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Marijuana use from adolescence to adulthood: developmental trajectories and their outcomes

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Abstract

Background The study assesses the degree to which individuals in different trajectories of marijuana use are similar or different in terms of unconventional behavior, sensation seeking, emotional dysregulation, nicotine dependence, alcohol dependence/abuse, children living at home, and spouse/partner marijuana use at age 43.

Method This study used a longitudinal design. The sample participants ($N = 548$) were first studied at mean age 14 and last studied at mean age 43.

Results Six trajectories of marijuana use were identified: chronic/heavy users (3.6 %), increasing users (5.1 %), chronic/occasional users (20 %), decreasers (14.3 %), quitters (22.5 %), and nonusers/experimenters (34.5 %). With three exceptions, as compared with being a nonuser/experimenter, a higher probability of belonging to the chronic/heavy, the increasing, or the chronic/occasional user trajectory group was significantly associated with a greater likelihood of unconventional behavior, sensation seeking, emotional dysregulation, nicotine dependence, alcohol dependence/abuse, not having children who lived at home, and having a spouse/partner who used marijuana at early midlife. In addition, compared with being a quitter, a higher probability of belonging to the chronic/heavy user trajectory group was significantly associated with a higher likelihood of unconventional behavior, sensation seeking, emotional dysregulation, alcohol dependence/abuse, and spouse/partner marijuana use. Implications for intervention are presented.

Conclusions Trajectories of marijuana use, especially chronic/heavy use, increasing use, and chronic/occasional use, are associated with unconventional behavior, sensation seeking, emotional dysregulation, nicotine dependence, alcohol dependence/abuse, having children who lived at home, and spouse/partner marijuana use at age 43. The importance of the findings for prevention and treatment programs are discussed.

Introduction

Several studies have examined the consequences of marijuana use on adolescent and young adult outcomes (e.g., health outcomes) [1–5]. In general, the findings have demonstrated that chronic marijuana users, compared to non-users, are more likely to demonstrate a number of adverse consequences, including psychiatric disorders [6], poor school achievement [7], financial difficulties [7], and difficulties at work [7]. In comparison, less is known about the adverse consequences of the trajectories of increasing marijuana users, occasional marijuana users, decreasers, and quitters.

Operating within a Family Interactional Theory (FIT) [8] and a Life Course framework [9], we focused on important trajectories in marijuana use (e.g., chronic use and increased use) as they relate to functioning in a variety

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of areas. For instance, the trajectories of chronic and increasing marijuana use may be associated with drug-prone personality attributes and psychiatric conditions, difficulties in interpersonal relations, and environmental factors, such as financial difficulty [10–14]. In recent years, a number of investigators have attempted to identify the patterns or trajectories of marijuana use [3, 15]. Examination of the trajectories or patterns of use enables the assessment of the consequences of multiple trajectories of marijuana use [16]. The present study adds to the literature by examining the effects of long-term trajectories of marijuana use from age 14 to age 43 on the following outcomes in early midlife. In the personal attribute area, we selected both externalizing and internalizing behaviors as they are both manifestations of personal attributes. We also postulated that certain trajectories of marijuana use would predict nicotine dependence and alcohol dependence/abuse. We further postulated that some trajectories of marijuana use would be associated with unconventional behaviors and ultimately, avoiding having children or children who lived at home. Finally, based on selection theory, we postulated that adults who use marijuana would be more likely to select a spouse/partner who used marijuana.

In the present research, we used the growth mixture modeling (GMM) approach to assess trajectories [11, 13, 17, 18]. This approach enabled us to compare multiple trajectories of marijuana use as related to some of the consequences of use (e.g., emotional problems, nicotine dependence, alcohol dependence/abuse). Several researchers have identified the following trajectories of marijuana use: non/experimental use, occasional use, chronic use, increasing use, and quitters [3, 14, 19]. For example, Caldeira et al. [3] reported that chronic and late-increasing marijuana users had the worst health outcomes, including functional impairment due to injury, illness, or emotion problems. In a sample of African American and Puerto Rican adolescents and adults, chronic marijuana use was associated with increased violence, greater financial instability, and increased sexual risk behavior [10, 16]. In a study using national panel data, Schulenberg and colleagues [13] reported that chronic marijuana use was related to a greater likelihood of marijuana dependence and substance abuse. The association of other trajectories of marijuana use with adverse outcomes has been reported in the literature. For example, in terms of mental health in adolescence, Brook, Lee et al. [16] reported that non-users did not differ from adolescent-limited users in symptoms of depression. A greater understanding of the nature of the trajectories of marijuana use is significant for the timing and targeting of interventions focused on trajectories of use related to adverse outcomes.

Our study departs from earlier research which covers a relatively short span of time, but there are some exceptions [3, 17, 20]. In this study, we build on earlier research and assess the long-term patterns of marijuana use as they relate to personal and interpersonal functioning at mean age 43. The current longitudinal study uses data beginning in adolescence and extending to the fifth decade of life. We hypothesize the following: membership in the chronic/heavy use, increasing use, and chronic/occasional use trajectory groups, as compared with the non/experimental use trajectory group, are associated in adulthood with greater unconventional behaviors, emotional problems, sensation seeking, nicotine dependence, alcohol dependence/abuse, avoiding having children or children who lived at home, and having a spouse/partner who was a marijuana user.

