# Trajectories of Marijuana Use From Adolescence Into Adulthood: Environmental and Individual Correlates

**Marina Epstein**[a], **Karl G. Hill**[a], **Alyssa M. Nevell**[a], **Katarina Guttmannova**[a], **Jennifer A. Bailey**[a], **Robert D. Abbott**[a,b], **Rick Kosterman**[a], and **J. David Hawkins**[a]

[a]Social Development Research Group, School of Social Work, University of Washington

[b]School of Education, University of Washington

## Abstract

This study sought to identify trajectories of marijuana use in the Seattle Social Development Project (n = 808) sample from age 14 through 30, and to examine the extent to which individuals in these trajectories differed in their substance use problems, mental health, problem behavior, economic outcomes, and positive functioning at age 33. In addition, analyses examined between-trajectory differences in family, peer, school, neighborhood, individual, mental health, and substance use factors at key developmental points in adolescence and adulthood. Four trajectories of marijuana use were identified: nonusers (27%), adolescent-limited (21%), late-onset (20%), and chronic (32%) users. At age 33, the chronic trajectory was associated with the worst functioning overall. The late-onset group reported more substance use and sexual risk behavior than nonusers, but was otherwise not differentiated. The adolescent-limited group reported significantly lower educational and economic outcomes at age 33 than the late-onset and nonuser groups. In analyses at earlier ages, adolescent-limited and late-onset groups reported more problems in functioning during the period of escalation in use and improvement in functioning with the beginning of desistance. Implications for prevention are discussed, particularly the unique risks associated with early adolescent versus later onset of marijuana use.

## Keywords

Marijuana use; developmental trajectories; family; peer; school; and neighborhood environments; social development; mental health; substance use

In 2012, 18.7% of people between the ages of 18 and 25 reported using marijuana in the past month (SAMHSA, 2012). Adolescents also report marijuana use, with almost half (46%) of 12th graders reporting lifetime use and close to a fifth (18.2%) reporting having used marijuana daily for at least one month at some point in their lives (Johnston, O'Malley, Bachman, & Shulenberg, 2013). Although marijuana use consequences among adolescents and young adults have been studied, much of this research compares chronic marijuana or early-onset users to nonusers (e.g., Brook, Adams, Balka, & Johnson, 2002; Brook, Balka, & Whiteman, 1999; Lynskey, Coffey, Degenhardt, Carlin, & Patton, 2003; Pope et al.,

Address correspondence to: Marina Epstein, Ph.D., Social Development Research Group, University of Washington, 9725 3rd Avenue NE, Suite 401, Seattle, WA 98115. marinaep@uw.edu. Phone: 206-221-4659. Fax: 206-543-4507.

2003). These studies generally find that early and chronic marijuana use is related to a range of negative outcomes, including school dropout, educational and employment underachievement, association with antisocial peers, and physical and mental health problems. Less is known about consequences of moderate marijuana use or of later onset.

Using person-centered analysis methods, prior research has sought to identify discrete developmental trajectories of marijuana use (Ellickson, Martino, & Collins, 2004; Schulenberg et al., 2005; Tucker, Ellickson, Orlando, Martino, & Klein, 2005). These approaches allow multiple patterns or trajectories of marijuana use to be examined and compared on predictors and outcomes. The large majority of studies have focused on marijuana use over a relatively short time span during adolescence and young adulthood, and many focus on a small set of predictors or outcomes (for exceptions, see Brook, Lee, Brown, Finch, & Brook, 2011; Juon, Fothergill, Green, Doherty, & Ensminger, 2011; Kandel & Chen, 2000). This has resulted in a fractured picture of marijuana use patterns, their etiologies, and outcomes. What is missing is a comprehensive effort that combines long-term marijuana use trajectories from adolescence to adulthood with a broad set of differentiating factors both at the onset and at the end of the trajectory. Moreover, trajectories are often presented as black boxes where only the beginning and end are open to investigation. No study has examined factors that operate during key turning points in marijuana use trajectories (acceleration, peak use, crossover with another trajectory). The current study addresses these gaps by (a) examining trajectories of marijuana use from ages 14 to 30; (b) comparing trajectory groups on a broad set of adult functioning measures at age 33; and (c) examining individual, family, school, and peer factors that differentiate patterns of use at key developmental transition points in the trajectories.

## Theoretical Considerations of Person-Centered Approaches

Research on the predictors and consequences of marijuana use has traditionally followed a variable-driven approach that focuses on average use in the population. According to nationally representative samples, about 15% of eighth-grade students reported ever using marijuana, whereas by young adulthood over half (56%) of individuals report having used at least once in their lifetime. The average age of marijuana initiation is 18 years, after which marijuana use peaks, on average, in the early 20s and then follows a steady decline (SAMHSA, 2012). Looking at average age trends alone, however, may obscure diversity in individual patterns of marijuana use over time, particularly patterns characterized by chronic use or by onset beyond adolescence.

Accordingly, in the past decade researchers have begun to explore longitudinal heterogeneity in marijuana use and adopt person-centered approaches that examine patterns among individuals and identify groups with similar behavior profiles (Brown, Flory, Lynam, Leukefeld, & Clayton, 2004; Kandel & Chen, 2000; Tucker et al., 2005; Windle & Wiesner, 2004). This approach, which generally draws on the life course perspective (Elder, 1998; Elder, Kirkpatrick Johnson, & Crosnoe, 2003), emphasizes the timing of key transitions of different marijuana use "careers" (e.g., onset, escalation, and desistance) and facilitates integration of the broader developmental context surrounding turning points in a person's marijuana trajectory. For example, early onset can interfere with negotiation of important

developmental challenges and milestones, like academic achievement, negotiation of school transitions, and development of healthy peer relationships (e.g., Lynskey & Hall, 2000; Lynskey et al., 2003). Failure to meet these challenges may set adolescents on a path toward antisocial behavior through increased opportunities to interact with drug-using peers and to engage in other problem behavior (Catalano & Hawkins, 1996). Likewise, escalation in use across mid- and late adolescence may interfere with secondary education and the transition to adulthood (Arria et al., 2013; Brook et al., 2002). Some have argued that marijuana and alcohol use during late adolescence and young adulthood may be a normative response to increased autonomy before the onset of adult roles increases pressure for desistence (Arnett, 2005; Maggs & Schulenberg, 2004; Schulenberg, Maggs, & O'Malley, 2003). Others, however, cautioned that a temporary increase in substance use in young adulthood at the population level may obscure more problematic patterns of use among those who are early and persistent users (Moffitt, 2003).

In order to discriminate between adolescent-limited increases in substance use from chronic use, the developmental trajectories approach examines stability and change as equifinality and multifinality (Schulenberg & Maggs, 2002). Equifinality can be observed at points of convergence of discrete trajectories, whereas multifinality refers to trajectories that diverge from a common point of origin. Differential patterns of risk and protective factors, both concurrent and distal, are theorized to belie stability and change in trajectories. Equifinality occurs when diverse patterns of risk and protective factors lead to a similar outcome, whereas multifinality may refer to different responses to a risk or protective factor. For example, having both a well-functioning family environment and a high commitment to school could lead to lower rates of substance use (equifinality). However, individuals with well-functioning families who are committed to school could have other risk factors, such risk-seeking personality type or substance-using peers, that could lead some to use marijuana (multifinality). Understanding the risk and protective factors associated with trajectory stability and change is important for the timing and targeting of interventions aimed at patterns of use associated with negative outcomes.

In order to examine which risk and protective factors differentiate between the trajectories, the current study draws upon the social development model (SDM, Catalano & Hawkins, 1996), which is based on lifecourse theory, social learning theory, and differential association theory. The SDM hypothesizes prosocial and antisocial socialization pathways that include opportunities for involvement with others, involvement and interaction, rewards or costs individuals receive from this involvement, and the social bond between those individuals and the socializing unit. The SDM theory suggests that salient changes in the opportunities, involvements, rewards, and bonding experienced by the individual should be observed concomitant with each transition in developmental trajectories. Thus, the observed equifinality and multifinality in the trajectories at each transition are hypothesized to be explained by these SDM constructs. The SDM has been tested in multiple datasets and was found to predict substance use outcomes, including marijuana, at different stages of development (Brown et al., 2005; Choi, Harachi, Gillmore, & Catalano, 2005; Fleming, Catalano, Oxford, & Harachi, 2002; Sullivan & Hirschfield, 2011).

