Health Psychology
2004, Vol. 23, No. 3, 299–307

0278-6133/04/$12.00 DOI: 10.1037/0278-6133.23.3.299

Marijuana Use From Adolescence to Young Adulthood: Multiple Developmental Trajectories and Their Associated Outcomes

Phyllis L. Ellickson, Steven C. Martino, and Rebecca L. Collins
RAND

This study used latent growth mixture modeling to identify discrete developmental patterns of marijuana use from early adolescence (age 13) to young adulthood (age 23) among a sample of 5,833 individuals. After the a priori removal of abstainers, 4 trajectory groups were identified: early high users, who decreased from a relatively high level of use at age 13 to a more moderate level; stable light users, who maintained a low level of use; steady increasers, who consistently increased use; and occasional light users, who began use at age 14 and used at low levels thereafter. Analyses of covariance comparing the trajectory groups on behavioral, socioeconomic, and health outcomes at age 29 revealed that abstainers consistently had the most favorable outcomes, whereas early high users consistently had the least favorable outcomes.

Key words: marijuana use trajectories, outcomes, modeling

Marijuana is the illicit drug of choice among youth and adults; 22% of high school seniors and 14% of adults aged 19 to 32 reported marijuana use in the past 30 days (Johnston, O'Malley, & Bachman, 2001, 2002). The long-term effects of marijuana use are only beginning to be revealed, but reviews highlight several areas of concern (Stephens, 1999; Sussman, Stacy, Dent, Simon, & Johnson, 1996). More frequent use of marijuana during adolescence is associated with poorer achievement and lower expectations for academic success (Brook, Gordon, Brook, & Brook, 1989; Donovan, 1996), family problems (Brook et al, 1989; Newcomb & Bentler, 1988), a greater likelihood of using other drugs (Kandel, 2003), and postponement of marriage and employment (Brook, Richter, Whiteman, & Cohen, 1999; Yamaguchi & Kandel, 1985). Marijuana may contribute to cognitive impairments (Pope & Yurgelun-Todd, 1996; Solowij, Michie, & Fox, 1995), adverse effects on long-term physical health (Sherman, Roth, Gong, & Tashkin, 1991; Tashkin et al., 1987), and higher levels of anxiety, depression, and suicidal ideation (Fergusson, Horwood, & Swain-Campbell, 2002; Green & Ritter, 2000; Patton et al., 2002). Although these relationships are not necessarily causal, a better understanding of how marijuana use develops and progresses over the course of early life might help to prevent negative consequences. Longitudinal studies that identify patterns of use over time and determine subsequent outcomes associated with different developmental patterns can help provide that understanding.

Previous research has defined the natural history of marijuana use from adolescence through mature young adulthood. The rate of initiation begins to accelerate at approximately age 13, reaches a peak at ages 18 to 19, and then declines sharply, such that the probability of initiating marijuana use after age 20 is very small (T. E. Duncan, Tildesley, Duncan, & Hops, 1995; Kandel & Logan, 1984; Kosterman, Hawkins, Guo, Catalano, & Abbott, 2000). Although males show slightly higher rates of use throughout adolescence and adulthood, the general developmental trajectory of marijuana use is similar for males and females: Marijuana use increases through age 19, stabilizes between ages 19 and 24, and then continuously declines at least until the mid-30s (Chen & Kandel, 1995; Kandel & Davies, 1992; Kandel & Logan, 1984; Raveis & Kandel, 1987).

To date, research on the development of marijuana use has focused on understanding the average trajectory of use. However, research has demonstrated considerable heterogeneity in developmental trajectories of substance use (Chassin, Presson, Pitts, & Sherman, 2000; Colder et al., 2001; Hill, White, Chung, Hawkins, & Catalano, 2000; Li, Duncan, & Hops, 2001; B. Muthén & Shedden, 1999; Tucker, Orlando, & Ellickson, 2003). Although subgroups with different trajectories of marijuana use have yet to be identified empirically, several studies have demonstrated substantial variation in age of initiation of marijuana use and in rates of change in use, suggesting that not all marijuana users follow the same developmental trajectory (Bachman, Wadsworth, O'Malley, Johnston, & Schulenberg, 1997; Brook, Adams, Balka, & Johnson, 2002; Ellickson, Bui, Bell, & McGuigan, 1998; Kandel & Chen, 2000; Labouvie & White, 2002; Morojele & Brook, 2001).

Identifying multiple developmental trajectories of marijuana use within a heterogeneous sample has numerous advantages (Rapkin & Dumont, 2000). The results may uncover time periods during which specific groups are particularly vulnerable to onset and escalation of use and thus most in need of prevention efforts (e.g., high school or college for late-onset users). They may also pinpoint subgroups in need of more intense intervention programs because they are at especially high risk for experiencing adverse consequences or exhibiting related problem behaviors. In addition,

Phyllis L. Ellickson, Steven C. Martino, and Rebecca L. Collins, RAND, Santa Monica, California.

This research was supported by National Institute on Drug Abuse Grant DA13515. We thank Bengt Muthén for his helpful comments on data analysis.

Correspondence concerning this article should be addressed to Phyllis L. Ellickson, RAND, 1700 Main Street, P.O. Box 2138, Santa Monica, CA 90407-2138. E-mail: Phyllis_Ellickson@rand.org

different trajectory groups are likely to be quite homogeneous; hence, distinguishing among them increases our ability to accurately predict subgroup behavior. Although risk and protective factors for onset and escalation of marijuana use have been identified in numerous studies (Bachman, Johnston, O'Malley, & Humphrey, 1988; Bachman, Johnston, & O'Malley, 1998; Bailey & Hubbard, 1990; Brook, Whiteman, Finch, Morojele, & Cohen, 2000; Chen & Kandel, 1995; T. E. Duncan et al., 1995; Kandel & Davies, 1992; Kandel & Logan, 1984; Kaplan, Martin, Johnson, & Robbins, 1986; Raveis & Kandel, 1987; Wills, McNamara, Vaccaro, & Hirky, 1996), these studies do not distinguish individuals on one trajectory from those on another. It is likely that different sets of risk factors are relevant to marijuana use that emerges in early versus later youth and to chronic use that escalates, declines, or remains steady. Outcomes of different developmental patterns of use are likely to differ as well. For example, research suggests that use histories that account for ages of onset and use intensities are superior to those based on age of onset alone for predicting drug abuse and dependence in young adulthood (Labouvie & White, 2002).