Methods

Participants and procedure

Data on the participants in this study came from a community-based random sample residing in one of two upstate New York counties (Albany and Saratoga) first assessed in 1983. The sample was taken from an earlier study using maternal interviews which began in 1975 (T1). The participants' mothers were interviewed about the participants in 1975 (T1) to assess problem behavior among youngsters. At T1, population data from the census (updated in 1975) for sampling units in Albany and Saratoga counties were obtained. A systematic sample of primary sampling units (blocks) in each county was then drawn with probability proportional to the number of households. At the time, the data were collected, the sampled families were generally representative of the population of families in the two upstate New York counties. There was a close match of the participants on family income, maternal education, and family structure with the 1980 census. Mothers with one or more child(ren) in the age range of 1–10 were recruited and, when there were multiple children in the family, one child in that age range was randomly selected. With regards to ethnicity, the children of the sample were 90 % White, 8 % African American, and 2 % other ethnic/racial minorities. Forty-nine percent of the children were females. The detailed sampling procedures were published elsewhere [8]. Interviews were conducted in 1983 (T2 $N = 756$), 1985–1986 (T3 $N = 739$), 1992 (T4 $N = 750$), 1997 (T5 $N = 749$), 2002 (T6 $N = 673$), 2007 (T7 $N = 607$), and 2012–2013 (T8 $N = 548$). The mean ages (standard deviations) of participants at the follow-up interviews were 14.1 (2.8) at T2, 16.3 (2.8) at T3, 22.3 (2.8) at T4, 27.0 (2.8) at T5, 31.9 (2.8) at T6, 36.6 (2.8) at T7, and 43.0 (2.8) at T8, respectively.

At T2–T7, extensively trained and supervised lay interviewers administered interviews in private. The T8 data collection involved an Internet-based self-administered questionnaire. Written informed consent was obtained from participants and their mothers in 1983, 1985–1986, and 1992, and from participants only in 1997, 2002, 2005–2006, and 2012–2013. The Institutional Review Board of the New York University School of Medicine authorized the use of human subjects in this research study at T8. Earlier waves of the study were approved by the Institutional Review Boards of the Mount Sinai School of Medicine or New York Medical College. Additional information regarding the study methodology is available in prior publications [8].

Measures

Marijuana use At each time wave (T2–T8), questions about marijuana use (adapted from the Monitoring the Future study [21]) were included. To measure the lifetime quantity and frequency of marijuana use from childhood to the mid 30s, at each time wave questions were asked about the frequency of marijuana use during the period from the last time wave through the current time wave. Specifically, the questions used were the frequency and quantity of marijuana use in childhood and early adolescence for T2 (prior to and at T2), during the past 2 years in adolescence for T3 (T2–T3), during the past 5 years in the early 20s for T4 (T3–T4), during the past 5 years in the late 20s for T5 (T4–T5), during the past 5 years in the late 20s and early 30s for T6 (T5–T6), during the past 5 years in the mid 30s for T7 (T6–T7), and during the past 5 years in the early 40s for T8 (T7–T8). The marijuana use measure at each point in time had a scale coded as none (0), a few times a year or less (1), once a month (2), several times a month (3), once a week (4), several times a week (5), and daily (6).

The dependent variables were assessed in 2012–2013 and consisted of unconventional behaviors (i.e., tolerance of deviance [22], rebellion [23], delinquency [24], and antisocial behaviors [25]), emotional problems [26], sensation seeking [27], nicotine dependence [28], alcohol dependence/abuse [25], children living at home, and spouse/partner marijuana use [29]. Table 1 lists the dependent variables, the number of items comprising each scale, response ranges, sample items, and Cronbach's alphas. For the indicator variable of high unconventional behaviors, a participant was assigned a score of 1 for the respective indicator variable if at least two of the component scale values were 1 standard deviation (SD) above the mean for that scale, respectively. For the indicator variables of high sensation seeking and high emotional dysregulation, a participant was assigned a score of 1 if the original scale was 1 SD above the sample mean for that scale. For the indicator variable of spouse/partner marijuana use, a participant was assigned a score of 1 if the participant reported that his/her spouse/partner used marijuana at least on 1–2 occasions in the past year (see Table 1 for further descriptions of the original scales).

Control variables The following variables were included as control variables: gender, T8 age, T2 family income in the past year before taxes, T2 highest parental educational level, T2 self-reported grade point average (GPA), T2 depressive mood (5 items, alpha = 0.75, e.g., In the past few years, how often have you been bothered by feeling low in energy or slowed down? [30]), T2 delinquency (5 items, alpha = 0.65, e.g., How often have you gotten into a serious fight at school or work? [24]), T2 alcohol use [21], and T2 cigarette smoking [21].
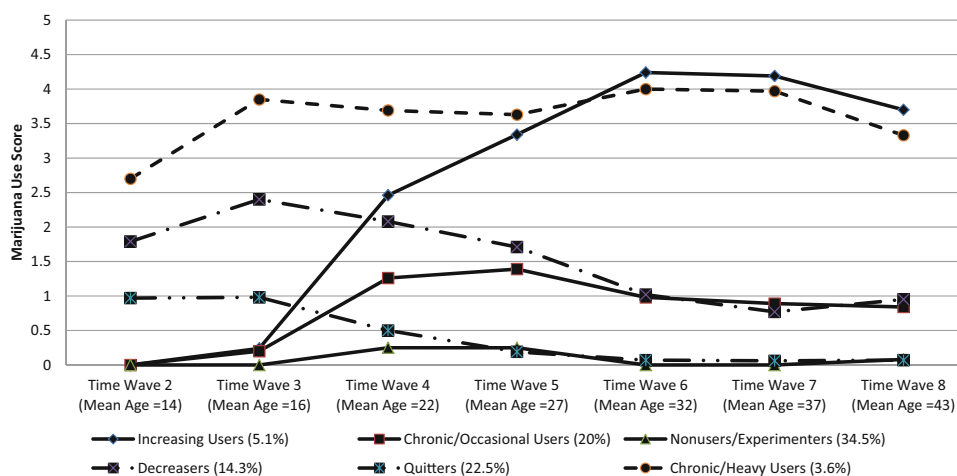
Analysis