## Previous Work on Marijuana Trajectories

### Common trajectory types

Previous studies that have used pattern-centered approaches to explore marijuana trajectories have varied in the population modeled, ages included, and ways that marijuana use was operationalized. Unlike the alcohol literature, where many analyses produce a four-trajectory "cat's cradle" pattern (made up of stable high, stable low, increasing, and decreasing groups) that has been called into question (Sher, Jackson, & Steinley, 2011), the four most commonly observed longitudinal patterns of marijuana reported in the literature are nonuse, chronic use, adolescent-limited use, and increasing use. Unlike the "decreasing" aspect of the "cat's cradle," an adolescent-limited pattern is one that shows an increase in use around late adolescence followed by a steady decline. The first two patterns were found in every article reviewed for this study. In most nonclinical populations, nonusers (which sometimes included some light or irregular users) typically represented 50% or more of the sample (Caldeira, O'Grady, Vincent, & Arria, 2012; Ellickson et al., 2004; Windle & Wiesner, 2004). Chronic users tended to initiate marijuana use by middle adolescence, between ages 14 and 15, and continued using at a stable rate into adulthood (Brook, Lee, et al., 2011; Brook, Zhang, & Brook, 2011; Caldeira et al., 2012). Prevalence in chronic use trajectories varied between 1.8% and 23.2% of the samples. In studies that identified adolescent-limited trajectories, individuals with adolescent-limited use typically began marijuana use in the early to mid-teen years, peaked in early adulthood, and then dropped steadily to little or no use by the late 20s (Juon et al., 2011; Pahl, Brook, & Koppel, 2011). This group has also been labeled "college-peak users" (Caldeira et al., 2012), and "maturing-out users" (Brook, Lee, et al., 2011). The fourth commonly estimated trajectory was characterized by increasing use and included individuals who initiated use in middle or later adolescence but then continued with a sharp or steady increase in use into their 20s and 30s (Brook, Zhang, et al., 2011; Ellickson et al., 2004). Other, less commonly reported trajectories included occasional, experimental, or light users that all reported using marijuana infrequently. Finally, the last set of trajectories, referred to as "quitters" (Pahl et al., 2011), "early adulthood decliners" (Juon et al., 2011), and "early decliners" (Caldeira et al., 2012), were all similar in that marijuana use ultimately declined to no use.

Some of the variability in the observed patterns of use is likely to be due to the differing time frames during which marijuana use was examined. For example, a number of studies that found an increasing use trajectory followed participants up to the early or mid-20s (e.g., Caldeira et al., 2012; Schulenberg et al., 2005; Tucker et al., 2005). In their perspective on developmental psychopathology, Cicchetti and Rogosch (2002) argued for modeling developmental pathways past the period of major risk, as in the current study. For substance use, extending trajectories past the peak ages of use is of key importance in order to distinguish temporary rises in use that may decline in the late 20s from trajectories that continue to increase. Spacing of data collection waves and operationalization of the marijuana use dependent variable are also likely to affect the shape and number of trajectories found in each study. Finally, the number and shape of trajectories is likely to be affected by sample size and by the specific operationalization of marijuana use. For example, whereas most studies looked at a range of marijuana use from light to heavy (e.g.,

Pahl et al., 2011; Schulenberg et al., 2005; Tucker et al., 2005), others only differentiated regular use from less frequent use (Finlay, White, Mun, Cronley, & Lee, 2012).

## Outcomes and predictors of marijuana use trajectories

Diverse patterns of marijuana use are likely to have different associated risks with respect to both early predictors and distal outcomes. Predictors and outcomes of trajectory groups can shed light on multifinality and equifinality in patterns of marijuana use and help identify intervention targets for future interventions. In particular, it is important to understand whether consequences differ for different marijuana trajectories and which trajectories are and are not associated with adverse outcomes.

Though not all previous studies of marijuana trajectories examined outcome variables, those that did are of particular interest to us. In previous works, chronic use was most consistently implicated in negative health outcomes, including poor mental health, lower educational attainment and financial stability, greater delinquency and criminal behavior, and more sexual risk (Brook, Lee, Finch, & Brook, 2014; Brook, Lee, Finch, Seltzer, & Brook, 2013; Brook, Zhang, et al., 2011; Caldeira et al., 2012; Kandel & Chen, 2000; Pahl et al., 2011; Schulenberg et al., 2005). The chronic pattern was also associated with a greater likelihood of developing marijuana dependence, and alcohol, tobacco, and other illicit drug problems (Schulenberg et al., 2005; Tucker et al., 2005). Outcomes for other patterns of use were more varied, and although nonusers generally reported the best outcomes, this was not universal. For example, Ellickson et al. (2004) found no difference in income between occasional light marijuana users and nonusers, and Schulenberg et al. (2005) reported that rare users were more financially independent than nonusers. In terms of mental health disparities, Brook, Lee, et al. (2011) found that nonusers did not differ from the adolescent-limited group in depression symptoms, and Caldeira and colleagues (2012) actually found that adolescent-limited users reported fewer depressive symptoms than nonusers.

Previous studies have also explored a number of predictors of marijuana trajectories consistent with the social development model. Most commonly explored were family factors such as family involvement, cohesion, rules, and norms (Flory, Lynam, Milich, Leukefeld, & Clayton, 2004; Juon et al., 2011; Windle & Wiesner, 2004). Others found that peer and school factors, such as association with marijuana-using peers, educational attainment, academic achievement, and GPA differentiated patterns of use (Juon et al., 2011; Kandel & Chen, 2000; Whitesell et al., 2014; Windle & Wiesner, 2004). Finally, individual-level factors related to mental health, personality, and substance use (Arria et al., 2013; Brook, Zhang, et al., 2011; Flory et al., 2004; Kandel & Chen, 2000) were found to be important predictors of marijuana use patterns.

Other environmental and individual factors, including sensation seeking, neighborhood factors, and family marijuana use, have been less explored in previous studies. All of these factors are outlined in the SDM and have been linked to marijuana use in related literatures (Beyers, Toumbourou, Catalano, Arthur, & Hawkins, 2004; Brown et al., 2004; Ellickson, D'Amico, Collins, & Klein, 2005; Oesterle et al., 2012; Roettger, Swisher, Kuhl, & Chavez, 2011) and are likely to play an important role in differentiating trajectories of marijuana use. The most important omission in the studies we reviewed was examination of how trajectory

groups differed in risk and protective factors during points of convergence and divergence of trajectory groups (other than the first and last time point). For example, is convergence in levels of marijuana use reflected in increased similarity in other domains? Do early risk factors that differentiate trajectories at the onset continue to differentiate later in the life course? Only one study using cluster analysis examined the changing role of risk factors (e.g., peer marijuana use) from adolescence to early adulthood (Kandel & Chen, 2000), and found that peer marijuana use at age 15 – 16 did not differentiate heavy and light early users in adolescence. However, early-heavy users reported almost 3 times as many marijuana-using peers at age 24 – 25 as early-light users, suggesting that interventions for heavy users need to address their social environment during young adulthood. Analyses such as these are important in order to understand what keeps individuals on certain trajectory paths and what may be effective intervention targets to facilitate a shift away from high-risk trajectories.

## Current Study

The analyses here are based on a community panel study with data available from adolescence to adulthood and a rich set of measures across multiple environmental domains, including family, school, peer, and neighborhood factors. The current study first estimated trajectories of marijuana use and then compared the trajectories across a broad set of outcomes in adulthood to establish the adult correlates of these trajectories. We generally hypothesized that the heaviest patterns of marijuana use would be associated with the worst outcomes. Next, analyses examined early factors that differentiate patterns of use before the trajectory onset. These factors help identify intervention targets for different marijuana trajectories, particularly those with the worst outcomes. We expected that early risk and protective factors would differentiate the trajectories characterized by heavy use and early onset from lighter use trajectories. Finally, this study compared the trajectories at developmental key points, such as peak use, convergence with other trajectories (equifinality), and divergence points (multifinality). In addition to identifying intervention targets in adolescence and young adulthood, this important step will help us understand changes in functioning at times of escalation and desistance. We broadly hypothesized that functioning would be most similar between different trajectory groups at the point of convergence or equifinality.

## Methods

### Participants

The Seattle Social Development Project (SSDP) is a longitudinal study of the development of prosocial and antisocial behaviors. Participants (N = 808, 50.9% male) were fifth-grade students (mean age ~10) recruited in 1985 from 18 Seattle public schools. The schools overrepresented high-crime neighborhoods, and a large portion of the sample (46%) came from families whose total income was less than $20,000 per year. Almost half (47%) of participants identified as White, 22% as Asian American, 26% African American, and 5% Native American. This study used annual data collected from participants at ages 10 – 16, and follow-up data collected at ages 18, 21, 24, 27, 30, and 33. Retention has remained high, consistently over 92% since age 14, greatly reducing the possibility of bias related to

attrition. Parent interviews were conducted annually when participants were ages 10 – 16. Teacher reports were collected at ages 10 to 14. Before the age of 18, youth gave assent and parents provided written consent to collect data. Upon turning 18, participant consent was collected at each interview. Institutional Review Board approval was obtained for all parts of the study.

### Measures

The measurement package was theory driven as guided by the social development model and included assessments of opportunities, involvements, rewards, and bonding in the family, school, peer, and neighborhood domains at every wave. As individuals matured and developed, effort was made to measure constructs that were relevant to their development. For example, parent and teacher reports were collected on internalizing behavior during late childhood before reliable self-report was able to be obtained in the teenage years. In another instance, the focus on school shifted to a focus on work in the early 20s. Effort was made to retain a core set of constructs across development.