Quantitative methods that allow for the identification of multiple discrete developmental trajectories within an overall longitudinal design have advanced considerably in recent years. Earlier methods of latent growth modeling involved the identification of a single growth trajectory, with individual differences in development captured by random effects. These effects represent variation in components of growth such as initial status and rate of change (Duncan, Duncan, Biglan, & Ary, 1998). However, this approach does not allow for the description of different classes of growth with distinct starting points and changes in use over time. Such differences can be captured by a newer method, latent growth mixture modeling (B. Muthén, 2001a, 2001b; B. Muthén & Shedden, 1999), which uses repeated measures of one or more indicators to estimate discrete latent trajectory classes, each of which has a unique random-effects growth model (B. Muthén, 2001a). Each estimated class describes a particular pattern of use, and each participant's data are assumed to be a random realization of one of the possible members of a class. Growth mixture modeling provides the average trajectory for each class, the trajectory variation within each class, and estimates of each participant's most likely class membership. Growth mixture modeling is also more versatile than related approaches (e.g., Nagin, 1999) in that it allows for individual variation within classes and does not assume that all individuals within a class follow the same developmental path.

The current study uses latent growth mixture modeling to identify discrete patterns of marijuana use from early age 13 to age 23 and analysis of covariance (ANCOVA) to examine whether membership in different trajectory groups predicts behavioral, socioeconomic, and health outcomes at age 29.

Method

Sample

This study involves participants in the RAND Adolescent/Young Adult Panel Study, a multiyear panel study originally conducted to evaluate Project ALERT, a drug prevention program for middle-school children (Ellickson & Bell, 1990). The baseline panel of 6,527 adolescents was drawn from 30 California and Oregon middle schools representing diverse community and school environments. Nine schools had minority populations of 50% or more, the schools varied in the socioeconomic status of their average enrollees, and they were of varying sizes, as were the communities in which they were situated. The result was a diverse sample with demographic characteristics similar to those observed nationally.

The growth mixture analysis used information about marijuana use from six waves of data collected over a 10-year period when participants were at average ages of 13 (Grade 7), 14 (Grade 8), 15 (Grade 9), 16 (Grade 10), 18 (Grade 12), and 23. As a consequence of intermittent attrition, not all panel members responded at every data collection point. Participants were excluded from the growth mixture analysis if they were missing marijuana use data for more than three of the six survey waves that were modeled ($n = 552$), lacked demographic information ($n = 5$), or were highly erratic in their responses to the marijuana use items over time (increasing 3 or more points from one wave to the next followed by a decrease of 3 or more points at the subsequent wave; $n = 137$). These omissions resulted in a final sample of 5,833. Participants who were involved in our examination of whether marijuana use trajectory class membership predicts outcomes at age 29 were a subset of this sample who completed a survey at age 29 (*n*s range from 2,499 to 2,526 because of missing data on particular outcome variables at this survey wave).

Procedure

Participants completed self-administered surveys in school at Grades 7 through 10 and by mail at Grade 12, age 23, and age 29. To examine the validity and reliability of self-reported substance use over the first four waves of the study, we collected saliva samples before the survey and compared the results for cotinine (a metabolite of nicotine) with self-reported smoking (Ellickson, Bell, Thomas, Robyn, & Zellman, 1988). We also examined the consistency of self-reported use of cigarette, alcohol, and marijuana use over time. The results suggest that the majority of students were honest about their substance use. At baseline and 15 months later, 95% of students with cotinine scores that identified them as recent tobacco users had admitted to using cigarettes or smokeless tobacco on their questionnaires (Freier, Bell, & Ellickson, 1991). Across four waves of data, the proportion of students who denied using cigarettes, alcohol, or marijuana after previously admitting use averaged about 5%. Retractions of frequent use averaged substantially less than 1% (Reinisch, Bell, & Ellickson, 1991).

Measures

Marijuana use was measured with a pair of items at each of the six assessments. At each assessment, participants reported the number of times in the past year and the number of days in the past month they used marijuana. Responses to these two items were used to create a 5-point index of marijuana use frequency (0 = *no use in past year*; 1 = *less than 3 times in past year*; 2 = *3–10 times in past year*; 3 = *11 or more times in past year and less than 6 times in past month*; 4 = *11 or more times in past year and 6 or more times in past month*). Thus, the outcome measure distinguished all participants on their frequency of past year marijuana use and further distinguished those who used 11 or more times in the past year based on their frequency of past month use.

Demographic characteristics included gender, race–ethnicity (four dummy-coded vectors used to compare Caucasians vs. African Americans, Hispanics, Asian Americans, and others), and whether participants lived in an intact nuclear family at age 13.

Outcomes at age 29 included educational attainment (1 = *8th grade or less* to 11 = *advanced professional degree*), earnings over the past year (in thousands of dollars), and participants' assessment of their overall health (1 = *poor* to 5 = *excellent*). The Mental Health Index–5 (Stewart, Hays, & Ware, 1988) was used as a measure of mental health (e.g., "How much of the time during the past 30 days have you felt calm and peaceful, been a nervous person, felt downhearted and blue?" Items were reverse-scored

as needed so that higher numbers indicate better mental health; $\alpha = .83$). We also examined life satisfaction at age 29 with a single item: "In general, how satisfied do you feel with your life?" (1 = *very dissatisfied*, 5 = *very satisfied*). A single dichotomous indicator represented any hard drug use (uppers, downers, cocaine, PCP [phencyclidine], LSD [D-lysergic acid diethylamide], and heroin) in the past year. We also included the index of marijuana use frequency described previously.

