physical fight?).

Procedure

The study was reviewed and approved by the university's Institutional Review Board, and a federal Certificate of Confidentiality was acquired. Informed consent was obtained from participants at each assessment.

Attrition

Data were collected for all 526 participants at Year 1. At Year 2, data were collected from 386 participants from the original sample, and at Year 3, data were collected from 332 participants from the original sample. Data from all 3 years were collected for 300 participants. Independent samples *t* tests were completed to examine potential differences between study completers versus noncompleters on study variables. There were no significant group differences on demographic (sex or race), substance use (alcohol, marijuana, or hard drug use), impulsive personality (urgency, lack of premeditation, lack of perseverance, sensation seeking), delinquency, or violence variables (*t* scores ranged from $t[506] = -1.49$ to $t[523] = 1.87$, all $ps > .05$).

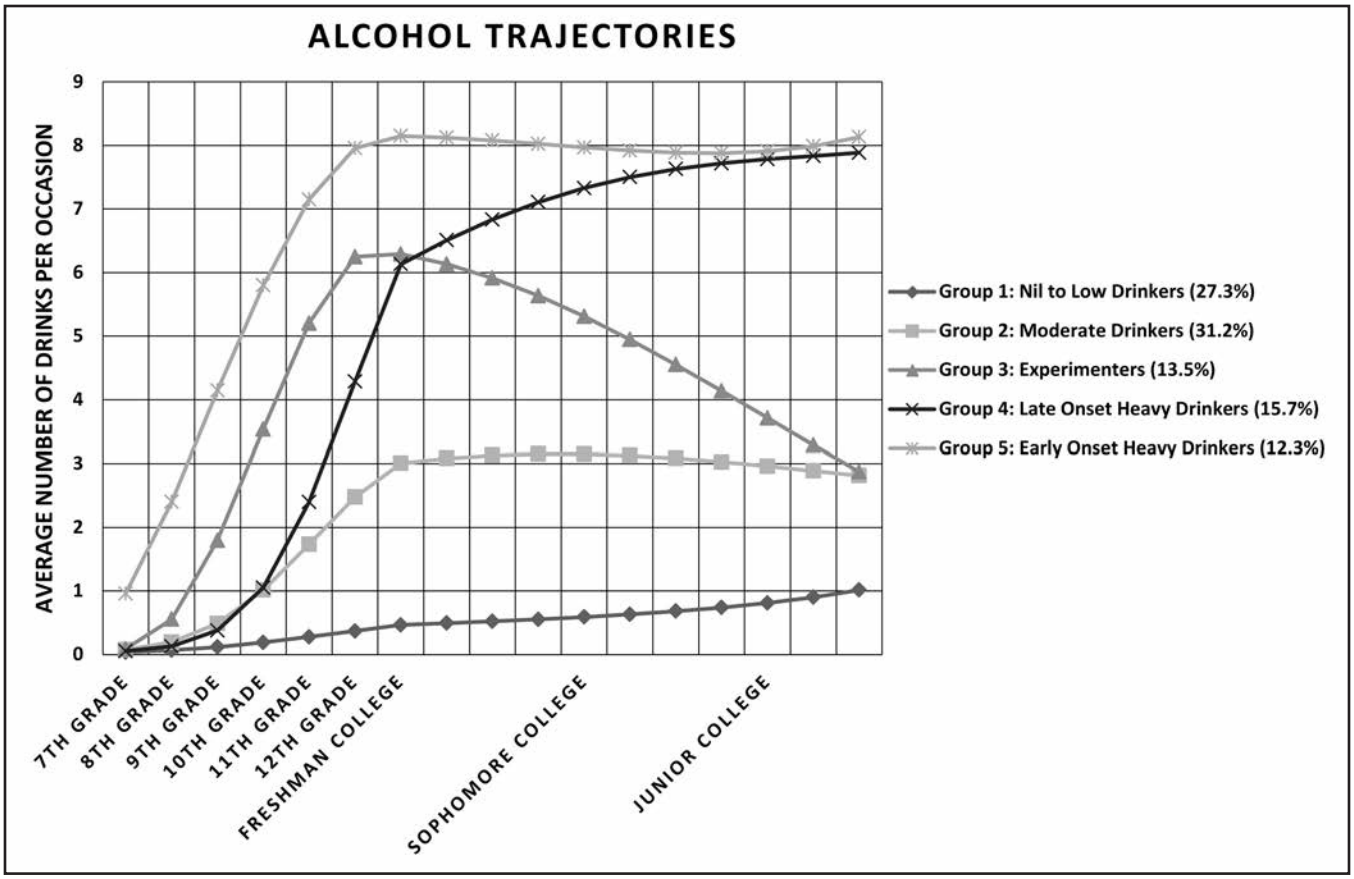

FIGURE 1. Alcohol use trajectories. *Y*-axis represents average amount of alcohol consumed per drinking occasion. One drink means 1 beer, 1 shot of distilled spirits, or one glass of wine. *X*-axis represents periods from the first assessment in seventh grade through junior year in college. The first 6 periods are yearly. Periods after college matriculation are every 3 months.

Data analysis

Group-based trajectory modeling, performed using the PROC TRAJ (Jones & Nagin, 2007) application in the SAS statistical software (Version 9.4; SAS Institute Inc., Cary, NC), was used to estimate trajectory groups for each of three substance use outcomes: alcohol, marijuana, and hard drugs. This statistical approach yields a discrete number of latent groups that are relatively homogeneous and exhibit prototypical patterns of change over time for the outcome of interest (Charnigo et al., 2011; Nagin & Odgers, 2010). PROC TRAJ allows persons with missing data at some time points to still contribute to estimation of model parameters. If missingness is not completely random, bias could be introduced into the results. Given the lack of significant differences between completers and noncompleters, we do not believe this is a concern.

There were 51 original observations possible for each individual. These data were aggregated via averaging the participant's self-reported substance use over three successive intervals and then rounding to the nearest integer. This aggregation resulted in yearly data points preceding freshman year (aggregation over the three periods assessed per year), and four data points per year following matriculation. This defined 17 possible time points, 6 preceding and 11 following college matriculation. This aggregation reduced the number of parameters in the subsequent statistical modeling, partly to reduce the computational difficulties that might be experienced with 51 time points (e.g., errors because of "false convergence") and partly to gain improved signal-to-noise in the data by smoothing out random monthly fluctuations. The final 17 data points presented in Figures 1–3 represent averages of use, ranging from 6 years before matriculation to 2.5 years after.