For all assessments, we make a distinction between index measures and scales. Scale measures combine several items that are hypothesized to tap into an underlying latent construct and are thus expected to be intercorrelated. Examples of this include positive family and antisocial peers. Index measures, on the other hand, reflect behaviors that do not necessarily share a common origin, but are meaningfully additive as part of the same risk or protective category. Crime involvement is one example of an index measure. Although different types of criminal acts are all part of the same question battery, they are not necessarily correlated because individuals often engage in cafeteria style delinquency (Klein, 1984), engaging in some types of activities (e.g., theft) but not others (e.g., drug selling), yet their composite into an index is meaningful. Cronbach's alphas are provided for scale measures; Cronbach's alpha is omitted for index measures, such as a sum of criminal activity, where items not expected to form a cohesive scale.

**Marijuana use (ages 14 to 30)—**Participants reported on past-month and past-year marijuana use starting at age 14, the first time point to have past-year data. The marijuana use measure was modeled after a similar analysis of the Monitoring the Future sample (Schulenberg et al., 2005) where past-month and past-year use were combined into a single measure of frequency of use. No use in the past year was coded as 0 or "no use." Using fewer than three times in the past month and fewer than 20 times in the past year was coded as 1, or "less than weekly use," and using three times or more in the past month or more than 20 times in the past year was coded as 2, "weekly use or more." Because of the highly non-normal distribution, marijuana use was modeled as count data with Poisson distribution in the analyses.

**Adult functioning variables (age 33)—***Substance abuse and dependence.* Substance-related outcomes were measured by examining participant's symptoms of marijuana and alcohol abuse and dependence, as well as symptoms of tobacco dependence. DSM-IV (American Psychiatric Association, 2000) abuse and dependence criteria were assessed using the Diagnostic Interview Schedule (DIS; Robins, Cottler, Bucholz, & Compton,

1998). ***Mental health*** outcomes were determined by measuring participants' self-reported DSM-IV (American Psychiatric Association, 2000) depressive and anxiety symptoms based on DSM-IV criteria (nine items for depression, six items for anxiety) (Robins et al., 1998). ***Problem behavior*** encompassed participant's involvement in crime and sexual risk behavior in the past year. *Crime involvement* included a summed index of 14 criminal activities in the past year, such as theft, breaking and entering, selling illegal drugs, assault, and fraud. Adult *sexual risk behavior* consisted of an index of four past-year behaviors: engaging in sex while under the influence of drugs or alcohol, inconsistent use of condoms, trading sex for money, and having multiple sexual partners. ***Socioeconomic outcomes*** assessed current individual income and whether participants graduated from high school or had a college degree by age 33. ***Positive functioning outcomes*** measured bonding to others and constructive engagement. *Bonding to others* measures included five items that assessed the degree to which participants reported feeling warmth and affection toward peers and toward a romantic partner (e.g., "I want to be like my partner"). Average Cronbach's alpha for the two types of bonding was .61. *Constructive engagement* was a 12-item index that measured how much time participants spent on activities that promote positive functioning, such as at work, at home (raising children), or in school (for details on the measure construction, see Hawkins, Kosterman, Catalano, Hill, & Abbott, 2005; Kosterman et al., 2014; Kosterman et al., 2011).

**Adolescent measures (ages 10 – 18)**—Measures were available starting at age 10, unless otherwise indicated. Items were combined at each age; at ages 10 – 14 items were then averaged across ages. ***General environment*** was composed of constructs that were not specifically related to marijuana, including measures of a positive family environment, positive school environment, antisocial peers, and neighborhood disorganization. The *positive family environment* scale included child report of 18 items that assessed family bonding, family management, family conflict (reverse-coded), and family involvement (Cronbach's alpha was .89 and .83 at ages 10 – 14 and 18, respectively). These constructs were used to gauge how well or poorly members of the family interacted with one another to solve problems, provide support, and set guidelines for behavior. Examples include "Do you share your thoughts and feelings with your mother/father?" and how often participants engaged in activities together with family members, e.g., "Has meals with family." The *positive school environment* scale contained 16 items that examined prosocial experiences in the educational context, including school bonding, opportunities, and involvement. Examples items included: "Most mornings I look forward to going to school," and "I have lots of chances to take part in class activities." Cronbach's alpha at ages 10 – 14 and 18 were .89 and .74. A measure of *antisocial peers* examined the behavior of participants' three best friends and other peers. The scale included 3 – 12 items depending on age. Items included "Have your friends done anything that could get them in trouble with the police?" and "Were you ever asked or expected to do troublesome things by friends?" Cronbach's alphas were .78 and .73 at ages 10 – 14 and 18. Finally, *neighborhood disorganization* (starting at age 14) examined participants' general perceptions of their living environment, including the presence of gangs, broken down buildings, crime, and rowdy neighbors. The scale included five to seven items; Cronbach's alphas were .84 and .91 at ages 10 – 14 and 18. ***Marijuana-specific environment*** measures included family marijuana use, peer

marijuana use, and community marijuana availability. The f*amily marijuana use* scale, available only at ages 10 – 14, included two to six items per year that measured parent and sibling marijuana use frequency and parent attitudes towards use (Cronbach's alpha = .78) . *Peer marijuana use* (starting at age 13) was assessed as whether participants' three best friends had smoked marijuana (three items at each age). Cronbach's alphas at ages 13 – 14 and 18 were .74 and .69. A *community marijuana availability* index, available at ages 10 – 14 and 18 only, examined how accessible marijuana was to the participant. At each age, participants were asked two to three questions such as "If you had money and wanted to get pot, could you?" and "Do you know anyone personally who has tried marijuana?" ***Individual characteristics.*** The *behavioral disinhibition* measure (starting at age 14) assessed impulsivity, sensation seeking, and reward orientation (Hill et al., 2010). The measure included five items (Cronbach's alpha was .76 at both ages 14 and 18). Examples included "How many times have you done what feels good no matter what?" and "How many times have you done things even if they were a little dangerous?" *Anxiety* and *depressive symptoms* were derived from teacher rating on the Achenbach Child Behavior Checklist (Achenbach, 1991; Lengua, Sadowski, Friedrich, & Fisher, 2001). Anxiety symptoms included items such as "fears going to school" and "nervous movements." *Depressive symptoms* included "loneliness," "feels worthless," and "underactive." Anxiety or depressive symptoms were not assessed at age 18. ***Substance use***. Participants self-reported the number of days in the past month that they used *alcohol* and *marijuana* (0 – 30)*. Tobacco use* was coded as the number of cigarettes used per day (none to pack a day or more). Alcohol and tobacco use were collected starting at age 10; marijuana use was measured starting at age 14.

**Young adult measures (ages 21, 24)—***General environment* was measured similarly as in the adolescent years. *Positive family environment* at ages 21 and 24 was based on the family of origin, and focused on family bonding. Items measured how much individuals depended on, trusted, and admired their parents. Example items from this construct include "How much do you depend on mother/father for advice?" and "Would you like to be the kind of person your mother/father is?" The scale included 20 items (Cronbach's alphas were .93 and .94 at ages 21 and 24, respectively). The *positive school/work environment* scale measured school/work bonding and opportunities for involvement. Participants were asked 12 school-related items (for those who were involved in schooling) and 16 work-related items (for those who were employed), which were combined into a single school/work environment scale (Cronbach's alphas were .90 and .88 at ages 21 and 24). Examples included "I try to do my best at work," "Continuing my education is important to me," and "At my school/college, students have a lot of chances to help decide and plan things such as school policies, activities, and events." The *antisocial peers* scale included 16 items that assessed problem behavior of participants' friends, housemates, and coworkers (Cronbach's alphas were .92 and .80 at ages 21 and 24). Items included "Does this person commit serious crimes like burglary or robbery?" and "Does this person belong to a gang?" Finally, the *neighborhood disorganization* scale included seven items (Cronbach's alpha was .88 and .89 at ages 21 and 24) that assessed whether participants experienced shootings, gangs, drug selling, and have abandoned buildings in their neighborhood. ***Marijuana-specific environment.*** The *peer marijuana use* scale included reports of whether housemates,

friends, and coworkers used marijuana (seven items; Cronbach's alphas were .74 and .70). *Community marijuana availability* was not measured in adulthood. **Individual characteristics** included behavioral disinhibition, depressive symptoms, and anxiety symptoms. A shortened *behavioral disinhibition* measure included three items identical to those used in adolescence (Cronbach's alpha was .58 and .55 at ages 21 and 24). *Anxiety* and *depressive symptoms* were based on DSM-IV criteria, and were self-reported. **Substance use** at ages 21 and 24 included self-reported past-month marijuana, alcohol, and tobacco use.

**Control variables**—Gender, ethnicity, and childhood SES were included in the trajectory estimation as control variables. Ethnicity was taken from school records and self-report. Childhood SES was operationalized as eligibility for the National School Breakfast/School Lunch program in Grades 5, 6, or 7.

## Results

### Growth Mixture Model Estimation

We modeled developmental trajectories of marijuana use through growth mixture modeling (GMM), an approach that combines latent growth curve and categorical latent variable (i.e., latent class) modeling. Given preliminary analysis of our data and the previous studies of marijuana trajectories, we expected to find several discrete patterns of marijuana use. The plotted mean marijuana use in the sample generally followed a pattern of acceleration during the adolescent years followed by a leveling out or desistance from use, suggesting nonlinear growth. Models were estimated using Mplus 7.1 (Muthén & Muthén, 1998–2010) based upon a Poisson distribution of marijuana use, which was modeled as count data. The slope factor loadings were set according to the time lapse between assessments. Growth factor variances and factor covariances were estimated but kept equal across classes. Because a large number of our participants reported never using marijuana, we specified an a priori "nonuser" class by setting the mean of the intercept, linear, and quadratic growth factors to 0 in one class while still allowing variability in the growth factors to capture participants who may have reported very infrequent use.