Analytic Approach

Estimation of latent growth trajectories. We used latent growth mixture modeling to identify subgroups of individuals with common patterns of marijuana use across the period from ages 13 to 23, using Mplus (L. K. Muthén & Muthén, 1998). The latest version of Mplus allows for missing values on the outcome variable at some time points and uses all available data to estimate the model parameters.[1] The modeled outcome variable was frequency of marijuana use. Latent growth mixture modeling can identify use trajectories only among those with multiple nonzero values on this outcome. Thus, one a priori class of use, abstainers ($n = 2{,}648$), was identified and omitted from the growth mixture analysis. Abstainers were those participants who reported no marijuana use over the six assessments. Data from the remaining 3,185 participants were used to estimate latent growth trajectories. To model different times and rates of growth in marijuana use, we followed procedures recommended by B. Muthén (2001a, 2001b). From our repeated measures of marijuana use, we estimated three continuous latent variables corresponding to the three components of quadratic growth (intercept, linear, and quadratic). By including the quadratic term, we allowed for estimation of nonlinear trajectory shapes. The log transformation of the year of data collection (from 1 to 11) was used to represent the passage of time over the study period. In addition to this overall growth model, we allowed for a number of latent classes, with each class possessing unique growth factor means, therefore, representing discrete growth trajectories. To achieve model identification, we set the residual variance of marijuana use scores at baseline to zero. This constraint was necessary because of limited variability in marijuana use at age 13. Growth factor variances and residual variances of the observed marijuana use values were constrained to be equal for all classes. We used three criteria to identify the most appropriate number of latent trajectory classes: (a) the difference in the model Bayesian information criterion values (BIC; Kass & Raftery, 1995; Schwartz, 1978);[2] (b) the average probability of class membership for each estimated class; and (c) the shape of the estimated growth trajectories. A good solution is one in which BIC is minimized, average probabilities of class membership are high, and trajectory shapes are sensible given previous findings (B. Muthén & Shedden, 1999). After determining the appropriate number of trajectory classes, we re-estimated the model with the addition of four time-invariant covariates—gender, race–ethnicity, family structure, and parents' education—as predictors of class membership.

Demographic characteristics and psychosocial trends among growth trajectory classes. Participants were assigned to the trajectory class for which they had the highest probability of membership[3] and then compared on several demographic characteristics to assess whether groups such as females or Caucasians were over- or underrepresented in specific trajectory classes. We examined all pairwise group comparisons, adjusting significance levels for these comparisons using the Bonferroni-Dunn approach to control familywise error rates (Dunn, 1961). To examine whether shifts in environmental and personal characteristics were associated with shifts in growth trajectories, we also examined the degree to which shifts in social influences and the ability to resist them paralleled the growth curves of the different trajectory classes. We did this by plotting adjusted means for each trajectory group on a single-item measure of received marijuana offers (0 = *not at all*, 5 = *20 or more times in the past year*) and a three-item measure of inability to resist such offers (standardized and averaged at each wave; mean α reliability = .77) at ages 13, 14, 15, and 18. We focused on social influence factors because they are central to both the initiation and the maintenance of substance use. We chose marijuana offers and perceived low resistance-self-efficacy as our measures because both constructs are likely to change over time, have been shown to predict marijuana use in previous research, and were measured in the relevant middle-school and high school years. The means were adjusted for gender, race–ethnicity, family composition, and parents' education.

Comparison of trajectory classes on outcomes at age 29. We used ANCOVA to compare trajectory classes on each of our age 29 outcome measures. ANCOVA adjusts within-class means to what they would be if all trajectory classes were equal on one or more covariates and then tests whether these adjusted means are equivalent. Covariates included in these analyses were gender, race–ethnicity, family structure, and parents' education. When an omnibus test of the adjusted means indicated a significant effect of class membership on an outcome variable, we followed it with pairwise comparisons of the adjusted means. Once again, significance levels for these comparisons were adjusted to maintain a familywise error rate of .05.

Sampling Weights

We used sampling and attrition weights to allow for inference back to the baseline sample of 6,527. In addition to the 11% of the baseline sample not eligible for inclusion in the growth mixture analysis, there was attrition within the selected sample from baseline to age 29 (56%). We constructed two sets of weights—one for the baseline demographic comparisons and one for our predictive analyses—that we derived from logistic regression models with multiple baseline characteristics (e.g., race–ethnicity, gender, family structure, deviance, substance use, and grades) as predictors of eligibility at baseline and eligibility and participation at age 29. Use of these weights, which are the inverse of the predicted probability of selection–participation, removes a considerable proportion of the sampling bias (McGuigan, Ellickson, Hays, & Bell, 1997) and results in larger standard errors and more conservative hypothesis tests.

Results

Identification of Trajectory Classes

Using change in BIC as an initial indicator of the comparative fit of models with different numbers of classes, we noted that BIC values decreased with the addition of a third and fourth class ($BIC_2 = 47596.1$, $BIC_3 = 45513.4$, $BIC_4 = 44908.8$). We were unable to attain convergence for a five-class solution. In further evaluating the relative suitability of these solutions, we inspected the shape of the marijuana use trajectories and considered the average predicted probabilities of class membership for each so-

[1] Maximum likelihood estimation is performed under MAR (missing at random).

[2] BIC is calculated as $-2\log(L) + r\ln(n)*(n)$, where L is the maximum likelihood value for the model, n is the sample size, and r is the number of free model parameters. As the model's fit with the data improves, the first term of the equation decreases. A decrease in this first term can be achieved by adding parameters to the model; however, the second term of the equation imposes a penalty for the addition of parameters. Thus, on the basis of the BIC criterion, the addition of a trajectory group is only warranted if the resulting improvement in the log likelihood is greater than the penalty imposed for increasing the complexity of the model.

[3] This is a limitation of our analysis in that there are likely to be a small number of individuals for whom class membership is not well defined even considering the high average probabilities for membership in each trajectory class.

lution. Again, the four-class solution appeared most appropriate. This solution yielded clearly distinct and interpretable trajectories that had high average probabilities for class membership (range = .80–1.00) and consisted of sufficient percentages of the analysis sample (53%, 25%, 17%, 5%). Our final solution specified four latent trajectory classes and included the four demographic covariates as predictors of class membership. To investigate the stability of this solution, we re-estimated the model with different starting values for the growth parameters. The solution proved robust to differences in starting values, suggesting that optimization was not achieved through identification of a local maximum. The *Z* scores for the growth parameter variance estimates were .05 (intercept term), 11.21 (linear term), and 10.16 (quadratic term). The solution accounted for a considerable amount of the variance in observed responses, R^2s = 1.00 (age 13), .46 (age 14), .57 (age 15), .48 (age 17), .32 (age 18), and .52 (age 23).

Figure 1 presents the four model-predicted marijuana use trajectories. Predicted marijuana use scores for each class are a function of the product of each growth parameter mean and the time variable (log transformation of the year of data collection) raised to the appropriate power (0 for intercepts, 1 for linear terms, 2 for quadratic terms). To facilitate discussion and interpretation, we have added descriptive labels to the classes. Early high users (5% of marijuana users, average probability of membership = 1.00) started out with a relatively high level of use at age 13 (between monthly and weekly use), decreased their use until approximately age 18, and thereafter maintained a relatively moderate level of use (approximately 3–10 times per year). Stable light users (17% of marijuana users, average probability of membership = 1.00) started out at age 13 with a relatively low level of use and maintained this level of use throughout the study period, never using more than 10 times in the past year on average. Occasional light users (53% of marijuana users, average probability of membership = .82) represented the normative class of marijuana users. The trajectory shape of occasional light users was similar to that of stable light users except that occasional light users exhibited no use at age 13 and comparatively lower levels of use at all other time points. Finally, steady increasers (25% of marijuana users, average probability of membership = .80) began with no use at age 13 and increased their use in a near-linear fashion throughout the study. By age 23, steady increasers exhibited the highest level of use of all marijuana users (between monthly and weekly use).