Because the outcomes were not normally distributed, partly due to the high proportions of zero responses, trajectories were estimated based on zero-inflated Poisson distributions. An ordinary Poisson model fit the hard drug data best. For all models, because an appropriate number of groups was not known a priori, we used the Bayesian information criterion (BIC) and Akaike information criterion (AIC) to decide on the number of groups, within the ranges of two to five prototypes for the consumption of each substance. Likewise, we used the BIC and AIC to decide on the

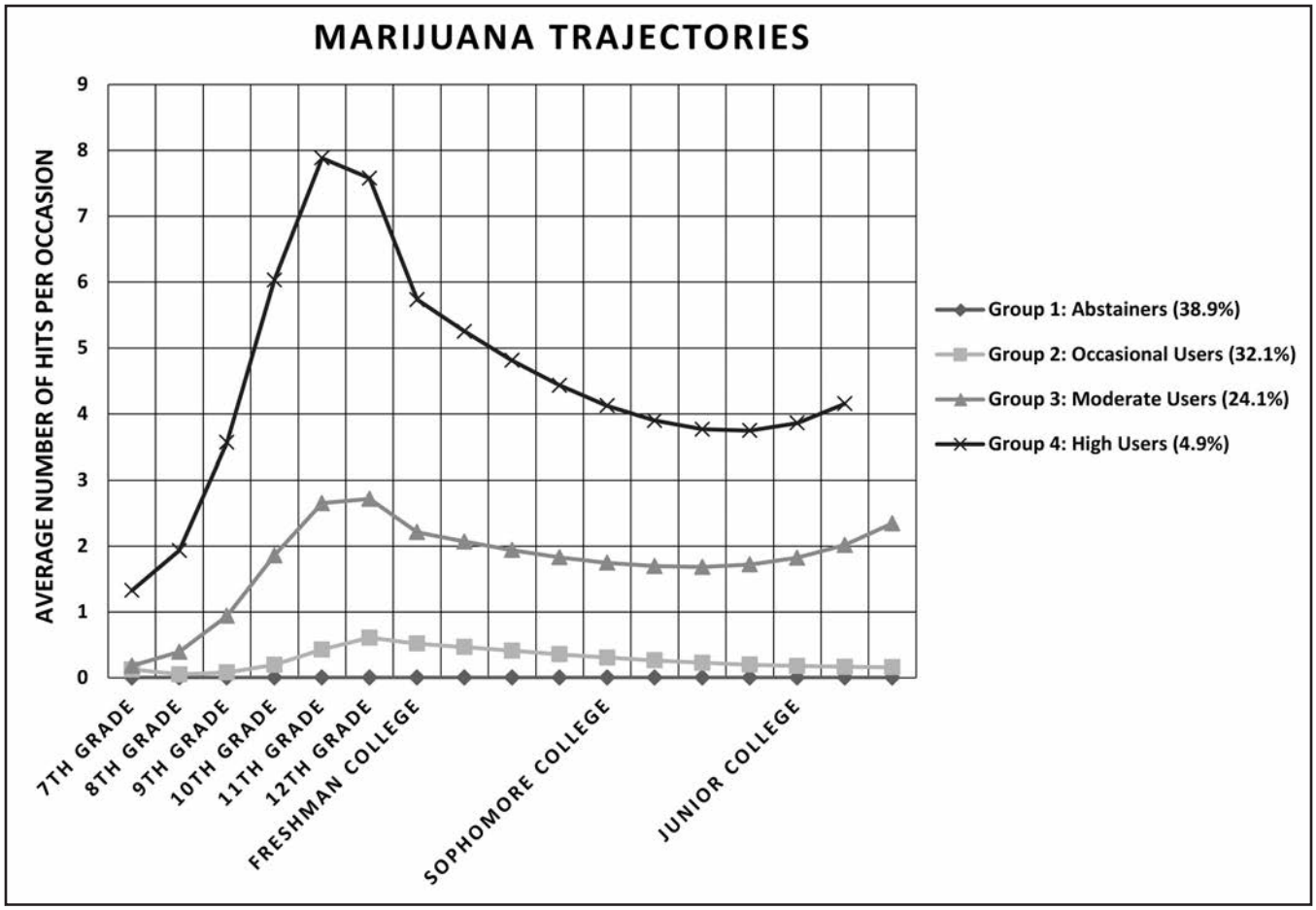

FIGURE 2. Marijuana use trajectories. *Y*-axis represents average number of hits of marijuana consumed per smoking occasion. One hit is equal to 1 joint, bong, or pipe hit. *X*-axis represents periods from the first assessment in seventh grade through junior year in college. The first 6 periods are yearly. Periods after college matriculation are every 3 months.

polynomial orders (with respect to time) of mean-level consumption for each group as well as the polynomial orders of zero inflation, with maximum allowable orders of four and two, respectively, for each group. Greater polynomial order corresponds, roughly speaking, to greater nonlinearity. The actual numbers of groups and polynomial orders were determined through an iterative process that sought an optimal compromise between fitting the sample data and generalizing to the larger population. Because we did not wish to assume that the trajectory groups for alcohol use would coincide with those for marijuana and hard drug use, we applied PROC TRAJ separately for each of these three outcomes. Because the most probable group memberships were nearly definitive (mean largest estimated probability of group membership was 96.5% [*SD* = 9.7%] for alcohol; 96.9% [*SD* = 7.8%] for marijuana; 97.2% [*SD* = 8.2%] for hard drugs), any bias attributable to uncertainty about group memberships was deemed negligibly small. All names applied to trajectory groups were created as descriptors of the use pattern (e.g., "heavy users").

Results

Table 1 presents the prevalence of use for all substances. Nearly all study participants reported alcohol use (94.8%), and more than half reported marijuana use (60.3%). Considerably fewer endorsed hard drug use. Of the hard drugs, the highest endorsement was for nonprescribed stimulants (24.7%), followed by opiates (20.5%). The lowest endorsement was for club drugs (0.6%).