We fit linear, quadratic, and cubic models with one, two, three, four, and five classes (see Table 1 for model fit statistics). All models were conditional on demographic controls. That is, gender, ethnicity, and childhood SES were included as predictors of class membership in model estimation. (An unconditional model without controls had a similar pattern of trajectories and the same optimal number of classes). A five-class solution produced convergence errors. A four-class quadratic model was selected for the final model based on the following criteria: (a) AIC, BIC, LRT, and BLRT indices of relative model fit; (b) overall model entropy; and (c) a solution that resulted in classes that were well populated and meaningfully differentiated. Based on estimated posterior probabilities, the nonuser class made up about 27% of the sample, the adolescent-limited class included 21%, the late-onset class 20%, and the chronic class 32%.

Next, we plotted the estimated marijuana trajectories (Figure 1) and determined important developmental transition points at which differentiating factors should be tested. Thus, we first examined variables that differentiated the classes at age 33 in order to confirm that

different classes were associated with different outcomes. Second, we examined general and marijuana-specific correlates prior to the onset of the trajectories (ages 10 – 14) to test different etiologies of the classes. Third, we sought to explore correlates at age 18 when the chronic and adolescent-limited, as well as nonuser and late-onset classes diverged. Fourth, we examined correlates at age 21 when the adolescent-limited and late-onset classes crossed over, and finally, we tested for class differentiation at age 24 when adolescent-limited and nonuser classes converged. Because the overall entropy was below the suggested cutoff of . 80 (Clark & Muthén, 2009), we used the Mplus AUXILIARY (e) function to estimate and compare means of each predictor and outcome variable across classes on a bivariate basis. The AUXILIARY function addresses the issue of uncertainty of class assignment by using pseudo-class draws based on the posterior probability of class membership. Thus, although we refer to trajectories or groups in this study, we acknowledge group membership uncertainty. Trajectories were conditioned on (i.e., adjusted for) demographic controls, gender, ethnicity, and childhood SES. Table 2 shows the demographic characteristics of the classes computed using posterior probabilities of class membership.

### Missing Data

Missing data in marijuana use variables that were used to model trajectories varied from 4% to 11% over the eight time points of the trajectory model, with average missingness of 7%. Missing data in the trajectory modeling was accounted for using Full Information Maximum Likelihood (FIML), which meant that all 808 participants had a probability of class assignment to one of the trajectory groups. Missing data of the predictor variables at the four time points (ages 10 – 14, 18, 21, and 24) used to compare trajectories in Tables 3 – 5 varied from 0% to 21%, with average missingness of 7% across all predictors. Percent of missing values on the predictor variables ranged from 0% to 4% (2% on average) at ages 10 – 14, 6% – 16% (7% on average) at age 18, 5% – 11% (6% on average) at age 21; 4% – 10% (7% on average) at age 24; and 11% – 21% (14% on average) at age 33. The AUXILIARY analyses were based on the bivariate relationships between the classes and the predictor variables; thus, missingness in individual analyses in Tables 3 – 5 differed by predictor variable but did not exceed 7%, on average.

### Adult Functioning Factors That Differentiate Marijuana Trajectories at Age 33

The first goal of this investigation was to estimate trajectories of marijuana use that were discrete and meaningful. In order to establish validity of the trajectory groups, we examined multifinality in consequences at age 33. Table 3 contains standardized bivariate mean differences of adult functioning variables at age 33. Results indicated substantial differentiation between the four trajectories. Chronic users, shown in the left-most column, scored the worst of the four groups on 6 of the 12 outcome measures of the four trajectories, including having the most symptoms of marijuana abuse and dependence. They also reported the most symptoms of alcohol abuse and dependence, tobacco dependence, crime involvement, and sexual risk behavior, and the least bonding to others. On the other end of the spectrum, nonusers of marijuana, in the rightmost column, scored the lowest of the four groups on symptoms of tobacco dependence and sexual risk behavior. The late-onset group most resembled the nonuser group whereas the adolescent-limited group fell in between the chronic and the nonuser groups.

Although by the early 30s the adolescent-limited group reported little to no marijuana use and had similarly low symptoms of marijuana dependence as the nonusers, functioning in this group differed substantially from nonusers. The adolescent-limited group scored equally low as the chronic (and significantly lower than the nonuser and late-onset) group on measures of economic wellbeing, including a lower individual income and a lower likelihood of obtaining a high school diploma or a college degree. The adolescent-limited and chronic groups also scored equally low (and again lower than the nonuser and late-onset groups) on constructive engagement, suggesting underemployment. On the other hand, the adolescent-limited group was not differentiated from the late-onset or the nonuser groups in crime involvement or bonding to others. Participants in the adolescent-limited trajectory reported similar levels of sexual risk behavior as the late-onset group.

Overall, the late-onset group continued using some marijuana by age 30 but reported similar functioning as the nonuser group in 9 of the 12 domains, including marijuana abuse and dependence, crime involvement, and all measures of mental health, economic outcomes, and positive outcomes at age 33. Participants in the late-onset trajectory had more symptoms of alcohol and tobacco addiction and greater sexual risk behavior than nonusers. There was no differentiation on symptoms of depression between the four groups, but the chronic group reported significantly more symptoms of anxiety than nonusers.

### General and Marijuana-Specific Factors That Differentiate Marijuana Trajectories at Onset (Ages 10 – 14)

Once differentiation in outcomes between the four groups at age 33 was established, we followed the trajectories developmentally back to adolescence and examined whether the groups differed at the trajectory onset in risk and protective factors. The top half of Table 4 shows standardized means and group differences in general and marijuana-specific environments, individual factors, and substance use at ages 10 – 14. Again, the chronic users showed the worst functioning and the nonuser group reported the best.

At this time, the adolescent-limited group largely resembled the chronic group, whereas the late-onset trajectory most resembled nonusers in their functioning. None of the four groups differed in levels of positive family environment, positive school environment, and anxiety symptoms. At ages 10 – 14, the chronic and adolescent-limited classes had already initiated marijuana and reported the same levels of past-month marijuana use. The two groups were not differentiated on 11 of the 13 risk and protective factors, including positive family, antisocial peers, neighborhood disorganization, family and peer marijuana use, community marijuana availability, mental health; the two groups also had similar levels of marijuana, alcohol, and tobacco use in the past month. The two groups were differentiated only by chronic users' higher scores on behavioral disinhibition.

The nonuser and late-onset classes reported, on average, no early marijuana use and presented similar profiles at ages 10 – 14, including similar levels of all general environment measures, family and peer marijuana use, and past-month marijuana, alcohol, and tobacco use. Nonusers, however, reported lower community marijuana availability and behavioral disinhibition than the late-onset group.

## General and Marijuana-Specific Factors That Differentiate Marijuana Trajectories at Key Developmental Points Within the Trajectories

Hypothesized comparisons between trajectories at points of equifinality and multifinality are discussed below. Comparisons between other trajectories (e.g., adolescent-limited and late-onset at age 18) are presented in Tables 4 and 5 and are not discussed in the text.

**Age 18 chronic and adolescent-limited divergence, nonuser and late-onset divergence—**As illustrated in Figure 1, the third aim of this study was to examine differences in functioning among the four trajectories at key developmental points of equifinality and mutlifinality. The first such point was evident at age 18 when the late-onset trajectory began diverging from the nonuse trajectory and when the chronic and adolescent-limited trajectories diverged. Age 18 marked the peak use of the adolescent-limited group and a transition toward desistance, whereas the chronic group continued to escalate in use. Thus, we expected greater differentiation between these two trajectories than at the earlier time point. Consistent with this prediction (bottom half of Table 4), the adolescent-limited group differed from the chronic trajectory on 7 of the 10 indicators at age 18, reporting similar levels only on positive family, neighborhood organization, and community marijuana availability.

We also expected differentiation between the late-onset and nonuser group consistent with those trajectories' divergence. Whereas at ages 10 – 14 the late-onset group mostly resembled the nonusers, by age 18 the two groups differed on 6 of the 10 comparison variables. Compared to nonusers, the late-onset group reported more antisocial peers, more peer marijuana use, greater availability of marijuana in the community, higher behavioral disinhibition, and more past-month alcohol and tobacco use.

**Age 21 adolescent-limited and late-onset convergence—**Age 21 marked the convergence of the adolescent-limited group, which started desisting from marijuana, with the late-onset group, which was escalating marijuana use. Of the 11 comparison measures, none differentiated the adolescent-limited group from late-onset group at age 21, supporting the equifinality hypothesis (top half of Table 5).