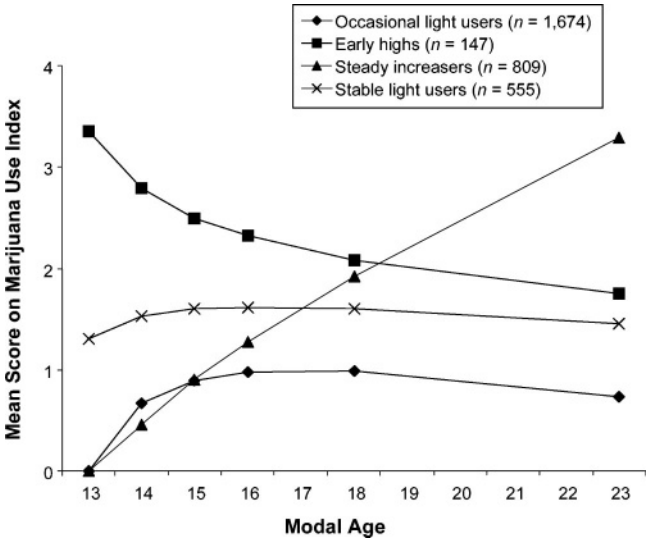

Figure 1. Model-predicted marijuana use trajectories from age 13 to age 23.

Demographic and Psychosocial Comparisons

Table 1 shows the percentage of participants in each demographic category as a function of marijuana class membership as well as the standing of each class on the continuous measure of parents' education. Women were significantly overrepresented among occasional light users and significantly underrepresented among steady increasers, although the percentages of women in the steady increaser and early high user groups are not significantly different from one another. Caucasians were most likely to be steady increasers and occasional light users. African Americans were most highly represented among stable light users, although the proportion of African Americans in the stable light user and early high user groups did not differ significantly. Hispanics were overrepresented among early high users and stable light users, the two classes with the highest levels of use at age 13, whereas Asian Americans were most highly represented among abstainers. Other racial and ethnic groups were overrepresented among early high users and stable light users, although the proportion of other racial and ethnic groups among steady increasers was not significantly different from the proportions represented in the early high and stable light user groups. The proportion of participants with intact two-parent families was highest among abstainers, followed by occasional light users, steady increasers, and, finally, early highs and stable light users (who did not differ in this regard). Parent education was highest among steady increasers, followed by abstainers, occasional light users, and, finally, stable light users and early high users. Parents of the latter two groups did not differ in their level of education.

Figure 2 shows adjusted means for marijuana offers and perceived ability to resist them over time. The early high users, who reduced their marijuana use after age 13, also had fewer offers at ages 14 and 15 than they had received earlier; at the same time, their perceived ability to resist marijuana offers increased. The steady increasers, whose use increased from age 13 to 23, experienced parallel increases in marijuana offers and decreases in resistance self-efficacy from ages 13 to 18. The occasional light users looked like the steady increasers on exposure and self-efficacy during middle school and early high school but diverged substantially after age 15. Trends for the stable light users paralleled those for the early high users (but at a lower level for offers and higher level for resistance self-efficacy). Abstainers had low exposure and high self-efficacy levels throughout middle school and high school.

Comparison of Trajectory Classes on Age 29 Outcomes

ANCOVAs revealed that trajectory class membership had a significant influence on educational attainment, subjective health judgments, mental health, life satisfaction, earnings, and rates of hard drug use at age 29, all *F*s > 3.94, all *p*s < .01. Table 2 contains trajectory group means on each of these outcome vari-

Table 1
Percentage of Participants in Each Demographic Group According to Marijuana Use Trajectory Class

Variable	Marijuana use trajectory class					
	Early high users (n = 147)	Steady increasers (n = 809)	Stable light Users (n = 555)	Occasional light users (n = 1,674)	Abstainers (n = 2,648)	Overall (n = 5,833)
Female	41_{bc}	32_{c}	49_{b}	58_{a}	48_{b}	49
White	60_{bc}	71_{a}	57_{c}	72_{a}	66_{b}	68
African American	11_{ab}	10_{b}	15_{a}	8_{b}	11_{b}	9
Hispanic	20_{a}	8_{b}	20_{a}	10_{b}	8_{b}	10
Asian American	2_{bc}	7_{b}	2_{c}	6_{bc}	2_{a}	9
Other race–ethnicity	7_{a}	4_{ab}	7_{a}	4_{b}	3_{b}	4
Nuclear family	31_{d}	61_{b}	34_{d}	55_{c}	68_{a}	61
Parents' education[a]	1.49_{d}	2.14_{a}	1.63_{d}	1.90_{c}	2.02_{b}	1.96

Note. Entries in each row with same subscript are not different from one another using a Bonferroni-Dunn adjusted p value of .005.
[a] Entries for parents' education are mean values on a scale from 0 (*less than high school*) to 3 (*college degree or more*).

ables (plus marijuana use), adjusted for gender, race–ethnicity, family structure, and parents' education. As Table 2 demonstrates, abstainers had a higher level of educational attainment, better overall health, greater life satisfaction, and lower rate of hard drug use at age 29 than all other trajectory classes. Abstainers also had higher earnings than all other groups except for occasional light users, whose earnings did not differ from those of abstainers. The mental health of abstainers was superior to that of occasional light users and steady increasers but not different from that of early highs or stable light users.

In contrast, early high users fared significantly worse than all other groups on overall health and yearly earnings and had the lowest educational attainment of all other groups except stable light users, with whom they did not differ. Early high users did not differ from any other group in terms of their mental health and did not differ from any other marijuana user group (i.e., occasional light users, stable light users, and steady increasers) on life satisfaction. Early high users had a higher rate of hard drug use than occasional light users and abstainers but did not differ from stable light users or steady increasers in this respect.