Trajectories

Each line in Figures 1–3 depicts the estimate with polynomial orders chosen by the BIC and AIC. The BIC and AIC are criteria for model selection among a finite set of models; the model with the lowest BIC and AIC values is preferred. BIC and AIC values for each competing number of components are presented in Table 2. PROC TRAJ also produces a corresponding line that depicts a nonparametric estimate of mean-level (i.e., without any constraints on polynomial

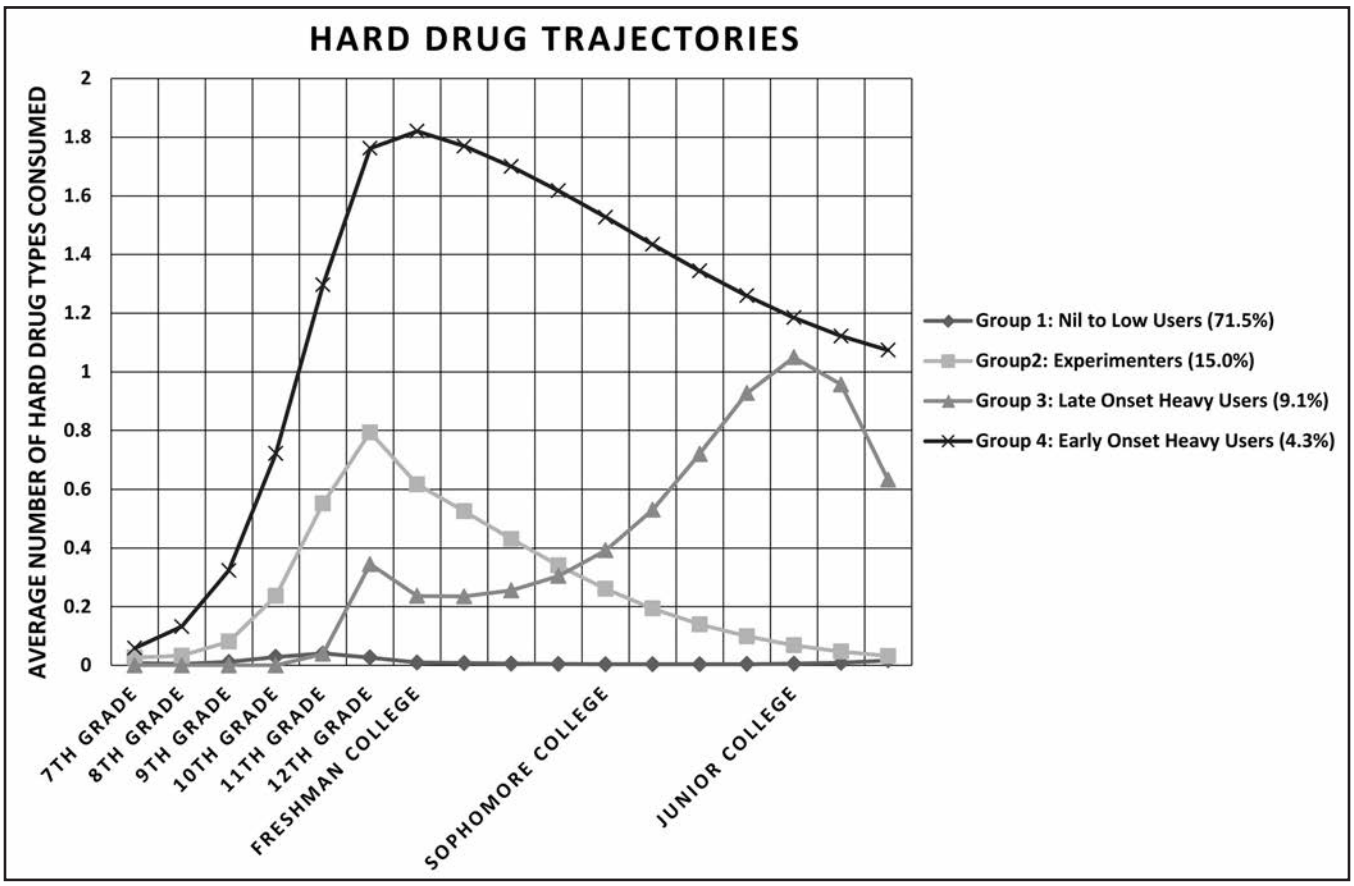

FIGURE 3. Hard drug use trajectories. *Y*-axis represents variety of hard drugs used per assessment period. *X*-axis represents periods from the first assessment in seventh grade through junior year in college. The first 6 periods are yearly. Periods after college matriculation are every 3 months.

TABLE 1. Lifetime prevalence of use

Variable	% of sample reporting any lifetime use
Alcohol	94.8%
Marijuana	60.3%
Hard drugs	
Cocaine	7.5%
Opiates	20.5%
Inhalants	1.3%
Stimulants (not prescribed)	24.7%
Hallucinogens	13.0%
MDMA	9.8%
Club drugs	0.6%

Notes: N = 526. Cocaine = Cocaine and/or crack; opiates = codeine, Darvon, Demerol, Dilaudid, methadone, morphine, opium, Percodan, Talwin; inhalants = glue, toluene, gasoline, paint, paint thinner; stimulants = amphetamines, ice, methamphetamine, Ritalin, speed, and/or uppers; hallucinogens = dimethyltryptamine (DMT), lysergic acid diethylamide (LSD), mescaline, peyote, psilocybin (magic mushrooms, 'shrooms); MDMA = 3,4-methylenedioxyamphetamine (Ecstasy, Molly); club drugs = gamma-hydroxybutyrate (GHB), ketamine, Rohypnol.

order) substance consumption. These were not presented in the figures but are available from the authors upon request.