**Age 24 adolescent-limited and late-onset divergence, adolescent-limited and nonuser convergence—**After converging at age 21, the adolescent-limited and late-onset trajectories diverged at age 24, suggesting multifinality in other domains of functioning. Although these two trajectories showed diverging patterns of marijuana use, contrary to prediction, there were no factors at age 24 that differentiated these two groups (bottom half of Table 5). By age 24, the adolescent-limited group resembled the nonuser trajectory by desisting from marijuana use, which indicated equifinality in functioning. However, comparing the adolescent-limited and nonuser groups showed that the two groups continued to differ on 8 of the 11 domains of comparison. Compared to nonusers, the adolescent-limited group reported less positive family environment, more neighborhood disorganization, peer marijuana use, behavioral disinhibition, anxiety symptoms, and more alcohol and tobacco use in the past month.

## Discussion

The current study adds to the body of knowledge on longitudinal patterns of marijuana use by examining developmental trajectories of marijuana use from ages 14 to 30 in a community sample. The current study further extends the field by comparing the trajectories on individual and environmental risk and protective factors at the onset of the trajectories, and at key developmental points determined by the trajectory transitions at ages 18, 21, and 24. Four discrete trajectory groups (nonuser, chronic, adolescent-limited, and late-onset) varied substantially on outcome variables at age 33. Overall, the nonuser group consistently reported the highest level of wellbeing whereas the chronic group scored lowest on most indicators. The adolescent-limited and late-onset trajectories showed a convergence in the amount of marijuana use at age 21. During the point of convergence, the two groups also showed similar levels of functioning with respect to social environmental factors, individual difference characteristics, and patterns of other substance use. On the other hand, points of divergence in marijuana use among pairs of trajectories were generally associated with divergence in functioning in all domains. These differences in functioning were evident even after accounting for variability due to gender, ethnicity, and childhood socioeconomic status. Our ability to differentiate marijuana trajectories in functioning beyond marijuana use, as well as linking those differentiating factors to important points in the trajectories (i.e., escalation, peak, decline), all lend validity to the trajectory method. A better understanding of the diversity in the longitudinal patterns of marijuana use is key to administering prevention and to delivering interventions to appropriate groups at given developmental periods.

### Onset Timing: Developmental Challenges and Milestones

The timing of marijuana use onset appeared to be a key differentiator of developmental trajectories, supporting the notion that adolescent drug use can interfere with individual development. Early adolescent use of marijuana, even when followed by desistance, was associated with lower levels of functioning in adulthood. The negative outcomes associated with early and persistent (i.e., chronic) use of marijuana has been demonstrated in other studies (Brook, Lee, et al., 2011; Ellickson et al., 2004; SAMHSA, 2013). However, the economic difficulties reported by the adolescent-limited group highlights what may be the mechanism of economic disparity between this group and the late-onset or nonuser trajectories. For example, early marijuana use among the adolescent-limited group may have reduced school motivation or brought on sanctions, such as police involvement or school suspension, which undermined academic achievement and may have contributed to higher levels of high school dropout among the chronic and adolescent-limited groups. On the other hand, compared to the nonuser group, the late-onset group did not differ in economic and positive outcomes, but did report more substance use problems and sexual risk behavior. This pattern of outcomes suggests that there may be developmental trajectories of marijuana use, characterized by adult onset and relatively low use, that are less harmful. Alternatively, early marijuana use may be self-selecting and linked with other adolescent problems such as antisocial peers, low family monitoring, and greater access to drugs and alcohol. Indeed, by age 14, participants in the adolescent-limited group reported more antisocial peers and greater alcohol use than the nonuser and late-onset groups. The analyses conducted in the

current study cannot shed light onto which of these behaviors, in addition to marijuana use, may be the driver of the observed educational and economic disparities.

It is important to note that different patterns of functioning were present at different ages. At age 21, the late-onset, nonuser, and adolescent-limited groups all showed generally similar levels of functioning with regards to positive school and work, positive family relationships, and levels of anxiety. Moffitt (1993, 2003) noted that this equifinality is typical at the peak ages of problem behavior and can make it difficult to distinguish normative rise in substance use that is limited to the adolescent years from enduring and more problematic patterns. Because of this, Cicchetti and Rogosch (2002) noted that follow-up beyond the peak years is necessary to determine whether certain patterns are indeed associated with negative outcomes. When functioning was assessed again at age 33, the multifinality between these three groups became more clear.

### Individual Characteristics

The current analysis assessed a number of individual-level characteristics at multiple time points throughout development. Traits such as behavioral disinhibition (BD) are often thought of as early manifestations of lifelong stable behavioral tendencies (Donovan & Jessor, 1985; Moffitt, 2003; Young, Stallings, Corley, Krauter, & Hewitt, 2000), so it would be expected that individuals with low BD in adolescence would continue to rank low in young adulthood and beyond. Indeed, the nonuser and the chronic groups reported stable low and stable high levels of BD, respectively, with the other two groups coming in the middle. The high levels of BD among the chronics was an important differentiator of trajectory group from the other patterns of use. In fact, BD was the only factor that distinguished the chronic from adolescent-limited group at ages 10 – 14, suggesting that individual differences in behavioral disinhibition manifest early on and may actually be driving high-risk behavior for the chronic group.

The other individual-level indicators of functioning assessed in this study were depressive and anxiety symptoms, which mostly differentiated the chronic group from the nonusers. Symptom levels varied between the other two groups without an obvious pattern. One explanation for the relationship between mental health and substance use is self-medication theory, which suggests that individuals with mental health problems use substances in greater amounts in order to ameliorate or deflect symptoms (Hall, 2006). A competing hypothesis posits that heavy or chronic substance use could alter brain chemistry and induce symptoms of depression and anxiety (Malone, Hill, & Rubino, 2010). Because the bivariate mean differences between groups examined in this study did not control for prior levels of mental health, this study cannot test the mechanisms by which mental health and marijuana use may be related, and either scenario could result from the pattern of results found here.

### Examining Diversity in Developmental Trajectories of Marijuana

Although a number of previous studies have modeled developmental trajectories of marijuana use, there is no consensus on the number and types of reported trajectories. Overall, the four trajectories found in the current investigation are most consistent with patterns reported in previous studies that used community samples with data spanning past

the early 20s (Brook, Zhang, et al., 2011; Caldeira et al., 2012; Pahl et al., 2011). Three of the four most common patterns—chronics, nonusers, and adolescent-limited—were also found in the current investigation. However, differences between the current study and others with similar samples exist. Brook, Zhang, and Brook (2011) found an increasing users class that onset in middle adolescence and continued escalating use into the late 20s that represented 8% of their sample. This class differed from the late-onset group in the present investigation primarily in the amount of marijuana use, whereas the late-onset group, relatively, reported moderate use even at peak use time (age 24); the increasing pattern found by Brook et al. trended toward the upper end of the scale, suggesting chronic or problematic use. It is possible that the moderate size of the SSDP sample obscured this pattern in current use. With larger samples it may be possible to differentiate more trajectories of use, including those patterns that are less common.

The most likely source of variation in the number of patterns found in one study versus another was the timeframe in which marijuana use was measured. For example, the number and shape of trajectories of marijuana use found when measuring every 6 months from ages 15 to 17 (Windle & Wiesner, 2004) are likely to differ from those found when the same number of assessment points span a much larger age range (Kandel & Chen, 2000). Studies spanning only a few years may be able to capture only a part of a larger trajectory. For example Ellickson, Martino, and Collins (2004) found a pattern of the steady increasers—users who began using marijuana around age 14 and continued using more frequently through age 18 (final time point). Had data collection continued, however, this group could have become an adolescent-limited trajectory group if their use declined in the early 20s.

Other variation between our and other solutions may have been due to differences in measurement of the dependent variable (i.e., marijuana use), treatment of dependent variables (continuous, categorical, censored, Poisson), and modeling techniques and software. For example, Caldeira and colleagues (2012) found a low-stable class that reported low use throughout development using PROC TRAJ, a modeling procedure that does not allow within-class variability of growth factors. On the other hand, our analysis allowed within-class variability and specified an a priori nonuser class that may have subsumed those users who would have fallen into the low-stable category otherwise. Despite the study-by-study differences, the substantial overlap in patterns of marijuana use across diverse samples gives confidence to the developmental trajectory approach to the study of marijuana use.

### Limitations and Strengths of This Study, and Directions for Additional Research

Limitations of research must also be acknowledged and the findings interpreted in light of these limitations. We want to stress that differences in adolescent, young adult, and adult functioning between the four groups should be interpreted as correlates and not causes or consequences of marijuana use. Although we included demographic controls in the class estimation, analyses were bivariate comparisons between the classes and do not eliminate the possibility of other variables that may explain both participants' trajectories of marijuana use and outcome variables. Nor do the present analyses support conclusions about causal ordering among variables. In addition, an important limitation of the trajectory literature, including the current analysis, is that the consequences of marijuana use trajectories have

not been adequately examined. Rigorous studies with well-chosen controls are needed to determine the effects of marijuana use patterns over and above common correlates and confounders. The focus of the present study was to take a broad view across development, identifying particular points of interest and differences in potential causes and consequences that subsequent studies should examine rigorously for tests of causal ordering and closure.

