EMPIRICAL RESEARCH

Marijuana Use from Middle to High School: Co-occurring Problem Behaviors, Teacher-Rated Academic Skills and Sixth-Grade Predictors

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Abstract Rising marijuana use and its lowered perceived risk among adolescents highlight the importance of examining patterns of marijuana use over time. This study identified trajectories of marijuana use among adolescents followed from middle through high school, characterized these by co-occurring problem behaviors and teacher-rated academic skills (study skills, attention problems, and learning problems), and tested sixth-grade predictors of trajectory membership. The sample consisted of a randomly-selected cohort of 619 students assessed annually from sixth to twelfth grade. Using group-based modeling, we identified four trajectories of marijuana use: *Abstainer* (65.6 %), *Sporadic* (13.9 %), *Experimental* (11.5 %), and *Increasing* (9.0 %). Compared to *Abstainers*, students in the *Sporadic*, *Experimental* and *Increasing* trajectories reported significantly more co-occurring problem behaviors of alcohol use, cigarette smoking, and physical aggression. *Sporadic* and *Experimental* users reported significantly less smoking and physical aggression, but not alcohol use, than *Increasing* users. Teachers consistently rated *Abstainers* as having better study skills and less attention and learning problems than the three marijuana use groups. Compared to *Abstainers*, the odds of dropping out of high school was at least 2.7 times higher for students in the marijuana use trajectories. Dropout rates did not vary significantly between marijuana use groups. In sixth grade, being male, cigarette smoking, physical aggression and attention problems increased the odds of being in the marijuana use trajectories. Multiple indicators—student self-reports, teacher ratings and high school dropout records—showed that marijuana was not an isolated or benign event in the life of adolescents but part of an overall problem behavior syndrome.

Keywords Adolescent marijuana use · Problem behaviors · Teacher ratings · Group-based modeling · Academic performance · Marijuana trajectories · Early adolescence

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Introduction

For the past 5 years, two concurrent trends are concerning: Adolescents have been increasing their use of marijuana and high school students perceive less risk in using marijuana regularly (Johnston et al. 2012; Substance Abuse and Mental Health Services Administration 2013). Recent political changes legalizing marijuana use in some states also point to a change in social norms regarding marijuana

use among adults. Scientists are concerned about these trends because of the possible long-term negative impact of marijuana use on adolescents' academic pursuits and intellectual abilities (Meier et al. 2012; Rogeberg 2013). Thus, more longitudinal studies are needed to understand the association of trajectories of marijuana use with other risk behaviors and academic performance.

Cross-sectional studies show a systematic increase in marijuana use as students progress from middle to high school. In the same years as our study, *Monitoring the Future*, an annual national survey supported by the National Institute on Drug Abuse, showed that 6.6 % of eighth graders, 14.2 % of tenth graders, and 20.6 % of twelfth graders reported using marijuana (Johnston et al. 2012). However, patterns of prevalence can mask variations in marijuana use by the individual over the course of several years. Based on previous research on substance use, it is reasonable to assume that distinct developmental trajectories are likely to emerge within a population (Brown et al. 2004; Schulenberg et al. 2005; Windle and Wiesner 2004). Some adolescents may report never using marijuana, while others may have increasing, decreasing, or consistently low or high levels of marijuana use. In longitudinal studies, researchers have identified three (Brown et al. 2004; Tucker et al. 2006; Wanner et al. 2006), five (Ellickson et al. 2004; Windle and Wiesner 2004) or six trajectories (Schulenberg et al. 2005) of marijuana use. All have in common a large group reporting low or no use. The adolescents in all these U.S. studies were surveyed in the 1980s when marijuana use declined by over 20 %, and binge drinking and cigarette use were also losing popularity (Johnston et al. 2012). Given the social changes experienced by adolescents today, it is important to identify in a current sample of students the trajectories of marijuana use, their association with other risk behaviors, and the behaviors that predict these trajectories.

The trajectories of marijuana use in adolescence are most clearly understood within Problem Behavior Theory (Jessor 1991; Jessor et al. 2003), a framework that posits that engaging in one risk behavior increases the likelihood of engaging in others. Research suggests that marijuana use is part of an overall problem behavior syndrome (Donovan 1996). In a longitudinal study of mostly White adolescents from high-income families, Ansary and Luthar (2009) found that problem behaviors (i.e., drinking alcohol, smoking cigarettes, using marijuana, and engaging in acts of delinquency or aggression) clustered and were associated with academic underachievement. In another longitudinal study of mostly African-American children living in poor neighborhoods, Green and Ensminger (2006) concluded that frequent marijuana use was associated with high school dropout, unemployment, and having children outside of marriage. For this study population, the

accompanying use of cocaine, alcohol and cigarettes added to the complexity of distinguishing the effects of marijuana from other problem behaviors. An examination of trajectories of marijuana use and other problem behaviors can facilitate comparisons of these trends. Other studies have shown strong positive associations between trajectories of marijuana and smoking among African-American and Puerto Rican adolescents (Brook et al. 2010), and trajectories of co-occurring marijuana, alcohol and gambling among White boys (Wanner et al. 2006). This study examines the marijuana trajectories of a more diverse sample to include White, Black and Latino boys and girls.