Alcohol. A five-group model was selected for alcohol use (Figure 1). The horizontal axis represents time in years before matriculation to college, and in 4-month increments after. The vertical axis represents the number of drinks per occasion. The first group consisted of those who primarily abstained throughout high school and had modest use throughout college (nil to low drinkers; an estimated 27.3% of the population). The second group (moderate drinkers; 31.2%) comprised individuals who were moderate drinkers at the start of and throughout college. The third group (experimenters; 13.5%) included individuals who appear to peak in their alcohol use during late high school and early college, followed by considerable reductions during sophomore and junior years. The fourth group (late-onset high drinkers; 15.7%) comprised individuals who had steep increases in use just before college entry with continued increases throughout college. The smallest group (early-onset heavy drinkers; 12.3%) included individuals who began drinking at age 13, rapidly escalated through high school, and maintained a high level of drinking (more than 8 drinks per occasion) through junior year of college.

TABLE 2. BIC and AIC values for competing models

Variable	2 Components	3 Components	4 Components	5 Components
Alcohol				
BIC	-18,223.90	-17,109.40	-16,554.99	**-16,259.74**
AIC	-18,189.81	-17,056.13	-16,482.54	**-16,168.12**
Marijuana				
BIC	Not viable: False convergence	-8,407.65	**-8,218.31**	Not viable: False convergence
AIC	Not viable: False convergence	-8,352.25	**-8,143.74**	Not viable: False convergence
Hard drugs				
BIC	-2,288.29	-2,199.26	**-2,162.59**	Not viable: False convergence
AIC	-2,264.85	-2,163.04	**-2,113.59**	Not viable: False convergence

Notes: BIC = Bayesian information criterion; AIC = Akaike information criterion. The BIC and AIC are criteria for model selection among a finite set of models; the model with the lowest BIC and AIC values is preferred. Highest values (in this case, least negative) highlighted in **bold.** False convergence indicates PROC TRAJ failed to estimate model parameters.

Marijuana. A four-group model was selected for marijuana use (Figure 2). The largest group (an estimated 38.9% of the population) comprised individuals who abstained from marijuana use. The second group (occasional users; 32.1%) initiated low-level marijuana use before college entry, followed by a gradual decrease in hits per occasion. The third group (moderate users; 24.1%) included individuals who steadily increased marijuana use throughout adolescence, peaking in high school and then decreasing throughout college. Finally, the smallest group (high users; 4.9%) was characterized by early onset of marijuana use at age 13, followed by steep increases in use until about age 18, and subtle decreases throughout college, averaging 4–5 hits (0.5 to 1 joint) per occasion.

Hard drugs. A four-group model for hard drug use was selected (Figure 3). The largest group (an estimated 71.5% of the population) comprised individuals who abstained from hard drug use or used at low rates (averaging less than one type of hard drug per 4-month period; nil to low users) throughout high school and college. The second group (experimenters; 15.0%) included individuals who exhibited steep increases in polydrug use up to college entry, then declining to virtually no use by junior year. The third group (late-onset heavy users; 9.1%) had averages of lower than one type of drug before college but increased polydrug use from freshman to junior year. The fourth group (early-onset heavy users; 4.3%) averaged more than one type of drug throughout high school, with subtle declines throughout college.

Gender and race differences across trajectories

We performed post hoc cross-tabulations to explore proportion differences among groups across gender and race (White vs. minority) categories (Table 3). For alcohol, cross-tabulations indicated significant differences across trajectory groups for gender, $\chi^2(4) = 79.92$, $p < .001$, and race, $\chi^2(4) = 40.67$, $p < .001$. Women comprised a significantly larger proportion of moderate drinkers and a significantly smaller proportion of late-onset and early-onset drinkers than men (all ps $< .05$). Participants who reported racial minority status comprised a larger proportion of nil to low drinkers and a smaller proportion of experimenters, late-onset, and early-onset drinkers than participants who reported being White (all ps $< .05$).

Cross-tabulations indicated significant differences across marijuana trajectory groups for gender, $\chi^2(3) = 31.83$, $p < .001$, and race, $\chi^2(3) = 8.19$, $p < .05$. Women comprised a significantly larger proportion of abstainers and a significantly smaller proportion of moderate and high users than men, and minority participants comprised a significantly larger proportion of high users than White participants. Cross-tabulations did not indicate significant differences across hard drug trajectory groups for gender, $\chi^2(3) = 6.16$, $p < .10$, or race, $\chi^2(3) = 4.45$, $p = .22$.

Relations across substances

We performed post hoc cross-tabulations of the most probable group memberships for the three substance use outcomes (Table 4). Analyses indicated a high degree of dependence between alcohol and marijuana groups, $\chi^2(12) = 10.78$, $p < .001$; alcohol and hard drug groups, $\chi^2(12) = 114.68$, $p < .001$; and marijuana and hard drug groups, $\chi^2(9) = 138.01$, $p < .001$, indicating that categories of use were interrelated across substances.

Percentages associated with cross-tabulations are provided in Table 4. Of note, low use in one substance use category was primarily associated with low use in other substance use categories, and high use with high use. For example, none of the 22 hard drug early-onset heavy users fell into the nil to low or moderate alcohol use trajectory groups. However,

Table 3. Demographic data by trajectory group

Alcohol	Alcohol Group 1 Nil to low drinkers (n = 142)	Alcohol Group 2 Moderate drinkers (n = 166)	Alcohol Group 3 Experimenters (n = 71)	Alcohol Group 4 Late-onset heavy drinkers (n = 81)	Alcohol Group 5 Early-onset heavy drinkers (n = 65)	Total n
% of total sample	27.3%	31.2%	13.5%	15.7%	12.3%	526
Males	27.8%	15.1%	14.7%	23.4%	19.0%	252
Females	26.3%	47.1%	12.4%	8.0%	6.2%	274
White	21.3%	32.6%	15.2%	17.1%	13.8%	427
Minority	51.5%	28.3%	6.1%	8.1%	6.1%	99
Marijuana	**Group 1 (Marijuana) Abstainers (n = 215)**	**Group 2 (Marijuana) Occasional users (n = 160)**	**Group 3 (Marijuana) Moderate users (n = 126)**	**Group 4 (Marijuana) High users (n = 25)**		
% of total sample	38.9%	32.1%	24.1%	4.9%		526
Males	38.1%	22.6%	31.3%	8.0%		252
Females	43.4%	37.6%	17.2%	2.6%		274
White	40.7%	31.4%	24.4%	3.5%		427
Minority	41.4%	26.3%	22.2%	10.1%		99
Hard drugs	**Group 1 (Hard drug) Nil to low users (n = 389)**	**Group 2 (Hard drug) Experimenters (n = 74)**	**Group 3 (Hard drug) Late-onset heavy users (n = 41)**	**Group 4 (Hard drug) Early-onset heavy users (n = 22)**		
% of total sample	71.5%	15.0%	9.1%	4.3%		526
Males	71.4%	13.1%	10.0%	6.0%		252
Females	76.3%	15.0%	6.2%	2.6%		274
White	72.1%	15.0%	8.2%	4.7%		427
Minority	81.8%	10.1%	6.1%	2.0%		99

Notes: Percentages may not add to 100 due to rounding. Comparisons across subgroups are based on modal assignment of participants.

a large portion fell into the highest alcohol use category (14 of the 22; 64%).