A major strength of this research is the use of a rich longitudinal dataset that allowed us to model developmental trajectories of marijuana use from adolescence into adulthood. The inclusion of annual assessments during the adolescent years allowed us to capture both early and late onset of use. Follow-up into adulthood afforded the possibility to examine outcomes past the age when major changes in use are likely. Future studies need to examine patterns of marijuana use in later adulthood and middle age, particularly in states where legalization of marijuana may have created a new market for previously infrequent users or nonusers.

Finally, the sample is geographically limited and, although economically and ethnically diverse, may not generalize to all U.S. populations. In particular, the sample does not include enough Native Americans or Hispanics to allow for generalization to these groups. Previous studies have found variability in the patterns of marijuana use by ethnicity (Brown et al., 2004; Finlay et al., 2012) and gender (Flory et al., 2004; Juon et al., 2011). Future studies should also investigate patterns of marijuana use in other countries, especially those that place structural constraints on adolescents and young adults (e.g., mandatory military service) or have different cultural climates (e.g., early marriage). The adolescent-limited pattern of marijuana use, for instance, may be primarily present in societies that support a Western-style extended adolescence when many youth are free from family and work obligations to pursue social and recreational substance use (Arnett, 2005).

### Implications

This work contributes in important ways to the recognition of the diversity of marijuana use patterns and the understanding that interventions must consider both which pattern of use to target, and at what developmental period to intervene. Further research needs to add to the body of knowledge that can identify signs of problematic patterns of behavior in order to deliver early intervention while recognizing that some patterns of marijuana use are associated with more negative outcomes than are other patterns. Finally, it is important to understand that marijuana use affects multiple domains of functioning, including peer, school, and neighborhood contexts, and often co-occurs with other mental health and substance use problems. Successful intervention programs need to address multiple underlying risk factors and intervene on multiple levels in order to prevent involvement in problematic patterns of marijuana use.

### References

Achenbach, TM. Manual for the Child Behavior Checklist/4–18 and 1991 profile. Burlington: University of Vermont Department of Psychiatry; 1991.

American Psychiatric Association. Diagnostic and statistical manual of mental disorders DSM-IV-TR. 4. Washington, DC: American Psychiatric Association; 2000.

Arnett JJ. The developmental context of substance use in emerging adulthood. Journal of Drug Issues. 2005; 35:235–254.

Arria AM, Garnier-Dykstra LM, Caldeira KM, Vincent KB, Winick ER, O'Grady KE. Drug use patterns and continuous enrollment in college: Results from a longitudinal study. Journal of Studies on Alcohol and Drugs. 2013; 74:71–83. [PubMed: 23200152]

Beyers JM, Toumbourou JW, Catalano RF, Arthur MW, Hawkins JD. A cross-national comparison of risk and protective factors for adolescent substance use: The United States and Australia. Journal of Adolescent Health. 2004; 35:3–16. [PubMed: 15193569]

Brook JS, Adams RE, Balka EB, Johnson E. Early adolescent marijuana use: Risks for the transition to young adulthood. Psychological Medicine. 2002; 32:79–91. [PubMed: 11883732]

Brook JS, Balka EB, Whiteman M. The risks for late adolescence of early adolescent marijuana use. American Journal of Public Health. 1999; 89:1549–1554. [PubMed: 10511838]

Brook JS, Lee JY, Brown EN, Finch SJ, Brook DW. Developmental trajectories of marijuana use from adolescence to adulthood: Personality and social role outcomes. Psychological Reports. 2011; 108:339–357. [PubMed: 21675549]

Brook JS, Lee JY, Finch SJ, Brook DW. Developmental trajectories of marijuana use from adolescence to adulthood: Relationship with using weapons including guns. Aggressive Behavior. 2014; 40:229–237. [PubMed: 24338741]

Brook JS, Lee JY, Finch SJ, Seltzer N, Brook DW. Adult work commitment, financial stability, and social environment as related to trajectories of marijuana use beginning in adolescence. Substance Abuse. 2013; 34:298–305. [PubMed: 23844962]

Brook JS, Zhang C, Brook DW. Antisocial behavior at age 37: Developmental trajectories of marijuana use extending from adolescence to adulthood. American Journal on Addictions. 2011; 20:509–515. [PubMed: 21999495]

Brown EC, Catalano RF, Fleming CB, Haggerty KP, Abbott RD, Cortes RC, Park J. Mediator effects in the social development model: An examination of constituent theories. Criminal Behaviour and Mental Health. 2005; 15:221–235. [PubMed: 16575843]

Brown TL, Flory K, Lynam DR, Leukefeld C, Clayton RR. Comparing the developmental trajectories of marijuana use of African American and Caucasian Adolescents: Patterns, antecedents, and consequences. Experimental and Clinical Psychopharmacology. 2004; 12:47–56. [PubMed: 14769099]

Caldeira KM, O'Grady KE, Vincent KB, Arria AM. Marijuana use trajectories during the post-college transition: Health outcomes in young adulthood. Drug and Alcohol Dependence. 2012; 125:267–275. [PubMed: 22464050]

Catalano, RF.; Hawkins, JD. The social development model: A theory of antisocial behavior. In: Hawkins, JD., editor. Delinquency and crime: Current theories. New York: Cambridge University Press; 1996. p. 149-197.

Choi Y, Harachi TW, Gillmore MR, Catalano RF. Applicability of the social development model to urban ethnic minority youth: Examining the relationship between external constraints, family socialization, and problem behaviors. Journal of Research on Adolescence. 2005; 15:505–534. [PubMed: 21625351]

Cicchetti D, Rogosch FA. A developmental psychopathology perspective on adolescence. Journal of Consulting and Clinical Psychology. 2002; 70:6–20. [PubMed: 11860057]

Clark, SL.; Muthén, B. Relating latent class analysis results to variables not included in the analysis. 2009. Retrieved from http://www.statmodel.com/download/relatinglca.pdf

Donovan JE, Jessor R. Structure of problem behavior in adolescence and young adulthood. Journal of Consulting and Clinical Psychology. 1985; 53:890–904. [PubMed: 4086689]

Elder GH Jr. The life course as developmental theory. Child Development. 1998; 69:1–12. [PubMed: 9499552]

Elder, GH., Jr; Kirkpatrick Johnson, M.; Crosnoe, R. The emergence and development of life course theory. In: Mortimer, JT.; Shanahan, MJ., editors. Handbook of the life course. New York: Kluwer Academic/Plenum Publishers; 2003. p. 3-19.

Ellickson PL, D'Amico EJ, Collins RL, Klein DJ. Marijuana use and later problems: When frequency of recent use explains age of initiation effects (and when it does not). Substance Use & Misuse. 2005; 40:343–359. [PubMed: 15776981]

Ellickson PL, Martino SC, Collins RL. Marijuana use from adolescence to young adulthood: Multiple developmental trajectories and their associated outcomes. Health Psychology. 2004; 23:299–307. [PubMed: 15099171]

Finlay AK, White HR, Mun EY, Cronley CC, Lee C. Racial differences in trajectories of heavy drinking and regular marijuana use from ages 13 to 24 among African-American and White males. Drug and Alcohol Dependence. 2012; 121:118–123. [PubMed: 21908109]

Fleming CB, Catalano RF, Oxford ML, Harachi TW. A test of generalizability of the social development model across gender and income groups with longitudinal data from the elementary school developmental period. Journal of Quantitative Criminology. 2002; 18:423–439.

Flory K, Lynam D, Milich R, Leukefeld C, Clayton R. Early adolescent through young adult alcohol and marijuana use trajectories: Early predictors, young adult outcomes, and predictive utility. Development and Psychopathology. 2004; 16:193–213. [PubMed: 15115071]

Hall WD. Cannabis use and the mental health of young people. Australian & New Zealand Journal of Psychiatry. 2006; 40:105–113. [PubMed: 16476127]

Hawkins JD, Kosterman R, Catalano RF, Hill KG, Abbott RD. Promoting positive adult functioning through social development intervention in childhood: Long-term effects from the Seattle Social Development Project. Archives of Pediatrics and Adolescent Medicine. 2005; 159:25–31. [PubMed: 15630054]

Hill KG, Hawkins JD, Bailey JA, Catalano RF, Abbott RD, Shapiro V. Person-environment interaction in the prediction of alcohol abuse and alcohol dependence in adulthood. Drug & Alcohol Dependence. 2010; 110:62–69. [PubMed: 20299164]

Johnston, LD.; O'Malley, PM.; Bachman, JG.; Shulenberg, JE. Monitoring the Future national survey results on drug use 1975–2012. Vol. 1: Secondary school students. Ann Arbor: Institute for Social Research, The University of Michigan; 2013.

Juon HS, Fothergill KE, Green KM, Doherty EE, Ensminger ME. Antecedents and consequences of marijuana use trajectories over the life course in an African American population. Drug and Alcohol Dependence. 2011; 118:216–223. [PubMed: 21514749]

Kandel DB, Chen K. Types of marijuana users by longitudinal course. Journal of Studies on Alcohol. 2000; 61:367–378. [PubMed: 10807207]

Klein MW. Offence specialisation and versatility among juveniles. British Journal of Criminology. 1984; 24:185–194.