Steady increasers, stable light users, and occasional light users had similar overall health, mental health, and life satisfaction. Occasional light users had higher educational attainment, a lower rate of hard drug use, and higher earnings than stable light users and steady increasers. Steady increasers attained a higher level of educational attainment than stable light users, but otherwise these two groups did not differ.[4]

Finally, we note that all five groups had lower mean scores on marijuana use at age 29 than they did at age 23. However, the steady increasers continued to exhibit substantially higher rates of marijuana use at age 29 than all other groups.

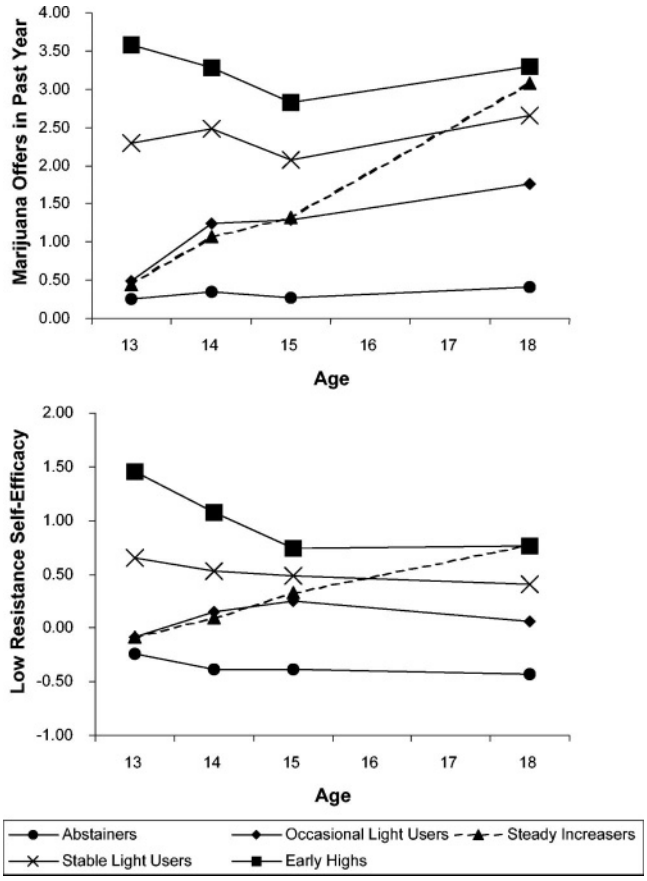

Figure 2. Mean marijuana offers and low resistance-self-efficacy at ages 13, 14, 15, and 18 by marijuana use trajectory group.

Discussion

Using latent growth mixture modeling with data from a diverse West Coast sample, we identified four distinct trajectories of marijuana use over a 10-year period from adolescence to young adulthood. Forty-five percent of the sample qualified as abstainers (reported no use at the six assessments) and were excluded from the growth mixture analysis. Among marijuana users, two trajectory groups had initiated use by age 13 (early high users and stable light users). Despite starting at the same age, these two groups had different patterns of use over time and different levels of earnings and health later in life, even after controlling for background

[4] We reran these analyses of covariance with a measure of binge drinking at age 29 included among the set of covariates. Adding this variable to the model did not change the results.

Table 2
Adjusted Means, and Standard Errors, and Percentages on Age 29 Outcomes by Marijuana Use Trajectory Classes

Variable	Marijuana use trajectory class					Overall *F*
	Early high users (n = 37)	Steady increasers (n = 336)	Stable light users (n = 171)	Occasional light users (n = 753)	Abstainers (n = 1,229)	
Overall health						
M	3.53_{c}	3.82_{b}	3.86_{b}	3.89_{b}	4.03_{a}	9.23**
SE	0.10	0.05	0.06	0.03	0.03	
Mental health						
M	3.64_{ab}	3.67_{b}	3.82_{ab}	3.72_{b}	3.84_{a}	3.94*
SE	0.10	0.05	0.05	0.03	0.03	
Life satisfaction						
M	3.88_{b}	3.99_{b}	4.03_{b}	4.10_{b}	4.27_{a}	9.93**
SE	0.11	0.05	0.06	0.03	0.03	
Educational attainment						
M	5.56_{d}	6.48_{c}	5.99_{d}	6.89_{b}	7.43_{a}	38.65**
SE	0.24	0.11	0.13	0.08	0.06	
Yearly earnings[a]						
M	20.94_{c}	28.14_{b}	27.71_{b}	32.29_{a}	31.93_{a}	8.58**
SE	2.39	1.12	1.32	0.78	0.64	
Past year hard drug use						
%	27.4_{c}	31.9_{c}	30.3_{c}	18.3_{b}	8.5_{a}	36.91**
Marijuana use frequency						
M	0.90_{c}	2.17_{e}	1.32_{d}	0.53_{b}	0.14_{a}	245.12**
SE	0.13	0.06	0.07	0.04	0.03	

Note. Means and percentages are adjusted for gender, race–ethnicity, parental education, and nuclear family. Entries in each row with same subscript are not different from one another using a Bonferroni-Dunn adjusted p value of .005.
[a] In thousands of dollars.
* $p < .01$. ** $p < .001$.

differences between the two subsamples. The other two trajectory groups (occasional light users and steady increasers) both initiated use between ages 13 and 15 but also showed sharply different patterns of use and outcomes.

The early high users, who accounted for 5% of the users, exhibited high marijuana use rates as young adolescents, attaining a level of use by age 13 that ranged between monthly and weekly. By the time these early starters made the transition into high school, however, they had reduced their consumption to less than once a month, a rate that further declined to between 3 and 10 times per year by age 23. In contrast, the stable light users (17% of the user sample) started using at a level that was close to where the early high users ended up and maintained that moderately low rate throughout the 10-year period. The occasional light users, who constituted the largest group of marijuana users (53%) and started using later, maintained experimental levels of use (less than 3 times a year) from adolescence to young adulthood. Only the steady increasers, who constituted 25% of the user sample, increased their level of use each year after initiation; by age 23, they had the highest use rate of all four marijuana user groups.

Despite the moderate to low use rates exhibited by three of the four user groups at age 23, their outcome profiles at age 29 varied substantially from each other and from those of the higher using steady increasers. Controlling for gender, race–ethnicity, household composition, and parental education, we found that the early high users had significantly lower earnings and overall health than all other groups and significantly lower educational attainment than all but the stable light users. The stable light users, who also started early but maintained moderately low levels of marijuana use for the succeeding 10 years, did no better educationally than the early high users and significantly worse than the other two trajectory groups. They also earned significantly less than the occasional light users and abstainers. These results indicate that early marijuana use predicts diminished income and schooling even when users maintain a consistently light level of use. They also suggest that the mechanism by which this relationship occurs may have more to do with lifestyle propensities shared by early marijuana users than with how much or how often marijuana is consumed over time.