Covariates

To explore relations between trajectory groups and individual differences, we fit several multinomial logistic regression models using IBM SPSS Statistics for Windows, Version 21.0 (IBM Corp., Armonk, NY). Trajectory group membership was regressed on individual difference variables (impulsive personality, delinquency, violence). Results of multinomial logistic regression models testing all reference categories across substance use trajectories are presented in Table 5, and centered mean values for each individual difference variable are presented for each trajectory group for comparison. To avoid multicollinearity, each class of independent variable was entered into different models.

Alcohol. Overall alcohol group membership was significantly associated with urgency, lack of premeditation, sensation seeking, delinquency, and violence (all ps < .05). Nil to low drinkers were significantly lower than moderate drinkers on urgency and delinquency and significantly lower than experimenters in all categories except lack of perseverance. Nil to low drinkers were significantly lower than late-onset heavy drinkers on all categories except urgency and lack of perseverance, and lower than early-onset heavy drinkers on all categories. Interestingly, alcohol experimenters did not differ from late-onset heavy drinkers on any of the covariates, although experimenters were lower on delinquency and violence and higher than early-onset heavy drinkers on lack of perseverance.

Marijuana. Overall marijuana group membership was significantly associated with urgency, lack of premeditation, sensation seeking, delinquency, and violence (all ps < .05). Abstainers were significantly lower than occasional users on lack of perseverance and sensation seeking. Abstainers were significantly lower than moderate users on all categories and were lower than high users on all categories except lack of premeditation.

Hard drugs. Overall hard drug group membership was significantly associated with urgency, sensation seeking, delinquency, and violence (all ps < .05). Nil to low users were significantly lower than experimenters on urgency, delinquency, and violence and significantly lower than late-onset heavy users on sensation seeking and delinquency. Nil to low users were significantly lower than early-onset heavy users on all categories except lack of perseverance. Hard drug experimenters were not significantly different from late-onset heavy users on any category but were lower in delinquency than early-onset heavy users.

Table 4. Cross-tabulations between trajectory groups

Variable	ALC 1 (*n* = 142)	ALC 2 (*n* = 166)	ALC 3 (*n* = 71)	ALC 4 (*n* = 81)	ALC 5 (*n* = 65)	MJ 1 (*n* = 215)	MJ 2 (*n* = 160)	MJ 3 (*n* = 126)	MJ 4 (*n* = 25)	HD 1 (*n* = 389)	HD 2 (*n* = 74)	HD 3 (*n* = 41)	HD 4 (*n* = 22)
ALC 1						49.3%	17.5%	4.8%	8.0%	34.4%	10.8%	0.0%	0.0%
ALC 2						34.4%	36.9%	22.2%	24.0%	32.4%	35.1%	36.6%	0.0%
ALC 3						6.0%	18.8%	18.3%	20.0%	11.8%	23.0%	7.3%	22.7%
ALC 4						8.8%	15.0%	25.4%	24.0%	13.4%	16.2%	34.1%	13.6%
ALC 5						1.4%	11.9%	29.4%	24.0%	8.0%	14.9%	22.0%	63.6%
MJ 1	74.6%	44.3%	18.3%	2.53%	4.6%					51.2%	18.9%	4.9%	0.0%
MJ 2	19.7%	35.3%	42.3%	29.6%	29.2%					32.6%	25.7%	29.3%	9.1%
MJ 3	4.2%	16.8%	32.4%	39.5%	56.9%					14.1%	44.6%	56.1%	68.2%
MJ 4	1.4%	3.6%	7.0%	7.4%	9.2%					2.1%	10.8%	9.8%	22.7%
HD 1	94.4%	75.4%	64.8%	64.2%	47.7%	92.6%	79.4%	43.7%	32.0%				
HD 2	5.6%	15.6%	23.9%	14.8%	16.9%	6.5%	11.9%	26.2%	32.0%				
HD 3	0.0%	9.0%	4.2%	17.3%	13.8%	0.9%	7.5%	18.3%	16.0%				
HD 4	0.0%	0.0%	7.0%	3.7%	21.5%	0.0%	1.3%	11.9%	20.0%				

Notes: ALC = alcohol trajectory group; ALC 1 = nil to low drinkers; ALC 2 = moderate drinkers; ALC 3 = experimenters; ALC 4 = late-onset heavy drinkers; ALC 5 = early-onset heavy drinkers; MJ = marijuana trajectory group; MJ 1 = abstainers; MJ 2 = occasional users; MJ 3 = moderate users; MJ 4 = high users; HD = hard drug trajectory group; HD 1 = nil to low users; HD 2 = experimenters; HD 3 = late-onset heavy users; HD 4 = early-onset heavy users. Percentages were calculated using the number of individuals in each trajectory group who also fit criteria for a different trajectory. Denominators are provided at the top of the table. For example, 106 of the 142 individuals (75%) in trajectory group ALC 1 were also placed in trajectory group MJ 1. Percentages may not add to 100 because of rounding. Comparisons across subgroups are based on modal assignment of participants.