Using the Mplus software [31], we conducted GMM analyses to identify the developmental trajectories of marijuana use. As suggested by Bray, Lanza, and Tan [32], the following demographic variables were included as control variables in the trajectories analyses: gender, T2 age, T2 family income, T2 highest parental educational level, and T2 GPA. We treated the dependent variable (marijuana use at each time point) as a censored normal variable. We applied the full information maximum likelihood (FIML) approach for the missing data in the analysis. We set each of the trajectory polynomials to be cubic. We used the minimum Bayesian Information Criterion (BIC) to determine the number of trajectory groups (G). We did not consider groups with fewer than 3 % of the sample because some investigators have cautioned against over-extraction of latent classes due to the presence of nonnormal data [33]. After extracting the latent classes, we assigned each participant to the trajectory group with the largest Bayesian posterior probability (BPP). For each of the trajectory groups, we created an indicator variable, which had a value of 1 if participants had the largest BPP for that group and 0 otherwise. The observed trajectory for a group was the average of marijuana use at each time point for participants assigned to the group (see Fig. 1).

We then conducted separate binary logistic regression analyses to examine the association between marijuana use trajectories and greater unconventional behavior, greater emotional problems, more sensation seeking, nicotine dependence, alcohol dependence/abuse, having children who lived at home, and having spouse/partner who used marijuana, respectively. Because specifying which trajectory group an individual belongs to is subject to error, we used the BPPs of belonging to each trajectory group as the independent variables. Because one group was chosen as the reference, the number of independent trajectory

Table 1 Psychometrics of psychosocial dependent variables: number of items, response range, sample items, and Cronbach's alpha

Dependent variable Number of items	Response range	Sample item	Cronbach's alpha
Unconventional behaviors			
Tolerance of deviance [22] 4 items	Very wrong (1)–not wrong (4)	How wrong do you think it is to take credit for other people's work?	0.63
Rebellion [23] 6 items	False (1)–true (4)	When rules get in my way, I sometimes ignore them	0.73
Delinquency [24] 5 items	Never (0)–5 or more times (4)	How often have you taken part in a fight in the past 5 years?	0.65
Antisocial behaviors [25] 7 items	No (0)–Yes (1)	Have you exposed others to danger without caring?	0.78
Emotional dysregulation [26] 9 items	Strongly disagree (1)–Strongly agree (5)	In general, I have a hard time handling my emotions	0.93
Sensation Seeking [27] 7 items	Strongly disagree (1)–Strongly agree (6)	I'd rather gamble than play it safe	0.84
Nicotine dependence [28] 10 items	No (0)–Yes (1)	Over time, did you develop a physical tolerance for tobacco in order to feel satisfied)?	NA
Alcohol dependence/abuse [25] 12 items	No (0)–Yes (1)	Did you need to drink more in order to get the same effect that you got when you first started drinking?	NA
Children living at home 1 item	No (0)–Yes (1)	Do you have children who currently live at home?	NA
Spouse/partner marijuana use in the past year [29] 1 item	0 (0)–40 or More (6)	On average, how many occasions (if any) has your spouse/partner used marijuana in the past year?	NA

Fig. 1 Developmental trajectories of marijuana use extending from adolescence to mean age 43. The marijuana use measure at each point in time had a scale coded as none (0), a few times a year or less (1), once a month (2), several times a month (3), once a week (4), several times a week (5), and daily (6)

variables was G-1, where G was the number of trajectory groups. We then conducted separate multivariate logistic regression analyses using the following control variables: age, gender, T2 parental educational level, T2 family income, T2 GPA, T2 delinquency, T2 depressive mood, T2 alcohol use, and T2 cigarette smoking.

Results

There were no statistically significant differences between participants included in the analyses of adult functioning at T8 ($N = 548$) and the T2 participants who were missing at T8 ($N = 258$) with respect to age ($t = 0.17$,

p value = 0.86), T2 family income ($t = -1.91$, p value = 0.06), T2 depressive mood ($t = -0.69$, p value = 0.49), T2 delinquency ($t = 1.79$, p value = 0.07), T2 alcohol use ($t = -1.57$, p value = 0.12), T2 cigarette smoking ($t = -0.02$, p value = 0.98), and T2 marijuana use ($t = 0.03$, p value = 0.97). However, there was a greater percentage of female participants (54.7 vs. 36.8 %; $\chi^2(1)$ = 22.55, p value <0.001) and a higher parental educational level (13.65 vs. 13.07; $t = -3.07$, p value = 0.002) among participants who were included in the T8 analyses, as compared to those who were excluded.

Trajectories of marijuana use

The mean (Standard Deviation) of the marijuana use scores at each time point were 0.56 (1.19), 0.75 (1.35), 1.00 (1.37), 0.94 (1.43), 0.72 (1.37), 0.61 (1.23), and 0.58 (1.26) for T2–T8, respectively. The percentage of marijuana users peaked at T4 (mean age = 22) and then decreased through T8 (mean age = 43).

We calculated solutions for the three-group trajectory (Likelihood Value = −5400; BIC = 11008; Entropy = 0.80), the four-group trajectory (Likelihood Value = −5254; BIC = 10782; Entropy = 0.81), the five-group trajectory (Likelihood Value = −5188; BIC = 10717; Entropy = 0.81), and the six-group trajectory (Likelihood Value = −5138; BIC = 10685; Entropy = 0.81). We chose the six-group solution, because the BIC value was lower than those for the five-group trajectory. Participants were then assigned to the marijuana trajectory group that best depicted their marijuana use over time. The average classification probabilities for group membership ranged from 0.84 to 0.90, which indicate a satisfactory classification.