In contrast, the steady increasers, who started using marijuana after age 13 but caught up to and exceeded all other groups in frequency of use at age 23, had significantly higher educational and earning levels than the two early-starting groups. However, they fared less well in terms of education and earnings than the occasional light users, who also started using marijuana later but consumed much less over the 10-year period. At age 29, the steady increasers were also substantially more likely to use hard drugs than the occasional lights; moreover, their levels of hard drug use equaled those of the early starters. Thus, delaying marijuana initiation does not necessarily protect young people from getting involved with hard drugs or from having problems at school, particularly if the late starters accelerate their marijuana use to levels that exceed the consumption rates of most of their peers.

However, abstaining from marijuana use altogether or keeping use to experimental levels of no more than three times per year does predict better young adult outcomes. By age 29, abstainers outperformed all other groups with regard to educational achievement, overall health, and life satisfaction; in addition, they had the lowest hard drug use rates and higher earnings than all but the occasional light users. The latter group, who never used more than

three times a year on average, earned as much as the abstainers at age 29 and had the second highest level of educational attainment and the second lowest rates of hard drug use.

Results from this study also indicate that early marijuana use does not necessarily presage escalated use. The early high users, who exhibited high use levels by age 13, reversed their trajectory during middle school, diminishing their marijuana consumption each year from grade 8 through age 23. The stable light users, who also started using marijuana by age 13, maintained a moderately low level of use over a 10-year period. Only the later starting steady increasers actually expanded their use over time. Thus, an important window of opportunity for preventing the escalation of marijuana use opens up during high school, one that may be missed by prevention programs targeted solely at middle-school students.

Although starting to use marijuana by Grade 7 does not necessarily predict deepening involvement with marijuana over time, starting to use before age 15 does indicate a higher risk for using other illicit drugs that is independent of demographic differences among the groups. By age 29, all four user groups exhibited levels of hard drug use that were between two and nearly four times higher than those registered by the abstainers. Less than 9% of those who abstained from using marijuana through age 23 were hard drug users at age 29 compared with 20% of the occasional light users and about 30% of the other three groups. These results indicate that even low or experimental marijuana use, if consistent over time, is associated with an increased risk of involvement with other illicit drugs.

Although our data reveal significant links between specific marijuana use trajectories and subsequent health, educational, and behavioral outcomes, we cannot conclude that marijuana use per se causes any of these relationships. It is also possible that marijuana use reflects preexisting propensities to choose lifestyles or environments that foster lower educational and occupational achievement, poorer health and life satisfaction, and greater use of illicit drugs (Gottfredson & Hirschi, 1994; Jessor & Jessor, 1977). Such a propensity may be reinforced when adolescents use marijuana and associate with other users.

Our study sheds only modest light on why some marijuana users start early and then curb their use, whereas others consistently maintain low levels of use and still others start later and steadily escalate over time. Hispanics were overrepresented in the two early-starter groups, as were youth from disrupted families and those whose parents had comparatively lower educational levels. Although coming from a broken home or a relatively disadvantaged economic background may contribute to early initiation, these characteristics do not explain why the early high users reduced their use after age 13 and why both early-starter groups converged to relatively low rates by age 23. Both abstainers and steady increasers were significantly more likely to come from two-parent families and to have comparatively well-educated parents, but one relatively advantaged group did not use marijuana at all and the other became the most frequent users by age 23. Our data do suggest that environmental and personal changes in a young person's life, particularly shifts in exposure to promarijuana social influences and in one's perceived ability to resist them, may be associated with diminished use among the early high users and escalated use among the steady increasers. However, we have not identified environmental or personality changes that precede trajectory shifts, which would provide stronger causal evidence. Nor have we examined changes in numerous other risk factors from the environmental, behavioral, and personality domains. Future analyses are needed to identify additional risk and protective factors that may be associated with different patterns of marijuana use over time.

Although in this article we have concentrated on the association between adolescent marijuana use and negative young adult outcomes, it is important to note that 45% of this multicommunity sample were nonusers throughout the vulnerable period from adolescence to emerging adulthood. Thus, a substantial proportion of young people were at low risk for most of the negative circumstances of young adulthood studied here. To further refine and enhance prevention programs and to promote these more positive life outcomes, we need a better understanding of the factors that protect these abstainers from using marijuana throughout adolescence and early adulthood.

We also note that marijuana use appeared to peak among all groups at age 23 and decline thereafter. These findings, which are consistent with other studies (Chen & Kandel, 1995; Kandel & Davies, 1992), underscore the importance of identifying factors that contribute to diminished use among all young adults after the early 20s.

Limitations of this study include its reliance on self-report measures and the loss of much of the baseline sample by the time participants were 29. Although we did not validate self-reports for all problem behaviors in our sample, reports of substance use in this cohort were found to be highly accurate when externally validated and subjected to internal reliability checks (Reinisch et al., 1991). To mitigate possible bias from attrition, we used weights for baseline demographic comparisons, psychosocial trends, and predictive analyses. In other analyses of this data set (McGuigan et al., 1997), such weights have been found to remove 90% or more of the attrition bias. We also note that our trajectories and outcome data are derived from a West Coast sample and may not be generalizable to other areas. However, previous analyses have shown that prevalence rates for drug use, school dropout, and multiple problem behaviors in this cohort are within the range typically found in national studies (Ellickson, Collins, & Bell, 1999; Ellickson, McGuigan, Adams, Bell, & Hays, 1996; Ellickson, Saner, & McGuigan, 1997). Finally, we have not captured variation in trajectories that may have occurred after age 23, although, as noted previously, data on marijuana use at age 29 suggest that use declines for all groups.

To our knowledge, this study is the first to identify multiple marijuana use trajectories during the period from adolescence to emerging adulthood and to link those trajectories with predicted outcomes 5 years later. It has yielded several important findings, including the convergence of three of the four trajectories by age 23, the steady rise in use among a subset of users, the significant association between early marijuana use and several negative outcomes at age 29 (even though the earliest users reduced their use or stabilized it at moderately low levels), and the fact that the earliest initiators did not deepen their involvement with marijuana during and after high school. Future analyses should seek to replicate these findings in other cohorts from different geographic areas and to extend the period of time over which the use trajectories are calculated into later stages of adulthood.