Table 5. Relations between trajectories and covariates using multinomial logistic regression

Alcohol	Group 1 (Alcohol) Nil to low drinkers (*n* = 142)	Group 2 (Alcohol) Moderate drinkers (*n* = 166)	Group 3 (Alcohol) Experimenter (*n* = 71)	Group 4 (Alcohol) Late-onset heavy drinkers (*n* = 81)	Group 5 (Alcohol) Early-onset heavy drinkers (*n* = 65)
Negative urgency	-0.35 (0.91)^{a}	-0.04 (1.04)^{b}	0.20 (1.00)^{b}	0.09 (0.95)^{a,b}	0.34 (0.97)^{b}
Lack of premeditation	-0.41 (0.86)^{a}	-0.08 (1.01)^{a,b}	0.34 (0.91)^{b,c}	0.27 (0.86)^{b,c}	0.41 (1.15)^{c}
Lack of perseverance	-0.15 (0.99)^{a,b}	0.00 (1.04)^{a,b}	0.27 (0.89)^{b}	0.08 (0.94)^{a,b}	-0.06 1.05)^{a}
Sensation seeking	-0.42 (0.96)^{a}	-0.13 (0.97)^{a}	0.25 (1.06)^{b}	0.43 (0.73)^{b}	0.45 .95)^{b}
Delinquency	-0.43 (0.66)^{a}	-0.13 (0.89)^{b}	0.23 (1.06)^{c}	0.31 (1.27)^{c,d}	0.63 (1.00)^{d}
Violence	-0.17 (0.79)^{a}	-0.25 (0.89)^{a}	0.18 (1.04)^{b}	0.16 (1.31)^{b}	0.63 (1.31)^{c}

Marijuana	Group 1 (Marijuana) Abstainers (*n* = 215)	Group 2 (Marijuana) Occasional users (*n* = 160)	Group 3 (Marijuana) Moderate users (*n* = 126)	Group 4 (Marijuana) High users (*n* = 25)
Negative urgency	-0.27 (0.95)^{a}	0.00 (0.96)^{a}	0.39 (0.98)^{b}	0.47 (1.03)^{b}
Lack of premeditation	-0.29 (0.89)^{a}	-0.01 (0.94)^{a,b}	0.50 (1.05)^{c}	0.29 (1.05)^{a,b}
Lack of perseverance	-0.18 (0.97)^{a}	0.09 (1.03)^{b}	0.16 (0.99)^{c}	0.14 (1.07)^{d}
Sensation seeking	-0.28 (0.96)^{a}	0.03 (0.96)^{b}	0.43 (0.93)^{c}	0.27 (1.04)^{b,c}
Delinquency	-0.44 (0.66)^{a}	-0.07 (0.91)^{a}	0.62 (1.07)^{b}	1.07 (1.26)^{b}
Violence	-0.24 (0.79)^{a}	-0.09 (0.90)^{a}	0.40 (1.22)^{b}	0.70 (1.11)^{b}

Hard drugs	Group 1 (Hard drug) Nil to low users (*n* = 389)	Group 2 (Hard drug) Experimenters (*n* = 74)	Group 3 (Hard drug) Late-onset heavy users (*n* = 41)	Group 4 (Hard drug) Early-onset heavy users (*n* = 22)
Negative urgency	-0.13 (0.97)^{a,b}	0.36 (1.06)^{c}	0.22 (0.88)^{b,c}	0.70 (0.88)^{c}
Lack of premeditation	-0.13 (0.95)^{a}	0.34 (1.00)^{a,b}	0.09 (1.10)^{a}	0.95 (1.01)^{b}
Lack of perseverance	-0.08 (0.98)^{a}	0.20 (1.04)^{a}	0.18 (1.07)^{a}	0.48 (0.89)^{a}
Sensation seeking	-0.13 (0.98)^{a}	0.33 (0.99)^{b}	0.26 (0.92)^{b}	0.72 (0.97)^{b}
Delinquency	-0.20 (0.86)^{a}	0.56 (1.10)^{b}	0.29 (1.06)^{b}	1.17 (1.20)^{c}
Violence	-0.10 (0.93)^{a}	0.29 (1.12)^{b,c}	0.06 (0.90)^{a,b}	0.77 (1.39)^{c}

Notes: Significance of differences between trajectory groups was derived from multinomial logistic regression models using IBM SPSS Statistics for Windows, Version 21.0. Trajectory group membership was regressed on individual difference variables (impulsive personality, delinquency, violence). To avoid multicollinearity, each class of independent variable was entered into different models. Variables that share a superscript letter are not significantly different from one another in the row ($p > .05$). Likewise, variables that do not share a superscript are significantly different from one another in the row. Means are centered; therefore, 0 = mean of that variable. Standard deviations are presented in parentheses after the means. Comparisons across subgroups are based on modal assignment of participants. Odds ratios for all comparisons are available from the authors.

Discussion

The current study examined multiple substance use trajectories across the college transition. Trajectories were based on retrospective and prospective data, thereby allowing for the identification of alcohol, marijuana, and hard drug use groups from age 13 to the junior year of college. The use of a broad timeframe provided descriptions of use before, during, and after the transition to college. Such rich information regarding the progression of use could not be gleaned from simple slices of behavior at any discrete time point; trends in alcohol use groups look remarkably different before and after the college transition, with some groups dramatically changing their use patterns.

The novel results from this study provided useful detail regarding the progression of use over time. Analyses indicated five trajectories for alcohol use, four trajectory groups for marijuana use, and four trajectories for hard drug use. These trajectories provide evidence that some forms of alcohol and substance use are time limited. For alcohol and hard drug use, clear "experimenter" groups emerged that exhibited escalating use in high school followed by decreases throughout college. Trajectories also show that outcomes for the early- and late-onset alcohol and hard drug use groups became strikingly similar by the junior year of college, suggesting that differences in age at onset may not result in appreciably different outcomes in terms of use.

In contrast to previous work examining community samples, this study indicated a higher number of trajectories for alcohol, marijuana, and hard drug use than did previous studies of these areas (Chassin et al. 2002; Flory et al., 2004; Guo et al., 2002; Tucker et al., 2005), suggesting that use by college students may follow different trends. Further, our heavier using alcohol groups do not indicate the same decreases with age found in previous work (Chassin et al., 2002), suggesting that heavy drinking college students are at risk for longer periods. The current analyses found similar gender divergence across alcohol and marijuana use trajectories as previous work (Flory et al., 2004; Greenbaum et al., 2005). Although percentages for women and men were similar among the nil to low and experimenter groups, women comprised a considerably higher proportion of the moderate drinking group and a much smaller proportion of the heaviest drinking groups than men. Similar gender differences were found for marijuana use, with men overrepresenting the highest use categories. As an extension of previous trajectory work (Chassin et al., 2002; Tucker et al., 2005), we explored racial differences across trajectory groups. Notably, more than half of the minority participants fell into the nil to low drinking group, and considerably fewer minority participants were placed in the highest drinking trajectory groups than White participants. Further, minority participants comprised a higher proportion of the highest marijuana use. These results indicate that White college students in this sample may be at higher risk for severe drinking outcomes, and minority participants may be at higher risk for heavy marijuana use.