A primary concern for parents and educators is the effect of marijuana on a child's academic performance. As early as middle school, students who used drugs also followed a path of deteriorating academic achievement (Henry 2010). Regular marijuana users, in particular, had higher odds of dropping out of high school, ranging from two to over five times the odds of non-users (Brook et al. 1999; McCaffrey et al. 2009). Even a low frequency of marijuana use (i.e., 1–2 occasions per year) was associated with a higher risk of not graduating from college (Tucker et al. 2005). To be clear, we consider dropout from high school or college an important harbinger of a child's future health and wellbeing and support it as a public health problem (Freudenberg and Ruglis 2007; Ross and Wu 1995). At the same time, we recognize that dropout is a long-term outcome that likely follows from a path of academic failures. For this reason, we examine dropout rates together with teacher ratings of academic skills to characterize adolescents in marijuana use trajectories.

School teachers provide a reliable indication of students' learning skills and behaviors at school. Green and Ensminger (2006) found that first-grade teachers rated future heavy marijuana users (i.e., at least 20 times by age 17) as more aggressive and inattentive. In another study, first-grade teachers, unexpectedly, rated those youth who tried marijuana at an earlier age as higher in readiness to learn math and English than their peers (Storr et al. 2011). It is possible that the discrepancy in ratings of academic performance depends on whether the children are "experimental" or heavy users of marijuana later in adolescence. Once again, longitudinal data of teacher ratings may be a better indicator of the association between marijuana use and academic performance than cross-sectional analyses.

Since many adolescents start using marijuana in middle school, it is important to examine predictors of prolonged use beginning in early adolescence. Lynne-Landsman et al. (2011) examined substance use, aggression, and delinquency trajectories through middle school and identified aggression, but not delinquency, as a predictor of substance use. In another study of middle school students, anger in sixth grade predicted drug use the following year (Nichols

et al. 2008). In both studies, the researchers grouped marijuana with other drugs or had to dichotomize responses because of low levels of use. Griffith-Lendering et al. (2011) found that externalizing behaviors of adolescents at a mean age of 11 years predicted marijuana use. The authors used self-reported aggression and rule-breaking as predictors of marijuana use at two discreet timepoints 2 and 3 years later, both of which were in middle school. In a study that spanned beyond middle school, Flory et al. (2004) identified two marijuana trajectories, early onset and late onset. Youth in both trajectories were significantly more dysfunctional than non-users, including having conduct disorder problems prior to sixth grade. These sixth grade measures of conduct disorder were taken from retrospective surveys of participants as young adults, which highlights the need for an analysis of prospective data. To our knowledge, the present study is one of the first to examine predictors of marijuana use through the end of high school, based on self-reported and teacher ratings of problem behaviors in sixth grade.

Purpose and Hypotheses

The aims of this study are to increase scientific understanding of the developmental trajectories of marijuana use from middle to high school and characterize these trajectories by co-occurring problem behaviors and academic skills. Thus, the present study has four objectives. The first objective is to identify trajectories of marijuana use in a cohort of students followed from sixth to twelfth grade. Based on prior research, we expect that adolescents will follow distinct trajectories of marijuana use, with a large proportion not using marijuana. The second objective is to investigate the association between trajectories of marijuana use and problem behaviors. Based on problem behavior theory and research, we expect that adolescents in trajectories of high marijuana use will be more likely to drink alcohol, smoke cigarettes, and report physical aggression from middle to high school than students who do not use marijuana. Of interest is whether similar patterns of increasing marijuana use correspond to increasing problem behaviors. The third objective is to investigate the association between trajectories of marijuana use and teacher-rated academic skills and high school dropout. We hypothesize that teacher ratings of study skills, attention problems, and learning problems will similarly correspond to the marijuana use trajectories. We expect that dropout rates will increase with increasing marijuana use. The fourth objective is to examine whether self-reported problem behaviors and teacher-rated academic skills in Grade 6 predict a youth's marijuana use trajectories. We expect that problem behaviors and poor academic skills in Grade 6 will

predict the trajectories of marijuana use from middle to high school.

Methods

Design, Setting, and Participants

The sample consisted of students who took part in the *Healthy Teens Longitudinal Study.* A randomly selected cohort of students from nine middle schools in six counties in Northeast Georgia was followed from middle through high school (2003–2009). These counties had higher poverty rates compared to U.S. national rates. For example, at the time the sample was invited to participate, 26.1 % of the children in the participating counties lived in poverty, while the US average was 15.7 %. The schools were located in urban (one-third) and rural (two-thirds) areas. Schools were racially diverse; the sixth grade population ranged by school between 12 and 88 % Caucasian, 3 and 67 % African American, and 2 and 26 % Latino. At the school level, the percentage of high school students who received free or reduced-price lunch at participating schools ranged between 20 and 67 %; no socio-economic information was collected at the individual level.

All youth participants completed annual surveys from Grades 6 through 12 (seven assessments). Each year, a different teacher from a core subject rated students using a nationally-normed system for measuring student behaviors. In sixth grade, 939 students were invited to participate. Of these, 745 (79 %) enrolled in the study and 624 (84 % of the participating students) consented to continue participation in ninth grade. Only students with three or more waves of data on marijuana use were included in the study. The records of five students were removed because they had less than three data points, resulting in a final sample of 619 participants of the 745 originally enrolled in the study. The sample had slightly more boys (52 %) than girls. The sample was racially diverse, and consisted of students who self-identified as White (48 %), African-American (36 %), Latino (12 %), or multiracial or other (4 %). The mean age in ninth grade was 14.8 years (SD = .57).

Measures

Marijuana Use

Students were asked: "How many times during the past 30 days did you use marijuana (pot, hash, reefer, or weed)?" Responses were converted into a count variable by using the conservative lower bound. Thus, response categories and coding were: 0 = *never*, 1 = *1–2 times*, 3 = *3–5 times*, 6 = *6–9 times*, 10 = *10–19 times*, and

$20 = 20$ *or more times*. The measure of marijuana use ranged from 0 to 20 times.