References

Bachman, J. G., Johnston, L. D., & O'Malley, P. M. (1998). Explaining recent increases in students' marijuana use: Impacts of perceived risks and disapproval, 1976 through 1996. *American Journal of Public Health, 88,* 887–892.

Bachman, J. G., Johnston, L. D., O'Malley, P. M., & Humphrey, R. H. (1988). Explaining the recent decline in marijuana use: Differentiating the effects of perceived risks, disapproval, and general lifestyle factors. *Journal of Health and Social Behavior, 29,* 92–112.

Bachman, J. G., Wadsworth, K. N., O'Malley, P. M., Johnston, L. D., & Schulenberg, J. E. (1997). *Smoking, drinking, and drug use in young adulthood*. Mahwah, NJ: Erlbaum.

Bailey, S. L., & Hubbard, R. L. (1990). Developmental variation in the context of marijuana initiation among adolescents. *Journal of Health and Social Behavior, 31,* 58–70.

Brook, J. S., Adams, R. E., Balka, E. B., & Johnson, E. (2002). Early adolescent marijuana use: Risks for the transition to young adulthood. *Psychological Medicine, 32,* 79–91.

Brook, J. S., Gordon, A. S., Brook, A., & Brook, D. W. (1989). The consequences of marijuana use on intrapersonal and interpersonal functioning in Black and White adolescents. *Genetic, Social, and General Psychology Monographs, 115,* 349–369.

Brook, J. S., Richter, L., Whiteman, M., & Cohen, P. (1999). Consequences of adolescent marijuana use: Incompatibility with the assumption of adult roles. *Genetic, Social, and General Psychology Monographs, 125,* 193–207.

Brook, J. S., Whiteman, M., Finch, S. J., Morojele, N. K., & Cohen, P. (2000). Individual latent growth curves in the development of marijuana use from childhood to young adulthood. *Journal of Behavioral Medicine, 23,* 451–464.

Chassin, L., Presson, C. C., Pitts, S. C., & Sherman, S. J. (2000). The natural history of cigarette smoking from adolescence to adulthood in a midwestern community sample: Multiple trajectories and their psychosocial correlates. *Health Psychology, 19,* 223–231.

Chen, K., & Kandel, D. B. (1995). The natural history of drug use from adolescence to the mid-thirties in a general population sample. *American Journal of Public Health, 85,* 41–47.

Colder, C. R., Mehta, P., Balanda, K., Campbell, R. T., Mayhew, K. P., Stanton, W. R., et al. (2001). Identifying trajectories of adolescent smoking: An application of latent growth mixture modeling. *Health Psychology, 20,* 127–135.

Donovan, J. E. (1996). Problem behavior theory and the explanation of adolescent marijuana use. *Journal of Drug Issues, 26,* 379–404.

Duncan, S. C., Duncan, T. E., Biglan, A., & Ary, D. (1998). Contributions of the social context to the development of adolescent substance use: A multivariate latent growth modeling approach. *Drug and Alcohol Dependence, 50,* 57–71.

Duncan, T. E., Tildesley, E., Duncan, S. C., & Hops, H. (1995). The consistency of family and peer influences on the development of substance use in adolescence. *Addiction, 90,* 1647–1660.

Dunn, O. J. (1961). Multiple comparisons among means. *Journal of the American Statistical Association, 56,* 52–64.

Ellickson, P. L., & Bell, R. M. (1990). Drug prevention in junior high: A multi-site longitudinal test. *Science, 247,* 1299–1304.

Ellickson, P. L., Bell, R. M., Thomas, M. A., Robyn, A. E., & Zellman, G. L. (1988). *Designing and implementing project ALERT*. Santa Monica, CA: RAND.

Ellickson, P. L., Bui, K., Bell, R., & McGuigan, K. A. (1998). Does early drug use increase the risk of dropping out of high school? *Journal of Drug Issues, 28,* 357–380.

Ellickson, P. L., Collins, R. L., & Bell, R. M. (1999). Adolescent use of illicit drugs other than marijuana: How important is social bonding and for which ethnic group. *Substance Use and Misuse, 34,* 317–346.

Ellickson, P. L., McGuigan, K. A., Adams, V., Bell, R. M., & Hays, R. D. (1996). Teenagers and alcohol misuse in the United States: By any definition, it's a big problem. *Addiction, 91,* 1489–1503.

Ellickson, P. L., Saner, H., & McGuigan, K. A. (1997). Profiles of violent youth: Substance use and other concurrent problems. *American Journal of Public Health, 87,* 985–991.

Fergusson, D. M., Horwood, L. J., & Swain-Campbell, N. (2002). Cannabis use and psychosocial adjustment in adolescence and young adulthood. *Addiction, 97,* 1123–1135.

Freier, M. E., Bell, R. M., & Ellickson, P. L. (1991). *Do teens tell the truth? The validity of self-reported tobacco use by adolescents*. Santa Monica, CA: RAND.

Gottfredson, M. R., & Hirschi, T. (1994). A general theory of adolescent problem behavior: Problems and prospects. In R. D. Ketterlinus & M. E. Lamb (Eds.), *Adolescent problem behaviors: Issues and research* (pp. 41–56). Hillsdale, NJ: Erlbaum.

Green, B. E., & Ritter, C. (2000). Marijuana use and depression. *Journal of Health and Social Behavior, 41,* 40–49.

Hill, K. G., White, H. R., Chung, I. J., Hawkins, J. D., & Catalano, R. F. (2000). Early outcomes of adolescent binge drinking: Person- and variable-centered analyses of binge drinking trajectories. *Alcoholism: Clinical and Experimental Research, 24,* 892–901.

Jessor, R., & Jessor, S. L. (1977). *Problem behavior and psychosocial development: A longitudinal study of youth*. New York: Academic Press.

Johnston, L. D., O'Malley, P. M., & Bachman, J. G. (2001). *Monitoring the future national survey results on drug use, 1975–2000. Volume II: College students and adults ages 19–40* (NIH Publication No. 01–4925). Bethesda, MD: National Institute on Drug Abuse.

Johnston, L. D., O'Malley, P. M., & Bachman, J. G. (2002). *Monitoring the future national survey results on drug use, 1975–2001. Volume I: Secondary school students* (NIH Publication No. 02–5106). Bethesda, MD: National Institute on Drug Abuse.