It is also notable that those in high-use groups were much more likely to be in a higher use group for other substances, a finding highly consistent with previous findings of simultaneous polysubstance use (Barrett et al., 2006). This suggests that high use of any class of drug represents increased risk for other forms of substance use. However, we are careful to limit what we conclude from these analyses given that trajectories represent patterns, not necessarily increasing indicators of severity. This can be quite misleading; for instance, the nil to low and experimenter hard drug groups represent considerably different patterns of use over time, yet by junior year of college the variety of hard drug use per period is virtually the same between these groups.

In addition to examining overlap between substance use classes, we examined factors that may differentiate trajectories. Not surprisingly, the highest use groups were characterized by similar traits across substances. This profile of use is consistent with other findings of personality and behavioral correlates of substance use (Kaiser et al., 2012; McAdams et al., 2012) and some previous trajectory work (Chassin et al. 2002; Flory et al., 2004; Guo et al., 2002) and suggests that heavy polysubstance users are higher in sensation seeking and urgency, and are prone to both delinquent and violent behavior.

The current findings can be applied to the development of prevention and intervention programming. Many universities are developing multi-tiered intervention programs designed to address substance use at different levels of risk, including school-wide education/prevention, targeted intervention for experimenters, and intensive programming for those already using at high rates. The current work suggests that those individuals most likely to be in need of more intensive intervention levels are characterized not only by specific demographic characteristics, but also by different forms of impulsivity, traits that may be of considerable importance when developing interventions. For instance, those high in urgency may benefit from emotion regulation strategies that address strong negative emotions, as highly urgent individuals are more impulsive under conditions of strong affect.

Limitations and future directions

The current work partly relies on retrospective data. Although the Life History Calendar has been shown to be a reliable method for the collection of this type of data across multiple years (Caspi et al., 1996), participants' abilities to accurately recollect specific rates and frequencies of use up to 5 years previously is naturally somewhat diminished. However, findings for alcohol and marijuana use trajectories were somewhat similar to those of previous work from community samples covering this age range, suggesting that methodology was adequate. Moreover, findings point to the importance of

future prospective studies starting earlier in development to overcome the limitations of retrospective reporting.

Although the current study extends previous work by examining trajectories through the transition into college, the prospective assessment ended with the conclusion of junior year. Future work could explore use after college to provide additional information about how use develops. In addition, trajectories past college might exhibit differential relations to impulsive personality; Steinberg (2007) has suggested that the influence of sensation seeking may remit with age. Over time the influence of other characteristics, such as urgency, may have larger contributions to the maintenance of use.

Another limitation of this work is the narrow breadth of the sample, indicating limited generalizability. Participants were at a large, public, southeastern university, with little racial/ethnic variation. Although trends suggested higher minority composition of the nil to low alcohol use group, findings may be different in a sample with greater power to investigate these variables. Gender differences among trajectory groups (with women more likely to populate the lower use categories) suggest that future work could consider gender-specific trajectories. Finally, the current study did not address tobacco products, and because of low endorsement rates, a variety variable was used in the hard drug trajectories. Although this provides a broad overview of use, different hard drugs may have quite varied risk factors and use trends (e.g. Woicik et al., 2009). Future work could explore the distinct differences in hard drug use in populations where this variability is present.

References

American Psychiatric Association. (1994). *Diagnostic and statistical manual of mental disorders* (4th ed.). Washington, DC: Author.

Arnett, J. J. (2000). Emerging adulthood. A theory of development from the late teens through the twenties. *American Psychologist, 55,* 469–480. doi:10.1037/0003-066X.55.5.469

Arria, A. M., Garnier-Dykstra, L. M., Caldeira, K. M., Vincent, K. B., Winick, E. R., & O'Grady, K. E. (2013). Drug use patterns and continuous enrollment in college: Results from a longitudinal study. *Journal of Studies on Alcohol and Drugs, 74,* 71–83. doi:10.15288/jsad.2013.74.71

Barrett, S. P., Darredeau, C., & Pihl, R. O. (2006). Patterns of simultaneous polysubstance use in drug using university students. *Human Psychopharmacology: Clinical and Experimental, 21,* 255–263. doi:10.1002/hup.766

Caspi, A., Moffitt, T. E., Thornton, A., Freedman, D., Amell, J. W., Harrington, H., . . . Silva, P. A. (1996). The life history calendar: A research and clinical assessment method for collecting retrospective event-history data. *International Journal of Methods in Psychiatric Research, 6,* 101–114.

Charnigo, R., Kryscio, R., Bardo, M. T., Lynam, D., & Zimmerman, R. S. (2011). Joint modeling of longitudinal data in multiple behavioral change. *Evaluation & the Health Professions, 34,* 181–200. doi:10.1177/0163278710392982

Chassin, L., Pitts, S. C., & Prost, J. (2002). Binge drinking trajectories from adolescence to emerging adulthood in a high-risk sample: Predictors and substance abuse outcomes. *Journal of Consulting and Clinical Psychology, 70,* 67–78. doi:10.1037/0022-006X.70.1.67

Dick, D. M., Smith, G., Olausson, P., Mitchell, S. H., Leeman, R. F., O'Malley, S. S., & Sher, K. (2010). Understanding the construct of impulsivity and its relationship to alcohol use disorders. *Addiction Biology, 15,* 217–226. doi:10.1111/j.1369-1600.2009.00190.x

Flory, K., Lynam, D., Milich, R., Leukefeld, C., & Clayton, R. (2004). Early adolescent through young adult alcohol and marijuana use trajectories: Early predictors, young adult outcomes, and predictive utility. *Development and Psychopathology, 16,* 193–213. doi:10.1017/S0954579404044475