Alcohol Use

Two items measured the frequency of drinking beer (more than a sip or taste) and wine or wine coolers (more than a sip or taste). Response categories were: $0 = never$, $1 = 1–2$ *times*, $3 = 3–5$ *times*, $6 = 6–9$ *times*, $10 = 10–19$ *times*, and $20 = 20$ *or more times*. The time frame was the prior 30 days. The overall alcohol use variable was calculated as a sum of the two items.

Smoking

A single item was used to measure smoking: "How many times during the past 30 days did you smoke cigarettes?" Responses were converted into a count variable by using the conservative lower bound. Response categories were: $0 = never$, $1 = 1–2$ *times*, $3 = 3–5$ *times*, $6 = 6–9$ *times*, $10 = 10–19$ *times*, and $20 = 20$ *or more times*.

Physical Aggression

A subscale of the Problem Behavior Frequency Scales (Farrell et al. 2000) was used to measure physical aggression (seven items, alpha in sixth grade = .83). Students indicated the frequency of aggressive behaviors during the 30 days prior to the survey, based on a 6-point scale ($0 = never$ to $5 = 20$ *or more times*). Items were throwing something to hurt someone, being in a fight in which someone was hit, shoving or pushing, hitting or slapping, threatening to hurt a teacher, threatening someone with a weapon, and threatening to hit or physically harm another student.

Dropout

Participants who dropped out of high school, were expelled, or who were not enrolled in an educational institution were categorized as dropouts. Youth who were enrolled in high school (public, private, or alternative), had already achieved a high school diploma, had a GED certificate, or were home-schooled were *not* classified as dropouts.

Teacher-Rated Study Skills, Attention Problems, and Learning Problems

Teachers rated students' academic skills using the Behavior Assessment System for Children (BASC) (Reynolds and Kamphaus 1992). The study skills scale (13 items; Cronbach's alpha in sixth grade = .95) measures strong academic performance, organizational skills, and good study habits. Examples of statements are "Uses the school library" and

"Completes homework." Attention Problems (6 items; alpha in sixth grade = .69) refers to being easily distracted and having difficulties concentrating. Examples of statements are "Does not pay attention to lectures" and "Is easily distracted from classwork." Learning Problems (9 items; alpha in sixth grade = .89) refers to difficulties understanding and completing school work. Examples of statements are "Says textbooks are hard to understand" and "Makes careless errors." Teachers followed the standard instructions for this nationally-normed assessment instrument, that is, to mark the response that describes the child's recent behavior using the following response categories: $0 = Never$, $1 = Sometimes$, $2 = Often$, and $3 = Almost$ *always*. Values were standardized T-Scores with a mean of 50 and a standard deviation of 10 using the national norm group.

Procedures

Data were collected during the spring semester of each academic year. All study activities, including written parental permission and student assent, were approved by the university Institutional Review Board. Research assistants received training in survey collection procedures. In middle school, youth used an audio computer-assisted survey interview (ACASI) system that displayed survey questions on a computer screen and allowed questions to be heard through headsets. In high school, students completed surveys online using computers at the respective schools. For youth not attending school, trained staff visited homes or other convenient locations where youth filled out paper-based surveys. For teacher assessments, project staff asked an academic teacher who knew the student well that year to rate the child. Each year a different teacher rated the child. Teachers did not rate students after they dropped out of high school.

Statistical Analyses

We conducted the analyses in four steps. First, we used a semi-parametric, group-based trajectory modeling (Proc TRAJ) approach to identify distinct subgroups of individuals following a similar pattern of marijuana use over time (Jones et al. 2001). Group-based trajectory modeling can be used to analyze longitudinal data if there is a reasonable belief that the population will contain subgroups of individuals who will have different patterns of behavior. For marijuana use, we can expect that some youth will never use it; some will consistently report high use, and others will have either increasing or decreasing patterns of behavior. Other studies have shown that marijuana use is not uniform within populations, as adolescents follow different patterns (Brown et al. 2004; Flory et al. 2004; Tucker et al. 2006). The group-based trajectory modeling procedure uses maximum likelihood to estimate model

parameters and can be used for continuous, count, and binary data. Since more students in our sample reported not using marijuana than is expected under a usual Poisson distribution, we used a zero order Poisson model to fit the data. Multiple starting values were specified to obtain stable model solutions. As recommended by Jones et al. (2001), we used the change in the Bayesian information criterion (BIC) for selecting the optimal model. Additional model selection criteria to identify the optimal number of groups were the size of the groups (greater than 5 %), posterior probabilities of group membership (≥ 0.7), and literature review of the developmental trajectories. Additionally, log Bayes factor approximation [2$\log_e$ (B10) values calculated as $2 \times (BIC_{k+1} - BIC_k)$] were calculated. If the 2$\log_e$ (B10) values are >10, there is a strong evidence favoring the more complex model (with more groups) (Jones et al. 2001). An advantage of Proc TRAJ is that it accommodates missing values, as individuals are not grouped on their raw score, but on the estimated trajectory. For each trajectory group, the models were further adjusted for a best trajectory shape (i.e., linear, quadratic, or cubic). For descriptive purposes, we examined whether the identified marijuana trajectories differed by demographic characteristics (gender and race), using Chi square test.

Second, we used mixed-effects modeling (Laird and Ware 1982) to examine whether the marijuana trajectory groups differed by drinking alcohol, smoking cigarettes, and perpetrating physical aggression over 7 years. We also examined teacher ratings of study skills, attention problems, and learning problems from sixth to tenth grade. We compared linear and quadratic mixed-effects models with different correlation structures (unstructured, ar(1), compound symmetry, and independence). The BIC criterion was used for final model selection.