Kandel, D. B. (2003). Does marijuana use cause the use of other drugs? *Journal of the American Medical Association, 289,* 482–483.

Kandel, D. B., & Chen, K. (2000). Types of marijuana users by longitudinal course. *Journal of Studies on Alcohol, 61,* 367–378.

Kandel, D. B., & Davies, M. (1992). Progression to regular marijuana involvement: Phenomenology and risk factors for near-daily use. In M. Glantz & R. Pickens (Eds.), *Vulnerability to drug abuse* (pp. 211–253). Washington, DC: American Psychological Association.

Kandel, D. B., & Logan, J. A. (1984). Patterns of drug use from adolescence to young adulthood: Periods of risk for initiation, continued use, and discontinuation. *American Journal of Public Health, 74,* 660–666.

Kaplan, H. B., Martin, S. S., Johnson, R. J., & Robbins, C. A. (1986). Escalation of marijuana use: Application of a general theory of deviant behavior. *Journal of Health and Social Behavior, 27,* 44–61.

Kass, R. E., & Raftery, A. E. (1995). Bayes factor. *Journal of the American Statistical Association, 90,* 773–795.

Kosterman, R., Hawkins, J. D., Guo, J., Catalano, R. F., & Abbott, R. D. (2000). The dynamics of alcohol and marijuana initiation: Patterns and predictors of first use in adolescence. *American Journal of Public Health, 90,* 360–366.

Labouvie, E., & White, H. R. (2002). Drug sequences, age of onset, and use trajectories as predictors of drug abuse/dependence in young adulthood. In D. B. Kandel (Ed.), *Stages and pathways of drug involvement: Examining the gateway hypothesis*. (pp. 19–41). Cambridge, England: Cambridge University Press.

Li, F., Duncan, T. E., & Hops, H. (2001). Examining developmental trajectories in adolescent alcohol use using piecewise growth mixture modeling analysis. *Journal of Studies on Alcohol, 62,* 199–210.

McGuigan, K. A., Ellickson, P. L., Hays, R. D., & Bell, R. M. (1997). Adjusting for attrition in school-based samples. *Evaluation Review, 21,* 554–567.

Morojele, N. K., & Brook, J. S. (2001). Adolescent precursors of intensity

of marijuana and other illicit drug use among adult initiators. *Journal of Genetic Psychology, 162,* 430–450.

Muthén, B. (2001a). Latent variable mixture modeling. In G. A. Marcoulides & R. E. Schumacker (Eds.), *Advanced structural equation modeling: New developments and techniques* (pp. 1–33). Hillsdale, NJ: Erlbaum.

Muthén, B. (2001b). Second-generation structural equation modeling with a combination of categorical and continuous latent variables. In L. M. Collins & A. Sayer (Eds.), *New methods for the analysis of change* (pp. 291–322). Washington, DC: American Psychological Association.

Muthén, B., & Shedden, K. (1999). Finite mixture modeling with mixture outcomes using the EM algorithm. *Biometrics, 55,* 463–469.

Muthén, L. K., & Muthén, B. (1998). *Mplus user's guide*. Los Angeles, CA: Muthén & Muthén.

Nagin, D. S. (1999). Analyzing developmental trajectories: A semiparametric group-based approach. *Psychological Methods, 4,* 139–157.

Newcomb, M. D., & Bentler, P. M. (1988). Impact of drug use and social support on problems of young adults. *Journal of Abnormal Psychology, 97,* 133–152.

Patton, G. C., Coffey, C., Carlin, J. B., Degenhardt, L., Lynskey, M., & Hall, W. (2002). Cannabis use and mental health in younger people: Cohort study. *British Medical Journal, 325,* 1195–1198.

Pope, H. G., & Yurgelun-Todd, D. (1996). The residual cognitive effects of heavy marijuana use in college students. *Journal of the American Medical Association, 275,* 521–527.

Rapkin, B. D., & Dumont, K. A. (2000). Methods for identifying and assessing groups in health behavior research. *Addiction, 95*(Suppl. 3), 395–417.

Raveis, V. H., & Kandel, D. B. (1987). Changes in drug behavior from middle to late twenties: Initiation, persistence, and cessation of use. *American Journal of Public Health, 77,* 607–611.

Reinisch, E., Bell, R. M., & Ellickson, P. L. (1991). *How accurate are adolescent reports of drug use?* Santa Monica, CA: RAND.

Schwartz, G. (1978). Estimating the dimension of a model. *Annals of Statistics, 6,* 461–464.

Sherman, M. P., Roth, M. D., Gong, H. J., & Tashkin, D. P. (1991). Marijuana smoking, pulmonary function and lung macrophage oxidant release. *Pharmacology, Biochemistry and Behavior, 40,* 663–669.

Solowij, N., Michie, P. T., & Fox, A. M. (1995). Differential impairments of selective attention due to frequency and duration of cannabis use. *Society of Biological Psychiatry, 37,* 731–739.

Stephens, R. S. (1999). Cannabis and hallucinogens. In B. S. McCrady & E. E. Epstein (Eds.), *Addictions: A comprehensive guidebook* (pp. 121–140). New York: Oxford University Press.

Stewart, A. L., Hays, R. D., & Ware, J. E., Jr. (1988). The MOS short-form general health survey: Reliability and validity in a patient population. *Medical Care, 26,* 724–735.

Sussman, S., Stacy, A. W., Dent, C. W., Simon, T. R., & Johnson, C. A. (1996). Marijuana use: Current issues and new research directions. *Journal of Drug Issues, 26,* 695–733.

Tashkin, D. P., Coulson, A. H., Clark, V. A., Simmons, M., Bourque, L. B., Duann, S., et al. (1987). Respiratory symptoms and lung function in habitual heavy smokers of marijuana alone, smokers of marijuana and tobacco, smokers of tobacco alone, and nonsmokers. *American Review of Respiratory Diseases, 135,* 209–216.

Tucker, J. S., Orlando, M., & Ellickson, P. L. (2003). Patterns and correlates of binge drinking trajectories from early adolescence to young adulthood. *Health Psychology, 22,* 79–87.

Wills, T. A., McNamara, G., Vaccaro, D., & Hirky, A. E. (1996). Escalated substance use: A longitudinal grouping analysis from early to middle adolescence. *Journal of Abnormal Psychology, 105,* 166–180.

Yamaguchi, K., & Kandel, D. B. (1985). On the resolution of role incompatibility: A life event analysis of family roles and marijuana use. *American Journal of Sociology, 90,* 1284–1325.