Garnier, L. M., Arria, A. M., Caldeira, K. M., Vincent, K. B., O'Grady, K. E., & Wish, E. D. (2009). Nonmedical prescription analgesic use and concurrent alcohol consumption among college students. *American Journal of Drug and Alcohol Abuse, 35,* 334–338. doi:10.1080/00952990903075059

Greenbaum, P. E., Del Boca, F. K., Darkes, J., Wang, C. P., & Goldman, M. S. (2005). Variation in the drinking trajectories of freshmen college students. *Journal of Consulting and Clinical Psychology, 73,* 229–238. doi:10.1037/0022-006X.73.2.229

Guo, J., Chung, I.-J., Hill, K. G., Hawkins, J. D., Catalano, R. F., & Abbott, R. D. (2002). Developmental relationships between adolescent substance use and risky sexual behavior in young adulthood. *Journal of Adolescent Health, 31,* 354–362. doi:10.1016/S1054-139X(02)00402-0

Jones, B. L., & Nagin, D. S. (2007). Advances in group-based trajectory modeling and an SAS procedure for estimating them. *Sociological Methods & Research, 35,* 542–571. doi:10.1177/0049124106292364

Kaiser, A. J., Milich, R., Lynam, D. R., & Charnigo, R. J. (2012). Negative urgency, distress tolerance, and substance abuse among college students. *Addictive Behaviors, 37,* 1075–1083. doi:10.1016/j.addbeh.2012.04.017

Kasperski, S. J., Vincent, K. B., Caldeira, K. M., Garnier-Dykstra, L. M., O'Grady, K. E., & Arria, A. M. (2011). College students' use of cocaine: Results from a longitudinal study. *Addictive Behaviors, 36,* 408–411. doi:10.1016/j.addbeh.2010.12.002

Lynam, D. R., Whiteside, S., & Jones, S. (1999). Self-reported psychopathy: A validation study. *Journal of Personality Assessment, 73,* 110–132. doi:10.1207/S15327752JPA730108

McAdams, T., Rowe, R., Rijsdijk, F., Maughan, B., & Eley, T. C. (2012). The covariation of antisocial behavior and substance use in adolescence: A behavioral genetic perspective. *Journal of Research on Adolescence, 22,* 100–112. doi:10.1111/j.1532-7795.2011.00758.x

McGue, M., Iacono, W. G., & Krueger, R. (2006). The association of early adolescent problem behavior and adult psychopathology: A multivariate behavioral genetic perspective. *Behavior Genetics, 36,* 591–602. doi:10.1007/s10519-006-9061-z

Mohler-Kuo, M., Lee, J. E., & Wechsler, H. (2003). Trends in marijuana and other illicit drug use among college students: Results from 4 Harvard School of Public Health College Alcohol Study surveys: 1993-2001. *Journal of American College Health, 52,* 17–24. doi:10.1080/07448480309595719

Nagin, D. S., & Odgers, C. L. (2010). Group-based trajectory modeling in clinical research. *Annual Review of Clinical Psychology, 6,* 109–138. doi:10.1146/annurev.clinpsy.121208.131413

Robbins, R. N., & Bryan, A. (2004). Relationships between future orientation, impulsive sensation seeking, and risk behavior among adjudicated adolescents. *Journal of Adolescent Research, 19,* 428–445. doi:10.1177/0743558403258860

Schulenberg, J. E., Maggs, J. M., & O'Malley, P. M. (2003). How and why the understanding of developmental continuity and discontinuity is important: The sample case of long-term consequences of adolescent substance use. In J. T. Mortimer & M. J. Shanahan (Eds.), *Handbook of the life course* (pp. 413–436). New York, NY: Plenum Publishers.

Schulenberg, J. E., Merline, A. C., Johnston, L. D., O'Malley, P. M., Bachman, J. G., & Laetz, V. B. (2005). Trajectories of marijuana use during the transition to adulthood: The big picture based

on national panel data. *Journal of Drug Issues, 35,* 255–280. doi:10.1177/002204260503500203

Sher, K. J., & Gotham, H. J. (1999). Pathological alcohol involvement: A developmental disorder of young adulthood. *Development and Psychopathology, 11,* 933–956. doi:10.1017/S0954579499002394

Slutske, W. S. (2005). Alcohol use disorders among US college students and their non-college-attending peers. *Archives of General Psychiatry, 62,* 321–327. doi:10.1001/archpsyc.62.3.321

Slutske, W. S., Hunt-Carter, E. E., Nabors-Oberg, R. E., Sher, K. J., Bucholz, K. K., Madden, P. A. F., . . . Heath, A. C. (2004). Do college students drink more than their non-college-attending peers? Evidence from a population-based longitudinal female twin study. *Journal of Abnormal Psychology, 113,* 530–540. doi:10.1037/0021-843X.113.4.530

Steinberg, L. (2007). Risk taking in adolescence: New perspectives from brain and behavioral science. *Current Directions in Psychological Science, 16,* 55–59. doi:10.1111/j.1467-8721.2007.00475.x

Tucker, J. S., Ellickson, P. L., Orlando, M., Martino, S. C., & Klein, D. J. (2005). Substance use trajectories from early adolescence to emerging adulthood: A comparison of smoking, binge drinking, and marijuana use. *Journal of Drug Issues, 35,* 307–332. doi:10.1177/002204260503500205

White, H. R., Labouvie, E. W., & Papadaratsakis, V. (2005). Changes in substance use during the transition to adulthood: A comparison of college students and their noncollege age peers. *Journal of Drug Issues, 35,* 281–306. doi:10.1177/002204260503500204

Whiteside, S. P., & Lynam, D. R. (2001). The Five Factor Model and impulsivity: Using a structural model of personality to understand impulsivity. *Personality and Individual Differences, 30,* 669–689. doi:10.1016/S0191-8869(00)00064-7

Woicik, P. A., Stewart, S. H., Pihl, R. O., & Conrod, P. J. (2009). The Substance Use Risk Profile Scale: A scale measuring traits linked to reinforcement-specific substance use profiles. *Addictive Behaviors, 34,* 1042–1055. doi:10.1016/j.addbeh.2009.07.001