Kosterman R, Hill KG, Lee JO, Meacham MC, Abbott RD, Catalano RF, Hawkins JD. Young adult social development as a mediator of alcohol use disorder symptoms from age 21 to 30. Psychology of Addictive Behaviors. 2014; 28:348–358. [PubMed: 24955663]

Kosterman R, Mason WA, Haggerty KP, Hawkins JD, Spoth R, Redmond C. Positive childhood experiences and positive adult functioning: Prosocial continuity and the role of adolescent substance use. Journal of Adolescent Health. 2011; 49:180–186. [PubMed: 21783051]

Lengua LJ, Sadowski CA, Friedrich WN, Fisher J. Rationally and empirically derived dimensions of children's symptomatology: Expert ratings and confirmatory factor analyses of the CBCL. Journal of Consulting and Clinical Psychology. 2001; 69:683–698. [PubMed: 11550734]

Lynskey M, Hall WD. The effects of adolescent cannabis use on educational attainment: A review. Addiction. 2000; 95:1621–1630. [PubMed: 11219366]

Lynskey MT, Coffey C, Degenhardt L, Carlin JB, Patton G. A longitudinal study of the effects of adolescent cannabis use on high school completion. Addiction. 2003; 98:685–692. [PubMed: 12751986]

Maggs JL, Schulenberg JE. Trajectories of alcohol use during the transition to adulthood. Alcohol Research & Health. 2004; 28:195–201.

Malone DT, Hill MN, Rubino T. Adolescent cannabis use and psychosis: Epidemiology and neurodevelopmental models. British Journal of Pharmacology. 2010; 160:511–522. [PubMed: 20590561]

Moffitt TE. Adolescence-limited and life-course-persistent antisocial behavior: A developmental taxonomy. Psychological Review. 1993; 100:674–701. [PubMed: 8255953]

Moffitt, TE. Life-course-persistent and adolescence-limited antisocial behavior: A 10-year research review and a research agenda. In: Lahey, BB.; Moffitt, TE.; Caspi, A., editors. Causes of conduct disorder and juvenile delinquency. New York: Guilford Press; 2003. p. 49-75.

Muthén, LK.; Muthén, BO. Mplus user's guide. 4. Los Angeles: Muthén & Muthén; 1998–2010.

Oesterle S, Hawkins JD, Steketee M, Jonkman H, Brown EC, Moll M, Haggerty KP. A cross-national comparison of risk and protective factors for adolescent drug use and delinquency in the United States and the Netherlands. Journal of Drug Issues. 2012; 42:337–357. [PubMed: 26166843]

Pahl K, Brook JS, Koppel J. Trajectories of marijuana use and psychological adjustment among urban African American and Puerto Rican women. Psychological Medicine. 2011; 41:1775–1783. [PubMed: 21205359]

Pope HG Jr, Gruber AJ, Hudson JI, Cohane G, Huestis MA, Yurgelun-Todd D. Early-onset cannabis use and cognitive deficits: What is the nature of the association? Drug & Alcohol Dependence. 2003; 69:303–310. [PubMed: 12633916]

Robins, L.; Cottler, L.; Bucholz, K.; Compton, W. National Institute of Mental Health Diagnostic Interview Schedule for DSM-IV. St. Louis, MO: Washington University, Department of Psychiatry; 1998.

Roettger ME, Swisher RR, Kuhl DC, Chavez J. Paternal incarceration and trajectories of marijuana and other illegal drug use from adolescence into young adulthood: Evidence from longitudinal panels of males and females in the United States. Addiction. 2011; 106:121–132. [PubMed: 20874861]

SAMHSA. Results from the 2011 National Survey on Drug Use and Health: Summary of National Findings, NSDUH Series H-44, HHS. Rockville, MD: Substance Abuse and Mental Health Services Administration; 2012.

SAMHSA. Results from the 2012 National Survey on Drug Use and Health: Mental Health Findings. Rockville, MD: Substance Abuse and Mental Health Services Administration; 2013.

Schulenberg JE, Maggs JL. A developmental perspective on alcohol use and heavy drinking during adolescence and the transition to young adulthood. Journal of Studies on Alcohol. 2002; 14:54–70.

Schulenberg, JE.; Maggs, JL.; O'Malley, PM. How and why the understanding of developmental continuity and discontinuity is important: The sample case of long-term consequences of adolescent substance use. In: Mortimer, JT.; Shanahan, MJ., editors. Handbook of the life course. New York: Plenum; 2003. p. 413-436.

Schulenberg JE, Merline AC, Johnston LD, O'Malley PM, Bachman JG, Laetz VB. Trajectories of marijuana use during the transition to adulthood: The big picture based on national panel data. Journal of Drug Issues. 2005; 35:255–280. [PubMed: 16534532]

Sher KJ, Jackson KM, Steinley D. Alcohol use trajectories and the ubiquitous cat's cradle: Cause for concern? Journal of Abnormal Psychology. 2011; 120:322–335. [PubMed: 21319874]

Sullivan CJ, Hirschfield P. Problem behavior in the middle school years: An assessment of the social development model. Journal of Research in Crime and Delinquency. 2011; 48:566–593.

Tucker JS, Ellickson PL, Orlando M, Martino SC, Klein DJ. Substance use trajectories from early adolescence to emerging adulthood: A comparison of smoking, binge drinking, and marijuana use. Journal of Drug Issues. 2005; 35:307–332.

Whitesell NR, Asdigian NL, Kaufman CE, Big Crow C, Shangreau C, Keane EM, Mousseau AC, Mitchell CM. Trajectories of substance use among young American Indian adolescents: Patterns and predictors. Journal of Youth and Adolescence. 2014; 43:437–453. [PubMed: 24136376]

Windle M, Wiesner M. Trajectories of marijuana use from adolescence to young adulthood: Predictors and outcomes. Development and Psychopathology. 2004; 16:1007–1027. [PubMed: 15704825]

Young SE, Stallings MC, Corley RP, Krauter KS, Hewitt JK. Genetic and environmental influences on behavioral disinhibition. American Journal of Medical Genetics. 2000; 96:684–695. [PubMed: 11054778]
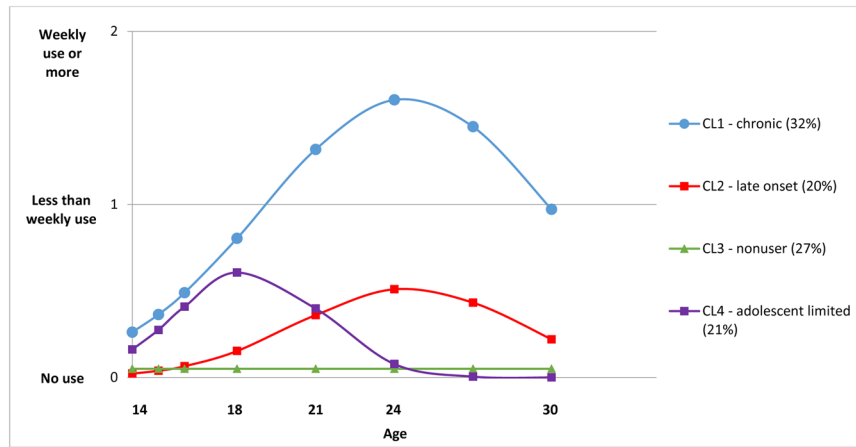
**Figure 1.**
Trajectories of marijuana use, age 14 through 30, SSDP sample.

**Table 1**

Quadratic Growth Mixture Modeling With Poisson Distribution

| No. Classes | AIC | BIC | SABIC | LL | No. para | Entropy | Adj LRT | BLRT | Class 1 N | Class 2 N | Class 3 N | Class 4 N | Class 5 N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 class | 8410.12 | 8480.50 | 8432.87 | −4190.06 | 15 | .793 | .0000 | .0000 | 578 | 227 | | | |
| 3 class | 8284.62 | 8397.23 | 8321.02 | −4118.31 | 24 | .700 | .0001 | .0000 | 280 | 323 | 202 | | |
| 4 class | 8218.02 | 8372.85 | 8268.06 | −4076.01 | 33 | .680 | .0009 | .0000 | 254 | 165 | 216 | 169 | |
| 5 class[*] | 8186.96 | 8384.02 | 8250.65 | −4051.48 | 42 | .688 | .0103 | .0000 | 240 | 189 | 103 | 118 | 155 |

Note. Class 1 – 5 composition is based on the estimated counts for the latent classes based on posterior probabilities.

AIC = Aikake Information Criterion; BIC = Bayesian Information Criterion; SABIC = Sample Adjusted Bayesian Information Criterion; Aj LRT = Adjusted Likelihood Ratio Test; BLRT = Bootstrap Adjusted Likelihood Ratio Test; para = parameter.

[*] Estimates from the 5-class solution are not trustworthy due to estimation errors.