Third, we calculated the odds of dropout by trajectory group membership controlling for race and gender in a logistic regression model. Fourth, we used multivariate logistic regression to predict the marijuana group membership based on Grade 6 problem behaviors (alcohol use, smoking, and physical aggression towards peers) and teacher-rated study skills, attention problems, and learning problems. All analyses controlled for gender and race, and all predictor variables were entered into multivariate logistic regression models. Stepwise selection (entry and removal $p = .15$) was used for variable selection.

Results

Marijuana Trajectories

The cross-sectional prevalence of marijuana use increased from 2.3 % in Grade 6 to 18.6 % in Grade 12 (Table 1).

Longitudinally, we identified three distinct trajectories of marijuana use from Grades 6 to 12. The BIC score for the 3-group model was −2496.1 and the 2$\log_e$ (B10) was 521.1. Table 2 displays BIC scores and group percentages by the number of groups considered. Although the BIC values for four group and five group models improved over a three-group model, the size of the groups was small (<5 %). The three trajectories identified using Proc TRAJ were named: *Abstainer/Sporadic*, *Experimental*, and *Increasing*. Figure 1 depicts the predicted values of the three trajectories, which were very similar to the observed values.

The *Abstainer/Sporadic* group was large (n = 492) and included youth who reported some marijuana use. Thus, we further distinguished *Abstainers* (i.e., students who never reported using marijuana) from *Sporadic* users (i.e., students who infrequently reported using marijuana). The *Abstainers* (n = 406) reported no marijuana use throughout the 7 years of the study. This group consisted of 52 % girls; 49.0 % White, 33.7 % African-American, and 17.2 % Latino students. The average marijuana use in the 30 days prior to the survey of the *Sporadic* group (n = 86) ranged from 0.08 times in Grade 6 to 0.44 times in Grade 12. This group consisted of 53 % girls; 48.8 % White, 39.5 % African-American, and 11.6 % Latino students.

The average marijuana use of the *Experimental* (n = 71) group was 0.19 in Grade 6 and increased to an average of 1.9 times in Grade 12. This group consisted of 38.0 % girls; 45.1 % White, 42.3 % African American, 11.3 % Latino.

The average marijuana use of the *Increasing* (n = 56) group was 0.38 in Grade 6 and steadily increased to an average of 10.2 times by Grade 12. This group consisted of 26.8 % girls; 42.9 % White, 35.7 % African American, 12.5 % Latino.

Students in the four marijuana groups differed by gender, $\chi^2(3) = 16.21$, $p = .001$. Significantly more boys than girls were in the highest two marijuana use trajectories. A similar proportion of boys and girls constituted the *Abstainer* and the *Sporadic* groups. Students in the four trajectories did not differ significantly by race or ethnic group.

Problem Behaviors

Figure 2 depicts the estimated mean trajectories of self-reported alcohol, smoking, and physical aggression for the four marijuana use trajectories. Contrasts between the groups for individual measures are reported in Table 3. Alcohol use scores followed a quadratic trajectory which differed significantly by marijuana trajectory [$\chi^2(9) = 145.85$, $p < .0001$]. *Abstainers* reported significantly lower alcohol use than students in the *Sporadic*, *Experimental*,

Table 1 Number of healthy teens participants reporting marijuana use—Grade 6 to 12

	Grade 6	Grade 7	Grade 8	Grade 9	Grade 10	Grade 11	Grade 12
0 times	587	513	593	511	508	489	474
1–2 times	11	16	23	22	41	28	50
3–5 times	1	9	13	14	12	16	17
6–9 times	1	9	6	2	10	12	10
10–19 times	0	0	3	3	6	7	9
20+ times	1	4	7	13	11	16	22
Proportion using one or more times (%)	2.3	6.9	9.5	9.6	13.6	13.9	18.6

Table 2 Bayesian information criterion (BIC) and $2\log_e$ (B10) marijuana use for zero-inflated Poisson (ZIP) model

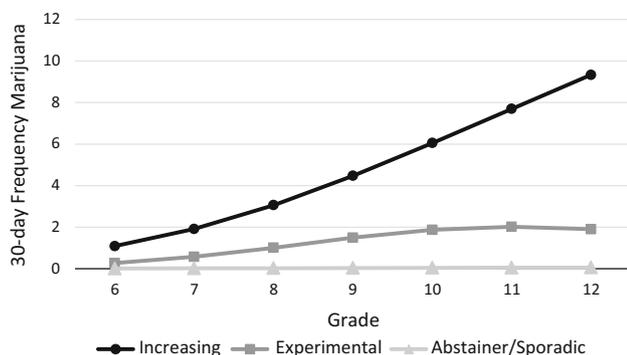| Number of groups	BIC	$2\log_e$ (B10)	Marijuana trajectory group percentage					
			1	2	3	4	5	6
1	−3,403.42		100					
2	−2,756.61	1,293.62	82.3	17.7				
3	−2,496.06	521.10	78.1	12.1	9.8			
4	−2,399.22	193.68	77.7	10.7	7.0	4.7		
5	−2,358.35	81.74	76.5	9.9	4.1	4.9	4.7	
6	−2,357.22	2.26	52.1	27.1	7.2	4.6	4.5	4.4

Fig. 1 Estimated trajectories of marijuana use—Grades 6 to 12

and *Increasing* groups. *Sporadic* users reported significantly less alcohol use than *Experimental* and *Increasing* users. *Experimental* and *Increasing* groups did not differ significantly in alcohol use over time.