Figure 1 presents the six observed marijuana use trajectories. The trajectory groups were named: chronic/heavy users ($N = 29$, 3.6 %), increasing users ($N = 41$, 5.1 %), chronic/occasional users ($N = 161$, 20 %), decreasers ($N = 115$, 14.3 %), quitters ($N = 181$, 22.5 %), and nonusers/experimenters ($N = 279$, 34.5 %). As noted in Fig. 1, the chronic/heavy users started early, achieved the level of use on a weekly basis in late adolescence (T3), and then stayed at that level through the early 40s, the increasing users started late, increased use from late adolescence/emerging adulthood to the early 30s (weekly, several times a week or daily), and then stayed at that level through the early 40s. The decreasers started early, achieved the maximum level of use on a monthly basis in late adolescence (T3), and then tapered off gradually. The chronic/occasional users started late and used marijuana less than on a monthly basis, but stayed at that level through the early 40s. The quitters started early, tapered off from late adolescence/emerging adulthood into adulthood,

and quit completely at mean age 32 (T6). There was a significant association between gender and marijuana trajectory group membership [$\chi^2(5) = 34.5$, $p < 0.001$]. Compared to females, males had higher likelihoods of being chronic/heavy users, increasers, decreasers, or chronic occasional users (see Table 2 for gender differences in the distribution of marijuana trajectory memberships). In addition, T2 age, delinquency, alcohol use, and cigarette smoking were associated with higher likelihoods of being a chronic/heavy user, a decreaser, or a quitter. T2 depressive mood was associated with higher likelihoods of being a decreaser or a quitter. T2 GPA was associated with a higher likelihood of being a non/experimental user.

Trajectories of marijuana use as predictors of T8 psychosocial outcomes

Table 3 presents the codes, sample means (or %), and standard deviations of the dependent and control variables used in the logistic regression analyses. Table 4 presents the results of the multivariate logistic regression analyses. The results of the multivariate logistic regressions indicated that, compared with belonging to the non/experimental user trajectory group: (1) a higher probability of belonging to the chronic/heavy, the increasing, or the chronic/occasional user trajectory group was associated with a significantly higher likelihood of engaging in unconventional behaviors {Adjusted Odds Ratio (AOR) [95 % Confidence Interval (CI)] = 8.53 (1.71–42.46), AOR (95 % CI) = 4.85 (1.37–17.14), and AOR (95 % CI) = 3.94 (1.52–10.19), respectively}, having nicotine dependence [AOR (95 % CI) = 10.87 (2.58–45.85), AOR (95 % CI) = 8.37 (2.77–25.3), and AOR (95 % CI) = 3.33 (1.56–7.12), respectively], having alcohol dependence/abuse [AOR (95 % CI) = 8.75 (2.12–36.21), AOR (95 % CI) = 3.69 (1.08–12.59), and AOR (95 % CI) = 4.3 (1.86--9.93), respectively], and having a spouse/partner who used marijuana in the past year [AOR (95 % CI) = 55.25 (10.61–287.69), AOR (95 % CI) = 52.24 (13.69–199.27), and AOR (95 % CI) = 12.47 (4.5–34.55), respectively]; (2) a higher probability of belonging to the chronic/heavy user trajectory group or the chronic/occasional user trajectory group was significantly associated with a higher likelihood of having greater emotional dysregulation [AOR (95 % CI) = 6.48 (1.39–20.2) and AOR (95 % CI) = 2.54 (1.19–5.42), respectively]; (3) a higher probability of belonging to the increasing or the chronic/occasional user trajectory group was associated with a significantly higher likelihood of having a sensation seeking orientation [AOR (95 % CI) = 6.9 (2.17–21.94) and AOR (95 % CI) = 4.5 (1.92–10.58), respectively] and a lower likelihood of having children who lived at home [AOR (95 % CI) = 0.18

Table 2 Frequencies of five marijuana use trajectories based on GMM results

Marijuana trajectories	Combined ($n = 806$), n (%)	Male ($n = 411$), n (%)	Female ($n = 395$), n (%)
Increasing users	41 (5.1 %)	30 (7.3 %)	11 (2.8 %)
Chronic/heavy users	29 (3.6 %)	23 (5.6 %)	6 (1.5 %)
Decreasers	115 (14.3 %)	68 (16.6 %)	47 (11.9 %)
Chronic/occasional users	161 (20 %)	92 (22.4 %)	69 (17.5 %)
Quitters	181 (22.5 %)	78 (19 %)	103 (26.1 %)
Nonusers/experimenters	279 (34.5 %)	120 (29.1 %)	159 (40.2 %)

The association analyses indicated that gender was significantly associated with marijuana use trajectories ($\chi^2(5) = 34.5$, $p < 0.001$)

Table 3 Psychosocial dependent variables and control variables: descriptive statistics ($N = 548$)

Variables	Coding	Mean (SD) or %
Unconventional behaviors (2012–2013)	No (0)–yes (1)	11.5 (yes)
Sensational seeking (2012–2013)	No (0)–yes (1)	16.2 (yes)
Nicotine dependence (2012–2013)	No (0)–yes (1)	24.1 (yes)
Alcohol dependence or abuse (2012–2013)	No (0)–yes (1)	17 (yes)
Emotional dysregulation (2012–2013)	No (0)–yes (1)	16.4 (yes)
Spouse/partner marijuana use (2012–2013)	No (0)–yes (1)	14.2 (yes)
Children living at home (2012–2013)	No (0)–yes (1)	66.8 (yes)
Gender	Female (0)–male (1)	45 (male)
Age (2012–2013)	Years	43.01 (2.78)
Parental educational level (1983)	Years of schooling	13.66 (2.48)
Family income of origin (1983)	Under $2000 (0)–$50,000 or over (12)	8.8[a] (2.43)
GPA (1983)	Very poor (F) (1)–excellent (A) (5)	4.03 (0.76)
Depressive mood (1983)	Not at all (0)–extremely (4)	2.1 (0.68)
Delinquency (1983)	Never (1)–5 or more times (5)	1.68 (0.70)
Alcohol use (1983)	Never (1)–3 or more drinks a day (5)	1.28 (0.52)
Cigarette smoking (1983)	Never (0)–About1.5 packs a day (5)	0.61 (1.10)

[a] A score of 8.8 is about $20,000

(0.06–0.5) and AOR (95 % CI) = 0.38 (0.2–0.71), respectively]; and (4) a higher probability of belonging to the decreasing user trajectory group was associated with a significantly higher likelihood of having nicotine dependence [AOR (95 % CI) = 4.45 (1.6–12.39)], alcohol dependence/abuser [AOR (95 % CI) = 3.83 (1.31–11.16)], and having a spouse/partner who used marijuana in the past year [AOR (95 % CI) = 9.63 (2.7–34.36)]. In addition, with the exception of nicotine dependence, the likelihood of having the personal and interpersonal psychosocial outcomes was not significantly different between being a non/experimental marijuana user and being a quitter.