Author Manuscript

Author Manuscript

Author Manuscript

Author Manuscript

**Table 2**

Descriptive Comparisons of (Conditional) Trajectories: Gender, Ethnicity, and SES Distribution Across Trajectories

| Domains of comparison | Chronic | Adolescent- limited | Late-onset | Nonuser | Overall chi-square |
|---|---|---|---|---|---|
| | | Percent of class membership within each class | | | |
| Demographics | | | | | |
| Male | 65[a] | 37[b] | 55[a] | 42[b] | 12.86** |
| Black | 33[a] | 33[a] | 15[b] | 20[b] | 28.16*** |
| Asian | 7[a] | 7[a] | 30[b] | 45[c] | 135.16*** |
| Native | 8[a] | 10[a] | 0[b] | 2[b] | 42.82*** |
| Free lunch | 52 | 56 | 45 | 55 | 3.10 |

Note. Percents in the same row that do not share superscripts are different at p < .05.

**Table 3**

Mean Values of Predictors: Comparison of Trajectories at Age 33

| Domains of comparison | Chronic | Adolescent - limited | Late-onset | Nonuser | Overall chi-square |
|---|---|---|---|---|---|
| | | Standardized means age 33 | | | |
| **Substance-related outcomes** | | | | | |
| Marijuana abuse/ dependence symptoms | .45[a] | −.21[b] | −.17[b] | −.23[b] | 34.95*** |
| Alcohol abuse/dependence symptoms | .39[a] | −.11[bc] | −.12[b] | −.30[c] | 36.07*** |
| Tobacco dependence symptoms | .42[a] | −.03[b] | −.06[b] | −.45[c] | 69.66*** |
| **Mental health outcomes** | | | | | |
| Depressive symptoms | .13 | .01 | −.04 | −.12 | 4.81 |
| Anxiety symptoms | .19[a] | .01[ab] | −.02[ab] | −.23[b] | 12.44** |
| **Problem behavior** | | | | | |
| Crime involvement | .31[a] | −.10[b] | −.13[b] | −.20[b] | 19.00*** |
| Sexual risk behavior | .48[a] | −.12[b] | −.14[b] | −.37[c] | 56.24*** |
| **Economic outcomes** | | | | | |
| Income (individual) | −.24[a] | −.10[a] | .15[b] | .23[b] | 22.02*** |
| Graduated high school | −.25[a] | −.10[a] | .14[b] | .28[b] | 33.50*** |
| Has a college degree | −.26[a] | −.15[a] | .15[b] | .32[b] | 37.36*** |
| **Positive functioning outcomes** | | | | | |
| Bonding to others | −.24[a] | .13[b] | .11[b] | .10[b] | 8.84* |
| Constructive engagement | −.17[a] | −.12[a] | .16[b] | .18[b] | 16.49** |

Note. Means in the same row that do not share superscripts are different at $p < .05$.

**Table 4**

Mean Values of Predictors: Comparisons of Trajectories at Ages 10 – 14 and 18

| Domains of comparison | Chronic | Adolescent- limited | Late-onset | Nonuser | Overall chi-square |
|---|---|---|---|---|---|
| | | Standardized means ages 10 – 14 | | | |
| General environment | | | | | |
| Positive family (of origin) | –.09 | .01 | .03 | .08 | 2.12 |
| Positive school | –.16 | .07 | .01 | .12 | 4.92 |
| Antisocial peers | .28[a] | .10[ac] | –.13[bc] | –.30[b] | 37.27*** |
| Neighborhood disorganization | .19[a] | .03[ab] | –.19[b] | –.08[b] | 14.35** |
| Marijuana-specific environment | | | | | |
| Family marijuana use | .19[a] | .07[ac] | –.10[bc] | –.20[b] | 16.46** |
| Peer marijuana use | .33[a] | .17[a] | –.22[b] | –.34[b] | 65.24*** |
| Community marijuana availability | .29[a] | .13[ab] | –.04[b] | –.42[c] | 57.26*** |
| Individual | | | | | |
| Behavioral disinhibition | .38[a] | .10[b] | –.12[b] | –.41[c] | 69.94*** |
| Depression symptoms | .15[a] | .16[ab] | –.09[bc] | –.23[c] | 22.65*** |
| Anxiety symptoms | .02 | .05 | .05 | –.11 | 3.24 |
| Substance use | | | | | |
| Past-month marijuana use | .19[a] | .06[a] | –.13[b] | –.15[b] | 16.36** |
| Past-month alcohol use | .21[a] | .10[a] | –.11[b] | –.23[b] | 24.31*** |
| Past-month tobacco use | .15[a] | .12[ac] | –.12[bc] | –.18[b] | 17.44** |
| | | Standardized means age 18 | | | |
| General environment | | | | | |
| Positive family (of origin) | –.22[a] | .02[ab] | .11[b] | .15[b] | 11.94** |
| Positive school | –.25[a] | –.07[b] | .17[bc] | .17[c] | 20.14*** |
| Antisocial peers | .44[a] | .03[b] | –.13[b] | –.40[c] | 70.89*** |
| Neighborhood disorganization | .17[a] | .12[a] | –.17[bc] | –.15[c] | 17.80*** |
| Marijuana-specific environment | | | | | |
| Peer marijuana use | .66[a] | .15[b] | –.35[c] | –.57[d] | 216.73*** |

| Domains of comparison | Chronic | Adolescent-limited | Late-onset | Nonuser | Overall chi-square |
|---|---|---|---|---|---|
| | | **Standardized means ages 10 – 14** | | | |
| Community marijuana availability | .28[a] | .16[ab] | .04[b] | -.48[c] | 47.09*** |
| Individual | | | | | |
| Behavioral disinhibition | .47[a] | .04[b] | -.06[b] | -.49[c] | 94.72*** |
| Internalizing symptoms | - | - | - | - | - |
| Anxiety symptoms | - | - | - | - | - |
| Substance use | | | | | |
| Past-month marijuana use | .57[a] | -.15[b] | -.28[c] | -.32[c] | 77.22*** |
| Past-month alcohol use | .42[a] | .07[b] | -.18[c] | -.37[d] | 87.18*** |
| Past-month tobacco use | .37[a] | .04[b] | -.15[b] | -.33[c] | 61.93*** |

Note. Means in the same row that do not share superscripts are different at p < .05.

**Table 5**

Mean Values of Predictors: Comparisons of Trajectories at Ages 21 and 24

| Domains of comparison | Chronic | Adolescent-limited | Late-onset | Nonuser | Overall chi-square |
|---|---|---|---|---|---|
| | | Standardized means age 21 | | | |
| General environment | | | | | |
| Positive family (of origin) | −.20[a] | .00[ab] | .09[b] | .17[b] | 12.38** |
| Positive school/work | −.22 | .09 | .08 | .11 | 7.16 |
| Antisocial peers | .25[a] | .02[ac] | −.15[bc] | −.19[b] | 20.83*** |
| Neighborhood disorganization | .28[a] | −.10[b] | −.08[b] | −.18[b] | 14.47** |
| Marijuana-specific environment | | | | | |
| Peer marijuana use | .72[a] | −.17[b] | −.14[b] | −.60[c] | 168.20*** |
| Community marijuana availability | - | - | - | - | - |
| Individual | | | | | |
| Behavioral disinhibition | .36[a] | −.11[b] | .03[b] | −.37[c] | 35.75*** |
| Depressive symptoms | .16[a] | .04[a] | −.04[ab] | −.20[b] | 11.74** |
| Anxiety symptoms | .21[a] | −.03[b] | −.04[b] | −.19[b] | 11.26** |
| Substance use | | | | | |
| Past-month marijuana use | .69[a] | −.28[b] | −.27[b] | −.36[c] | 115.77*** |
| Past-month alcohol use | .42[a] | .11[b] | −.01[b] | −.41[c] | 68.14*** |
| Past-month tobacco use | .30[a] | .01[b] | −.07[b] | −.31[c] | 37.74*** |
| | | Standardized means age 24 | | | |
| General environment | | | | | |
| Positive family (of origin) | −.13[a] | −.11[a] | .08[ab] | .18[b] | 13.31** |
| Positive school/work | −.14 | .07 | −.03 | .14 | 4.29 |
| Antisocial peers | .32[a] | −.11[b] | −.09[b] | −.21[b] | 19.58*** |
| Neighborhood disorganization | .25[a] | .01[ab] | −.01[b] | −.29[c] | 25.59*** |
| Marijuana-specific environment | | | | | |
| Peer marijuana use | .74[a] | −.31[b] | −.08[b] | −.56[c] | 150.41*** |
| Community marijuana availability | - | - | - | - | - |

| Domains of comparison | Chronic | Adolescent-limited | Late-onset | Nonuser | Overall chi-square |
|---|---|---|---|---|---|
| | | Standardized means age 21 | | | |
| Individual | | | | | |
| Behavioral disinhibition | .43[a] | −.16[b] | .03[b] | −.39[c] | 41.84** |
| Depressive symptoms | .12 | .02 | −.02 | −.14 | 6.58 |
| Anxiety symptoms | .15[a] | .10[a] | −.09[ab] | −.17[b] | 13.95*** |
| Substance use | | | | | |
| Past-month marijuana use | .67[a] | −.32[bc] | −.23[b] | −.33[c] | 98.77*** |
| Past-month alcohol use | .45[a] | −.17[b] | .01[b] | −.40[c] | 65.53*** |
| Past-month tobacco use | .26[a] | .02[a] | .01[a] | −.34[b] | 44.60*** |

Note. Means in the same row that do not share superscripts are different at p < .05.