Smoking scores followed a quadratic trajectory, which differed significantly by marijuana trajectory [$\chi^2(9) = 219.35$, $p < .0001$] and increased with increasing marijuana use groups. *Abstainers* reported significantly less smoking than students in the *Sporadic*, *Experimental*, and *Increasing* groups. *Sporadic* users reported significantly less smoking than *Experimental* and *Increasing* users. *Experimental* users smoked significantly less than *Increasing* users.

Physical aggression scores followed a quadratic trajectory and differed significantly by the four marijuana trajectories [$\chi^2(9) = 132.87$, $p < .0001$]. *Abstainers* reported significantly less physical aggression than students in the *Sporadic*, *Experimental*, and *Increasing* groups. *Sporadic* users reported significantly less aggression than *Experimental* and *Increasing* users. In addition, physical aggression scores were significantly lower for *Experimental* than for the *Increasing* users.

Teacher-Rated Academic Skills

Figure 3 depicts the estimated mean trajectories of teacher-rated study skills, attention problems, and learning problems for the four marijuana use trajectories. We estimated the trajectories from sixth to tenth grade due to the large number of students who dropped out in the latter years of high school. Teachers only rated those students who remained in school. Results from the group contrasts are reported in Table 3.

The four marijuana trajectories differed significantly over time in study skills [$\chi^2(6) = 76.01$, $p < .0001$], attention problems [$\chi^2(6) = 89.37$, $p < .0001$], and learning problems [$\chi^2(6) = 57.25$, $p < .0001$]. These teacher ratings followed a similar pattern. The best outcomes were for the *Abstainer* group, whose students had significantly better scores than those in the *Sporadic*, *Experimental*, and *Increasing* groups. Study skills scores for the *Abstainer*
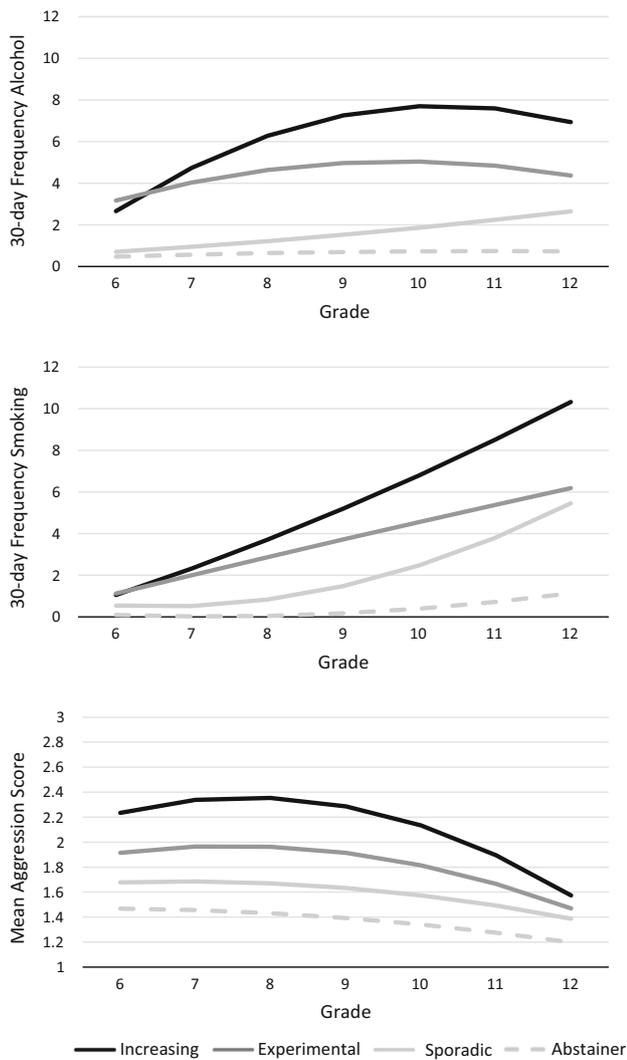
Fig. 2 Estimated trajectories of self-reported alcohol use, smoking, and physical aggression for marijuana use trajectories: Increasing, Experimental, Sporadic, and Abstainer—Grades 6 to 12

Table 3 Marijuana group differences for problem behaviors (alcohol use, cigarette smoking, physical aggression) and teacher-rated academic skills (study skills, attention problems, learning problems)