We also conducted the multivariate logistic regressions using the BPP of the quitter trajectory group as the reference. The results (see Table 5) indicated that, compared with belonging to the quitter group, (1) a higher probability of belonging to the chronic/heavy, the increasing group, the chronic/occasional group, or the decreasing user trajectory group was associated with a significantly higher likelihood of having an orientation toward sensation seeking [AOR (95 % CI) = 4.2 (1.02–17.35), AOR (95 % CI) = 11.38 (2.56–50.67), AOR (95 % CI) = 7.43 (2.1–26.33), and AOR (95 % CI) = 4.46 (1.67–11.92), respectively], and having a spouse/partner who used marijuana in the past year [AOR (95 % CI) = 67.28 (13.78–328.61), AOR (95 % CI) = 63.59 (11.57–348.99), AOR (95 % CI) = 15.18 (3.55–64.87), and AOR (95 % CI) = 11.33 (3.59–38.32), respectively]; (2) a higher probability of belonging to the chronic/heavy user trajectory group was associated with a significantly higher likelihood of engaging in unconventional behaviors [AOR (95 % CI) = 9.45 (2.03–43.97)], having greater emotional dysregulation [AOR (95 % CI) = 4.87 (1.16–20.42)], and having alcohol dependence/abuse [AOR (95 % CI) = 5.16 (1.44–18.44)]; and (3) a higher probability of belonging to the increasing or the chronic/occasional user trajectory group was

Table 4 Logistic regressions: trajectories of marijuana use from adolescence to mean age 43 as related to psychosocial functioning among men and women in the early 40s (N = 548)

Independent variables	Unconventional behaviors AOR (95 % CI) (11.5 %)[a]	Sensation seeking AOR (95 % CI) (16.2 %)[a]	Emotional dysregulation AOR (95 % CI) (16.4 %)[a]	Nicotine dependence AOR (95 % CI) (24.1 %)[a]	Alcohol dependence/abuse AOR (95 % CI) (17 %)[a]	Partner Marijuana Use AOR (95 % C.I.) (14.2 %)[a]	Children Living at Home AOR (95 % C.I.) (66.8 %)[a]
BPP of chronic/heavy users	8.53 (1.71–42.46)**	2.66 (0.57–11.39)	6.48 (1.39–20.2)*	10.87 (2.58–45.85)**	8.75 (2.12–36.21)**	55.25 (10.61–287.69)***	1.04 (0.28–3.8)
BPP of increasers	4.85 (1.37–17.14)*	6.90 (2.17–21.94)**	3.07 (0.93–10.14)	8.37 (2.77–25.3)***	3.69 (1.08–12.59)*	52.24 (13.69–199.27)***	0.18 (0.06–0.5)**
BPP of chronic/occasional users	3.94 (1.52–10.19)**	4.5 (1.92–10.58)***	2.54 (1.19–5.42)*	3.33 (1.56–7.12)**	4.3 (1.86–9.93)***	12.47 (4.5–34.55)***	0.38 (0.2–0.71)**
BPP of decreasers	2.51 (0.63–9.98)	2.7 (0.91–8.06)	2.28 (0.78–6.65)	4.45 (1.6–12.39)**	3.83 (1.31–11.16)*	9.63 (2.7–34.36)***	1.49 (0.63–3.53)
BPP of quitters	0.9 (0.2–4.16)	0.61 (0.18–2.07)	1.33 (0.46–3.85)	3.06 (1.12–8.31)*	1.7 (0.56–5.15)	0.82 (0.18–3.69)	1.31 (0.59–2.94)

The following variables were included as control variables in each regression analysis: age, gender, parental educational level, family income, GPA, delinquency, depressive mood, alcohol use, and cigarette smoking at mean age 14

BPP of belonging to non-user group serves as the reference

AOR adjusted odds ratio, CI confidence interval, BPP Bayesian posterior probability

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

[a] Percentage of the sample that the dependent variable = 1

Table 5 Logistic regressions: trajectories of marijuana use from adolescence to mean age 43 as related to psychosocial functioning among men and women in the early 40s ($N = 548$)