Measure	df	Chi square	F value	p value
Alcohol use (6th–12th grade)				
Abstainer versus Sporadic	3, 2,145	23.75	7.92	<.0001
Abstainer versus Experimental	3, 2,145	50.84	16.95	<.0001
Abstainer versus Increasing	3, 2,145	79.65	26.55	<.0001
Sporadic versus Experimental	3, 2,145	24.52	8.17	<.0001
Sporadic versus Increasing	3, 2,145	47.98	15.99	<.0001
Experimental versus Increasing	3, 2,145	6.51	2.17	0.09
Cigarette smoking (6th–12th grade)				
Abstainer versus Sporadic	3, 2,153	50.33	16.78	<.0001
Abstainer versus Experimental	3, 2,153	65.58	21.86	<.0001
Abstainer versus Increasing	3, 2,153	123.44	41.15	<.0001
Sporadic versus Experimental	3, 2,153	12.67	4.22	0.01
Sporadic versus Increasing	3, 2,153	39.13	13.04	<.0,001
Experimental versus Increasing	3, 2153	11.11	3.70	0.01
Physical aggression (6th–12th grade)				
Abstainer versus Sporadic	3, 2,160	13.72	4.57	0.003
Abstainer versus Experimental	3, 2,160	49.04	16.35	<.0001
Abstainer versus Increasing	3, 2,160	87.71	29.24	<.0001
Sporadic versus Experimental	3, 2,160	8.02	2.67	0.05
Sporadic versus Increasing	3, 2,160	31.90	10.63	<.0001
Experimental versus Increasing	3, 2,160	9.92	3.31	0.02
Study skills (6th–10th grade)				
Abstainer versus Sporadic	2, 1,556	15.35	7.67	0.0005
Abstainer versus Experimental	2, 1,556	41.75	20.88	<.0001
Abstainer versus Increasing	2, 1,556	36.51	18.26	<.0001
Sporadic versus Experimental	2, 1,556	10.02	5.01	0.007
Sporadic versus Increasing	2, 1,556	5.79	2.89	0.06
Experimental versus Increasing	2, 1,556	2.58	1.29	0.28
Attention problems (6th–10th grade)				
Abstainer versus Sporadic	2, 1,559	18.18	9.09	0.0001
Abstainer versus Experimental	2, 1,559	49.89	24.95	<.0001
Abstainer versus Increasing	2, 1,559	40.12	20.06	<.0001
Sporadic versus Experimental	2, 1,559	12.52	6.26	0.002
Sporadic versus Increasing	2, 1,559	4.94	2.47	0.08

group were stable over time and right at the national average, while attention and learning problems scores slightly decreased over time. For the *Sporadic* group, scores were significantly worse than the *Abstainer* group, but better than the two trajectories of higher marijuana use. The study skills and attention problem scores for the *Sporadic* group worsened slightly over time, while learning problems remained stable and at the national average. For the *Experimental* group, study skills scores remained stable over time—about half a standard deviation below the mean—while attention and learning problems decreased. For the *Increasing* group, all scores worsened over time. The trajectories of the *Increasing* and *Experimental* groups crossed between eighth and ninth grade.

Table 3 continued

Measure	df	Chi square	F value	p value
Experimental versus Increasing	2, 1,559	7.55	3.77	0.02
Learning problems (6th–10th grade)				
Abstainer versus Sporadic	2, 1,559	10.28	5.14	0.006
Abstainer versus Experimental	2, 1,559	33.22	16.61	<.0001
Abstainer versus Increasing	2, 1,559	24.45	12.22	<.0001
Sporadic versus Experimental	2, 1,559	9.64	4.82	0.008
Sporadic versus Increasing	2, 1,559	3.25	1.63	0.20
Experimental versus Increasing	2, 1,559	8.52	4.26	0.01

High School Dropout

The overall dropout rate was 17.6 % for the total sample, but differed significantly by marijuana trajectory [$\chi^2(3) = 25.03$, $p < .0001$]. Compared to *Abstainers*, the odds of dropping out was significantly higher for students in the *Sporadic* (OR 2.9; 95 % CI 1.61, 5.06), *Experimental* (OR 3.5; 95 % CI 1.90, 6.36) and *Increasing* groups (OR 2.7; 95 % CI 1.36, 5.30). The dropout rates among the three marijuana user groups did not differ significantly from one another. From 619 students, we did not have dropout information for 18 participants. Twelve of these students were in the *Abstainer* and *Sporadic* trajectories, and the remaining six students were in the two higher marijuana use trajectories.

Sixth Grade Predictors of Marijuana Trajectories

To address the fourth objective, we used a multinomial logistic regression model to examine whether self-reported problem behaviors (alcohol use, smoking, and physical aggression) and teacher-rated educational variables (study skills, attention problems, and learning problems) evaluated in Grade 6, and demographic variables (race, gender), predicted marijuana group membership. Gender, smoking, physical aggression and attention problems in Grade 6 predicted marijuana use. Compared to the *Abstainer* group, girls were less likely to be in the *Increasing* user group (OR 0.36; 95 % CI 0.18, 0.73). Adolescents who smoked tobacco in Grade 6 were more likely to be in the *Sporadic* (OR 4.11; 95 % CI 1.77, 9.54), *Experimental* (OR 5.09; 95 % CI 2.23, 11.60), and *Increasing* (OR 4.59; 95 % CI 2.0, 10.53) marijuana user groups than in the *Abstainer* group. Compared to *Abstainers*, adolescents with higher physical aggression scores in Grade 6 were more likely to be in the *Experimental* (OR 1.55; 95 % CI 1.09, 2.21) and
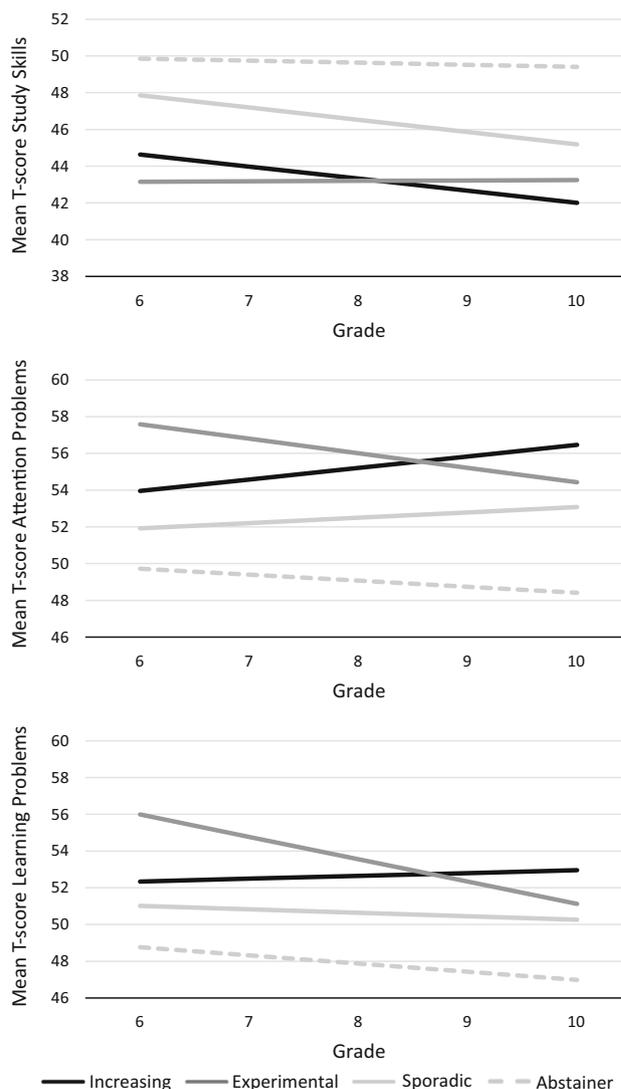

Fig. 3 Estimated trajectories of teacher-rated study skills, attention problems, and learning problems for marijuana use trajectories: Increasing, Experimental, Sporadic, and Abstainer—Grades 6 to 10

Increasing (OR 2.25; 95 % CI 1.61, 3.15) marijuana user groups. Compared to *Abstainers*, adolescents with worse attention problems were in the *Experimental* (OR 1.05; 95 % CI 1.02, 1.08) marijuana user group. In univariate logistic regression models, each predictor variable was statistically significant when controlling for race and gender.

Discussion

During the past years, worrying trends related to marijuana have emerged: Marijuana use is rising among adolescents and their perceived risk of using marijuana is falling (Johnston et al. 2012; Substance Abuse and Mental Health

Services Administration 2013). Parents, educators, and researchers are concerned about the possible impact of marijuana use on academic performance and ultimately on school dropout. Previous longitudinal research with samples of mostly White adolescents from the 1980s showed that youth did follow different trajectories of marijuana use (Brown et al. 2004; Ellickson et al. 2004; Schulenberg et al. 2005; Tucker et al. 2006; Windle and Wiesner 2004; Wanner et al. 2006). The purpose of this study was to identify trajectories of marijuana use in a current sample of adolescents followed annually from sixth to twelfth grade, recognize patterns of co-occurring problem behaviors and teacher-rated academic skills, and test whether these behaviors and skills in sixth grade predict longitudinal patterns of marijuana use. The study's findings contribute to an understanding of patterns of marijuana use from early to late adolescence, and the associations between increasing marijuana use and increasing problem behaviors and poor academic skills. While this study is not able to draw any causal link between marijuana use and its effect on academic outcomes, the findings underline the complexities of marijuana use as part of a problem behavior syndrome with implications for prevention in early adolescence.

Confirming our first hypothesis, we identified four distinct trajectories of marijuana use: *Abstainer*, *Sporadic*, *Experimental*, and *Increasing* users. These trajectories are similar to those identified in prior studies (Brown et al. 2004; Flory et al. 2004; Tucker et al. 2006). We considered adolescents "experimenters" when using marijuana an average of two times in the preceding 30 days, a threshold value also used by Tucker et al. (2006). Other researchers classified experimenters and increasing users similarly, but based on reports in the past year (Brown et al. 2004; Wanner et al. 2006), 6 months (Windle and Wiesner 2004), or in combination of past year and 30 days (Schulenberg et al. 2005; Tucker et al. 2006). Proportionally, the *Abstainers* comprised the largest part of the sample. This widespread abstinence parallels decade-long trends in which a majority of adolescents have disapproved regular use of marijuana (Johnston et al. 2012).

Our study showed that boys were more than twice as likely than girls to use marijuana increasingly over time, with boys comprising almost three-quarters of the highest user group. This gender difference was less pronounced in the *Abstainer* and *Sporadic* user groups where the proportions of girls to boys were roughly equal. The literature has shown mixed evidence for gender differences in frequency of marijuana use, showing no differences in early adolescence (Griffith-Lendering et al. 2011; Lynne-Landsman et al. 2011) and historically higher frequency of use among boys (Little et al. 2008). Flory et al. (2004) found girls more likely to be in an early onset marijuana

use trajectory (ages 11–12 years) and boys more likely in the late onset trajectory (ages 15–16). More research is needed on how girls and boys might differ in their patterns of marijuana use beginning in early adolescence.

The study's findings confirmed our second hypothesis that alcohol use, smoking and aggression would be higher for students in the higher marijuana user groups. Previous research supports considerable overlap in the trajectories of marijuana with other substance use (Brook et al. 2010; Flory et al. 2004), which strongly indicates a problem behavior syndrome (Donovan 1996; Park et al. 2009). *Abstainers* consistently had the most positive outcomes, showing better adjustment through high school and potentially into young adulthood, as the study by Tucker et al. (2006) has shown. In our study, the problem behaviors peaked in seventh grade (aggression), tenth grade (alcohol), and twelfth grade (smoking), with the marijuana user groups clearly differentiating the students by the frequency of these behaviors throughout middle and high school. Alcohol use was only marginally significant when distinguishing the *Experimental* from the *Increasing* users yet still reflected a similar overall trend.

In support of our third hypothesis, teachers rated students in the marijuana use trajectories as having significantly lower study skills, worse attention problems, and more learning problems than students who abstained. Contrary to expectations, the *Sporadic* users did not have consistently better teacher ratings than the higher marijuana users. Still, all marijuana users had worse than average ratings through middle and high school. Interpreting these results as a dose–response relationship is challenging, since differences in academic skills may be influenced by multiple problem behaviors and environmental factors (Green and Ensminger 2006).