Independent variables	Unconventional behaviors AOR (95 % CI) (11.5 %)[a]	Sensation seeking AOR (95 % CI) (16.2 %)[a]	Emotional dysregulation AOR (95 % CI) (16.4 %)[a]	Nicotine dependence AOR (95 % CI) (24.1 %)[a]	Alcohol dependence/abuse AOR (95 % CI) (17 %)[a]	Partner marijuana use AOR (95 % CI) (14.2 %)[a]	Children living at home AOR (95 % CI) (66.8 %)[a]
BPP of chronic/heavy users	9.45 (2.03–43.97)**	4.2 (1.02–17.35)*	4.87 (1.16–20.42)*	3.57 (0.96–13.24)	5.16 (1.44–18.44)*	67.28 (13.78–328.61)***	0.79 (0.24–2.67)
BPP of increasers	5.38 (0.94–30.98)	11.38 (2.56–50.67)**	2.31 (0.52–10.16)	2.75 (0.73–10.46)	2.18 (0.51–9.32)	63.59 (11.57–348.99)***	0.14 (0.04–0.47)**
BPP of chronic/occasional users	4.37 (0.96–19.85)	7.43 (2.1–26.33)**	1.91 (0.61–6.03)	1.09 (0.38–3.18)	2.53 (0.82–7.86)	15.18 (3.55–64.87)***	0.29 (0.12–0.73)**
BPP of decreasers	2.78 (0.77–10.01)	4.46 (1.67–11.92)**	1.72 (0.66–4.48)	1.46 (0.63–3.4)	2.26 (0.95–5.38)	11.33 (3.59–38.32)***	1.14 (0.55–2.36)
BPP of nonusers/experimental users	1.11 (0.24–5.12)	1.65 (0.48–5.64)	0.75 (0.26–2.18)	0.33 (0.12–0.9)*	0.59 (0.19–1.79)	1.22 (0.27–5.48)	0.76 (0.34–1.71)

The following variables were included as control variables in each regression analysis: age, gender, parental educational level, family income, GPA, delinquency, depressive mood, alcohol use, and cigarette smoking at mean age 14

BPP of belonging to quitter group serves as the reference

AOR adjusted odds ratio, CI confidence interval, BPP Bayesian posterior probability

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

[a] Percentage of the sample that the dependent variable = 1

associated with a significantly lower likelihood of having children who lived at home [AOR (95 % CI) = 0.14 (0.04–0.47) and AOR (95 % CI) = 0.29 (0.12–0.73), respectively].

Among the control variables, T2 depressive mood was significantly associated with the higher likelihood of T8 unconventional behaviors, emotional dysregulation, and conflictual relations with a spouse/partner (all significant at $p < 0.05$), but a lower likelihood of having a spouse/partner who was a marijuana user. T2 delinquency was significantly associated with T8 emotional dysregulation ($p < 0.05$). T2 cigarette smoking was significantly associated with T8 nicotine dependence ($p < 0.05$).

Discussion

To our knowledge, this is the first longitudinal study of the trajectories of marijuana use beginning at age 14 and extending to age 43 in a sample selected from the community. This study, building upon our prior research [17], adds to our knowledge by identifying six distinct trajectory groups (i.e., the chronic/heavy, increasing, decreasing, chronic/occasional, quitter, and non/experimental user trajectory groups) and their associations with personal and interpersonal functioning in adulthood. Overall, individuals with a higher probability of belonging to the chronic/heavy or the increasing user trajectory group showed the highest level of cumulative marijuana use, and the non-user/experimental group scored the lowest level of marijuana use. The relationship between trajectories of marijuana use and personal and interpersonal functioning emerged with control on age, gender, T2 parental educational level, T2 family income, T2 GPA, T2 delinquency, T2 depressive mood, T2 alcohol use, and T2 cigarette smoking. These control variables had binary/multivariate associations with the outcome variables, as well as the marijuana use trajectories (all significant at $p < 0.05$). Therefore, the associations between marijuana use trajectories and the outcomes were unlikely to be affected by these control variables.

As regards the association between the trajectories of marijuana use and adult unconventional behaviors, sensation seeking, nicotine dependence, and alcohol dependence/abuse, the findings provide partial support for our hypotheses. Our results suggest that, compared with being a nonuser/experimenter, individuals with a higher probability of belonging to the chronic/heavy group, the increasing group, or the chronic/occasional user trajectory group had adverse outcomes in terms of unconventional behavior, nicotine dependence, and alcohol dependence/abuse, suggesting that chronic and increasing use of marijuana interferes with adolescent and adult development. In addition, compared with being a quitter, a higher probability of belonging to the chronic/heavy user trajectory group was significantly associated with a higher likelihood of unconventional behavior and alcohol dependence/abuse. Similar findings regarding early and chronic marijuana use have been found in other research [16, 34]. The results of the present study are consistent with problem behavior theory [35], which incorporates a number of problem behaviors into an overall syndrome of problem behavior. Marijuana use in turn predicts an increased risk of disorders of other substances [36, 37]. Research has found that long-term marijuana use can lead to addiction [38]. One mechanism is that earlier and chronic marijuana use may lead to a reduction in dopamine reactivity in the brain's reward circuitry, which in turn is associated with later increased susceptibility to other substances [38]. Our study contributes to the literature by assessing specific trajectories of marijuana use that began in early adolescence and their relationship to adult unconventional behavior, nicotine dependence, and alcohol dependence/abuse. This more complete delineation of the correlation of patterns of marijuana use over 29 years and unconventional behavior, including nicotine dependence, and alcohol dependence/abuser, provides information for early preventive interventions.

As regards the association between the trajectories of marijuana use and adult emotional dysfunction, the findings partially provide support for our hypotheses. The findings indicated that, as compared to individuals with a higher probability of belonging to the non/experimental use group, individuals with a higher probability of belonging to the chronic/heavy, the increasing (AOR = 3.07 but not statistically significant), or the chronic/occasional user trajectory group, manifested greater emotional dysfunction. In addition, compared with being a quitter, a higher probability of being a chronic/heavy user was significantly associated with a higher likelihood of emotional dysregulation. These findings are in accord with the self-medication theory, which indicates that individuals with psychiatric symptoms (e.g., anxiety, depression) use substances to alleviate their symptoms [39]. The association between increasing marijuana use and emotional dysfunction may also be due to the neuroadaptation mechanism [38]. According to the substance effect model, marijuana use is associated with white matter disorganization, which in turn predicts emotional dysregulation [40].

As regards the association between the trajectories of marijuana use and the family dimension, we found that, compared with being a nonuser/experimenter (with the exception of belonging to the quitter trajectory group) a higher probability of belonging to other marijuana user trajectory groups was associated with a significantly higher likelihood of having a spouse/partner who used marijuana.

Compared with being a quitter, a higher probability of being a chronic/heavy user was significantly associated with a higher likelihood of spouse/partner marijuana use. Thus, marijuana users, especially chronic/heavy users, may select to have a spouse/partner who also uses marijuana. However, our hypothesis that, compared with being a nonuser/experimenter or a quitter, a higher probability of belonging to the chronic/heavy user trajectory group is associated with a lower likelihood of having children who lived at home was not supported by the data.

One limitation of the research is its lack of representation of ethnic minorities. Flory et al. (2004) [12] did report that the pattern of marijuana use differed by ethnicity. We can only generalize our findings to a population of primarily white adolescents and adults. Future research with diverse samples may enhance the generalizability of the findings. Second, caution must be exercised in the interpretation of the results. Due to the small sample size, some statistical confidence intervals were relatively wide. We may have missed trajectory patterns (or periods) of marijuana use shorter than the time intervals between waves of data collection. Future research should include a larger sample observed with shorter intervals between waves. Third, although we included a number of confounding factors in the analyses, we were not able to include other factors which may explain the association of the trajectories of marijuana use and the effects on adult functioning. For example, we did not include life events. Fourth, the marijuana use item could miss periods of heavy use. Unfortunately, measures of more recent marijuana use, such as marijuana use in the past year, were not available in the present study. Finally, the present study does not enable us to provide inferences regarding causality. Future research should focus on assessing the causal ordering of the trajectories of marijuana use and adult functioning.

Future research is also needed to identify the mechanisms that serve to mediate the relationship between patterns of marijuana use and unconventional behaviors, emotional problems, sensation seeking, nicotine dependence, alcohol dependence/abuse, having children who lived at home, and having a spouse/partner who used marijuana in adulthood. Detailed information concerning these developmental processes will better inform prevention and intervention strategies for high-risk individuals.

This study has several strengths. First, we employed longitudinal data to assess the developmental trajectories of marijuana use beginning in adolescence and extending to adulthood. This enabled us to assess changes in marijuana use over important developmental periods as related to adult functioning. With the advent of the legalization of marijuana, it will be important to examine the changes in the trajectories of marijuana use, particularly as related to personal and interpersonal adult functioning. It may be that legalization of the use of marijuana may have adverse effects on adult functioning.

Implications

The present study adds to the literature on the different patterns of marijuana use. Based on the results of this study and the findings of other investigators, we are well positioned to target the stages of individual development in which to intervene. Regarding marijuana use, different patterns of marijuana use are associated with unconventional behavior, emotional difficulties, nicotine dependence, and alcohol dependence/abuse. Interventions that address different patterns of marijuana use may result in increased personal and interpersonal functioning.

From a clinical perspective, two approaches to the treatment of marijuana use have proven to be effective: cognitive behavioral therapy and motivational enhancement therapy. At the present time, there is no approved pharmacotherapy for the treatment of marijuana use or its withdrawal syndrome. However, there is active research in these areas [41]. Several drugs such as Δ^9–tetrahydrocannabinol (the active ingredient in marijuana), buspirone (for treatment of anxiety), zolpidem, and gabapentin (both for insomnia), appear to be promising treatments for the marijuana withdrawal syndrome [41]. The management of this syndrome is important as it may reduce the likelihood that individuals resume marijuana use in order to alleviate withdrawal symptoms, i.e., relapse. A decrease or elimination of marijuana use may then lead to an increase in personal and interpersonal functioning.

Compliance with ethical standards

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest. J. S. Brook, C. Zhang, C. G. Leukefeld, and D. W. Brook have no involvement in any organization or entity with a direct financial interest in the subject matter or materials discussed in the manuscript.

References

1. Brook JS, Adams RE, Balka EB, Johnson E (2002) Early adolescent marijuana use: risks for the transition to young adulthood. Psychol Med 32(1):79–91
2. Lynskey MT, Coffey C, Degenhardt L, Carlin JB, Patton G (2003) A longitudinal study of the effects of adolescent cannabis use on high school completion. Addiction 98(5):685–692
3. Caldeira KM, O'Grady KE, Vincent KB, Arria AM (2012) Marijuana use trajectories during the post-college transition:

health outcomes in young adulthood. Drug Alcohol Depend 125:267–275

4. Fergusson DM, Boden JM, Horwood LJ (2015) Psychosocial sequelae of cannabis use and implications for policy: findings from the Christchurch Health and Development Study. Soc Psychiatry Psychiatr Epidemiol 50:1317–1326

5. Meier MH, Caspi A, Ambler A et al (2012) Persistent cannabis users show neuropsychological decline from childhood to midlife. Proc Natl Acad Sci 109:E2657–E2664

6. Brook DW, Brook JS, Zhang C, Cohen P, Whiteman M (2002) Drug use and the risk of major depressive disorder, alcohol dependence, and substance use disorders. Arch Gen Psychiat 59:1039–1044

7. Degenhardt L, Hall W, Lynskey MT (2001) The relationship between cannabis use and other substance use in the general population. Drug Alcohol Depend 64:319–327

8. Brook JS, Brook DW, Gordon AS, Whiteman M, Cohen P (1990) The psychosocial etiology of adolescent drug use: a family interactional approach. Genet Soc Gen Psych 116:111–267

9. Elder GH (1998) The life course as developmental theory. Child Dev 69(1):1–12

10. Brook JS, Lee JY, Finch SJ, Brook DW (2014) Developmental trajectories of marijuana use from adolescence to adulthood: relationship with using weapons including guns. Aggressive Behav 40(3):229–237

11. Caldeira KM, O'Grady KE, Vincent KB, Arria AM (2012) Marijuana use trajectories during the post-college transition: health outcomes in young adulthood. Drug Alcohol Depend 125(3):267–275