Compared to nonusers, adolescents in the marijuana use trajectories had over twice the odds of dropping out of high school. Previous research has shown that even experimental marijuana use is associated with worse academic performance in Grade 12 and risk of not graduating from college, as compared to abstainers (Tucker et al. 2006). Our results showed that students in the marijuana user groups had comparable dropout rates. Thus, it is not possible to attribute the dropout rates to marijuana use alone. In a recent study of twins, the shared environment of the twins eliminated the effects of marijuana use on dropout (Verweij et al. 2013). Dropout is undoubtedly a complex process that depends not only on individual drug-related behaviors but other factors, such as mental health problems and parental education and involvement (Gonzalez and Swanson 2012; Rogeberg 2013).

In testing our final hypothesis, we found that cigarette smoking and physical aggression in sixth grade increased the odds of being in the marijuana use trajectories

compared to *Abstainers*. Our findings underline the strong association in early adolescence of marijuana with aggression (Brook et al. 2011; Griffith-Lendering et al. 2011) and smoking (Baumeister and Tossmann 2005; Brook et al. 2010). Tobacco use, in particular, has been considered a gateway behavior to marijuana use. In a national sample of adult smokers, cigarette smoking increased the odds of initiating marijuana sevenfold (Lai et al. 2000). However, in a sample of high-risk African-American adolescents, marijuana use preceded cigarette use, suggesting that the gateway effect may not apply equally across different race and ethnicities (Vaughn et al. 2008). Surprisingly, sixth grade alcohol use was not a significant predictor of marijuana use, as has been shown in other studies (Flory et al. 2004; Tucker et al. 2005). Some studies indicate that while one third of adolescents have tried alcohol before age 13, the peak of initiation was in seventh and eighth grades (U.S. Dept. of Health and Human Services 2007). Future studies should examine predictors in seventh and eighth grades, where alcohol, and possibly other drug use, may be higher.

Our results showed that teachers rated attention problems as slightly worse in sixth grade for *Experimental* users only. Attention problems in elementary school have been shown in other studies as predictive of aggressive behaviors in middle school (Harachi et al. 2006; Nagin and Tremblay 2001) but not necessarily predictive of initiating marijuana use as a young adult (Storr et al. 2011). Contrary to expectation, learning problems and study skills in sixth grade did not predict marijuana users at all. One plausible reason to explain the lack of statistical significance is that the teacher ratings were highly correlated, ranging from .68 to .79. In fact, the univariate logistic models showed that the teacher ratings predicted marijuana trajectories. It is important to recognize that teachers had rated *Abstainers* as significantly better already in sixth grade than all other marijuana user groups, according to results from our analyses using mixed effects models.

The study's findings advance our scientific understanding of the complex relation between marijuana use, co-occurring drug use and aggression, and academic performance. This study has particular strengths that increase the robustness of the findings. First, this large and diverse cohort of adolescents completed surveys for seven consecutive years from Grades 6 to 12. Second, a different teacher rated the participant's study skills, attention problems, and learning problems in five waves of assessment, which provided an independent measure of academic performance and diminished potential single rater bias. Third, students who dropped out of school were surveyed in the community and included in the sample.

The study has some limitations. Marijuana use is based on self-report, a method often questioned for its veracity and accuracy in capturing drug use behaviors. However, studies have found relatively high agreement between anonymous adolescent reports of marijuana use and drug use biomarkers (Delaney-Black et al. 2010; Lennox et al. 2006), especially with recently reported and tested use (Buchan et al. 2002). Also, the sample of this study is from a relatively small section of the Southeastern United States, which can limit generalizability of the findings. In support of our results, the 30-day prevalence of marijuana use reported in the *Healthy Teens* sample was relatively similar to the results from the national *Monitoring the Future* study for the same years as our study; these prevalence rates differed at most by 3 %. Finally, even though this study is longitudinal, which allows us to examine temporal relationships between the variables of interest, we need to be cautious in interpreting the results as establishing causation.

Conclusions

This study contributes substantively to understanding marijuana use among adolescents. First, using marijuana was not an isolated or benign event in the life of adolescents. Over a 7 year period, it was associated with multiple negative behaviors, such as alcohol use, smoking and physical aggression. As clearly described in problem behavior theory, multiple health-compromising behaviors tend to co-exist and engagement in one behavior will strongly predict engagement in others. With cigarette smoking and physical aggression as predictors in sixth grade of marijuana use, early adolescence is a salient time to intervene. Marijuana prevention efforts should address multiple substance use and risk behaviors at this period of an adolescent's life. Increased parental monitoring and feedback from teachers about students' behavior are effective approaches to decreasing substance use and anti-social behavior (Connell et al. 2007). Interventions that involve parents, schools and community media show promise in preventing marijuana and other drug use for adolescents (Porath-Waller et al. 2010; Riggs et al. 2006; Slater et al. 2006). Finally, based on independent measures of school performance (annual teacher ratings using nationally normed scales and high school dropout records), the findings clearly show that adolescents who used marijuana had worse academic performance. Low study skills, attention problems, and learning problems were present even when marijuana use was very low, suggesting that other problems in the life of adolescents may be influencing youth into a path of problem behaviors.

performed the statistical analysis and interpreted the results; P.O. participated in the conceptual design and data analysis plan, coordinated the study and helped draft the manuscript: S.O. advised on the statistical analyses and interpreted results. All authors read and approved the final manuscript.

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