12. Flory K, Lynam D, Milich R, Leukefeld C, Clayton R (2004) Early adolescent through young adult alcohol and marijuana use trajectories: early predictors, young adult outcomes, and predictive utility. Dev Psychopathol 16(1):193–213

13. Schulenberg JE, Merline AC, Johnston LD, O'Malley PM, Bachman JG, Laetz VB (2005) Trajectories of marijuana use during the transition to adulthood: the big picture based on national panel data. J Drug Issues 35(2):255–280

14. Tucker JS, Ellickson PL, Orlando M, Martino SC, Klein DJ (2005) Substance use trajectories from early adolescence to emerging adulthood: a comparison of smoking, binge drinking, and marijuana use. J Drug Issues 35(2):307–332

15. Ellickson PL, Martino SC, Collins RL (2004) Marijuana use from adolescence to young adulthood: multiple developmental trajectories and their associated outcomes. Health Psychol 23(3):299–307

16. Brook JS, Lee JY, Brown EN, Finch SJ, Brook DW (2011) Developmental trajectories of marijuana use from adolescence to adulthood: personality and social role outcomes. Psychol Rep 108(2):339–357

17. Brook JS, Zhang C, Brook DW (2011) Developmental trajectories of marijuana use from adolescence to adulthood: personal predictors. Arch Pediat Adol Med 165(1):55–60

18. Pahl K, Brook JS, Koppel J (2011) Trajectories of marijuana use and psychological adjustment among urban African American and Puerto Rican women. Psychol Med 41(8):1775–1783

19. Brown TL, Flory K, Lynam DR, Leukefeld C, Clayton RR (2004) Comparing the developmental trajectories of marijuana use of African American and Caucasian adolescents: patterns, antecedents, and consequences. Exp Clin Psychopharm 12(1):47–56

20. Juon HS, Fothergill KE, Green KM, Doherty EE, Ensminger ME (2011) Antecedents and consequences of marijuana use trajectories over the life course in an African American population. Drug Alcohol Depend 118(2):216–223

21. Johnston LD, O'Malley PM, Bachman JG, Schulenberg JE (2006) Monitoring the Future national survey results on drug use, 1975–2005. Volume II: College students and adults ages 19–45 (NIH Publication No. 06-5884). Bethesda, MD: National Institute on Drug Abuse

22. Jessor R, Graves TD, Hanson RC, Jessor SL (1968) Society, personality, and deviant behavior: A study of a tri-ethnic community. Holt, Rinehart, and Winson, New York

23. Smith GE, Fogg CP (1979) Psychological antecedents of teenage drug use. In: Simmons R (ed) Research in community and mental health: An annual compilation of research. JAI, Greenwich, CT, pp 87–102

24. Gold M (1966) Undetected delinquent behavior. J Res Crime Delinq 3:27–46

25. Kessler RC, Nelson CB, McGonagle KA, Edlund MJ, Frank RG, Leaf JP (1996) The epidemiology of co-occurring mental disorders and substance use disorders in the National Comorbidity Survey: implications for service utilization. Am J Orthopsychiatry 66:17–31

26. Newhill CE, Bell MM, Eack SM, Mulvey EP (2010) Confirmatory factor analysis of the emotion dysregulation measure. J Soc Social Work Res 1:159–168

27. Zuckerman M, Eysenck S, Eysenck HJ (1978) Sensation seeking in England and America: crosscultural, age, and sex comparisons. J Consult Clin Psych 46:139–149

28. Anthony JC, Warner LA, Kessler RC (1994) Comparative Epidemiology of Dependence on Tobacco, Alcohol, Controlled Substances, and Inhalants: basic Findings From the National Comorbidity Survey. Exp Clin Psychopharm 2:244–268

29. Spanier GB (1976) Measuring dyadic adjustment: new scales for assessing the quality of marriage and similar dyads. J Marriage Fam 38:15–28

30. Derogatis LR (1994) Symptom Checklist 90-R: Administration, scoring, and procedures manual, 3rd edn. National Computer Systems, Minneapolis

31. Muthén LK, Muthén BO (2010) Mplus User's Guide, 6th edn. Muthén & Muthén, Los Angeles

32. Bray BC, Lanza ST, Tan X (2015) Eliminating bias in classify-analyze approaches for latent class analysis. Struct Equ Modeling Multidiscip J 22:1–11

33. Bauer DJ, Curran PJ (2003) Distributional assumptions of growth mixture models: implications for overextraction of latent trajectory classes. Psychol Methods 8:338–363

34. Center for Behavioral Health Statistics and Quality. National survey on drug use and health (2013) Rockville MD: Substance Abuse and Mental Health Services Administration

35. Jessor R, Jessor SL (1977) Problem behavior and psychosocial development: a longitudinal study of youth. Academic Press, San Diego

36. Hall W, Degenhardt L (2007) Prevalence and correlates of cannabis use in developed and developing countries. Curr Opin Psychiatr 20(4):393–397

37. Agrawal A, Neale MC, Prescott CA, Kendler KS (2004) A twin study of early cannabis use and subsequent use and abuse/dependence of other illicit drugs. Psychol Med 34(7):1227–1237

38. Volkow ND, Baler RD, Compton WM, Weiss SR (2014) Adverse health effects of marijuana use. New Engl J Med 370(23):2219–2227

39. Khantzian EJ (1997) The self-medication hypothesis of substance use disorders: a reconsideration and recent applications. Harvard Rev Psychiat 4(5):231–244

40. Clark DB, Chung T, Thatcher DL, Pajtek S, Long EC (2012) Psychological dysregulation, white matter disorganization and substance use disorders in adolescence. Addiction 107:206–214

41. Weinstein AM, Gorelick DA (2011) Pharmacological treatment of cannabis dependence. Curr Pharm Des 17(14):1351–1358