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Associations between marijuana use and anxious mood lability during adolescence

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HIGHLIGHTS

- Anxious mood lability was significantly higher for adolescents reporting recent marijuana use.
- Female adolescents were higher in anxious mood lability than males.
- The association between anxious mood liability and recent marijuana use did not differ by gender.

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ABSTRACT

Objective: To date, research investigating the association between adolescent marijuana use and anxiety is mixed, given differences in how anxiety is measured and the age ranges studied. The research is further limited as many relevant studies have small sample sizes. This investigation examines the association between marijuana use (use in the past 30 days) and anxious mood lability (rapid fluctuation in emotional states) during early adolescence (average age 14.4, spring of 8th grade) through midadolescence (10th grade).

Methods: Participating adolescents (N = 466; 52.8% female) were from rural and suburban communities and 38% were Hispanic/Latino. Ecological Momentary Assessment (EMA) was used to measure adolescents' anxious mood in real time; the EMAs were collected within 30 days of the adolescent report of their marijuana use.

Results: Multilevel models with measurement waves (7 time points) nested in individuals showed that anxious mood lability was significantly higher for adolescents reporting recent marijuana use compared to those reporting no recent marijuana use. Although females were higher than males in anxious mood lability, the association between anxious mood lability and recent marijuana use did not differ by gender. Post hoc analysis showed that the associations between anxious mood lability and recent marijuana use did not differ between assessments conducted pre and post legalization of adult recreational marijuana use.

Conclusions: The association between recent marijuana use and anxious mood lability for youth is important for understanding the developmental processes of cannabis use and anxious mood disorders in adolescence and young adulthood.

1. Introduction

Nationally, 14% of 8th grade youth (ages 13–14) and 31% of 10th grade youth (ages 15–16) have tried marijuana and 6% of 8th grade youth and 14% of 10th grade youth have used marijuana in the past 30 days (Monitoring the Future; Johnston et al., 2018). It appears that the percentage of adolescents who have tried marijuana and current marijuana use more than doubles within this two year period from early to midadolescence in the U.S. Such increases during a time when the adolescent brain is still developing are concerning, as youth who use marijuana on a regular basis are vulnerable to reduced high-level cognitive skills, such as executive control, working memory, problem solving, and decision making (Crane, Schuster, Fusar-Poli, & Gonzalez, 2013; Schneider, 2008), particularly for those whose age of onset is 16 years or younger (Gruber, Sagar, Dahlgren, Racine, & Lukas, 2012). Moreover, chronic marijuana use that begins during adolescence was associated with greater marijuana dependence, crime involvement, and poorer social relationships (Epstein et al., 2015) and with greater problem behaviors and depressive symptoms (Thompson, Merrin, Ames, & Leadbeater, 2018) in adulthood. Furthermore, marijuana use in early adolescence was associated with subsequent illegal drug use and dependence in later adolescence and adulthood (Andrews & Westling,

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2016). Given these potential harmful effects, it is important to understand factors that are associated with marijuana use during early to midadolescence.

An association between marijuana use and anxiety has been found in adults, but research about how anxiety and marijuana use are associated during adolescence is limited. For example, Buckner et al. (2011) used Ecological Momentary Assessment (EMA) to measure "anxiety sensitivity," defined as fear of anxiety, in a sample of 49 marijuana-using young adults (ages 18–22), and found an association between anxiety sensitivity and problematic marijuana use. In a sample of heavy marijuana-using adults (ages 18–55) Ketcherside and Filbey (2015) found an association between perceived stress and greater marijuana use, and this association was mediated by anxiety and depression. A study of marijuana-using adults (ages 18–60) found that social anxiety was associated with marijuana use as a coping strategy for men, but not women (Buckner, Zvolensky, & Schmidt, 2012). Yet these studies have focused on adults who used marijuana and did not include those who abstained from marijuana use. These results generalize to adults who use marijuana, and are helpful to inform prognoses and relevant interventions for heavy users and those who have addiction problems.

A prevention approach for adolescents is warranted, given that the majority of adolescents have not yet tried marijuana. Marijuana use accelerates during adolescence with about one third having tried marijuana by the time they are 16 years old (Johnston et al., 2018). Research utilizing frequent assessment time points to examine the association between anxiety and recent marijuana use in adolescents generalizes across the adolescent population, and can be informative for prevention of marijuana onset and use acceleration.

To our knowledge, only two small-scale studies have examined the association between marijuana use and anxiety, and only one of those studies had a sample of users and nonusers. This study ($n = 62$, ages 14–20) found that trait anxiety was higher in those who used marijuana compared to those who did not (Dorard, Berthoz, Phan, Corcos, & Bungener, 2008). The other study sample only included adolescents who used marijuana ($n = 56$, ages 12–17 years old) and concluded that social anxiety was not associated with the frequency of marijuana use (Cloutier, Blumenthal, & Mischel, 2016). The present study addresses prior study limitations with a somewhat large sample of adolescents who use and who do not use marijuana during the developmental period when growth in use occurs.

Longitudinal studies that follow adolescents into adulthood have found that marijuana use during adolescence predicted adult anxiety disorders (Wittchen et al., 2007), and that chronic users (those who used marijuana throughout adolescence) had significantly greater anxiety symptoms in adulthood than those who did not use marijuana during adolescence (Epstein et al., 2015). Others studies have examined multiple substances (i.e., alcohol, tobacco, and marijuana) and anxiety with mixed results. One study did not find an association with marijuana and anxiety in adolescent boys or girls (Cerdá, Prins, Galea, Howe, & Pardini, 2016). Another study found that marijuana use onset was associated with a decrease in adolescent girl's social anxiety (Marmorstein et al., 2010). Another study found that polysubstance use (tobacco, alcohol, and marijuana) during late adolescence was associated with greater anxiety in adulthood (Brook, Lee, Rubenstone, Brook, & Finch, 2014). Mixed results are also found in these longitudinal studies utilizing different measures of anxiety at differing developmental times.

To get a better understanding about the association between marijuana use and anxiety during adolescence, the present study utilizes EMA to measure anxious mood in real time, a methodology that minimizes recall bias and maximizes ecological validity (Shiffman, Stone, & Hufford, 2008). The EMA methodology also allows for the measurement of rapid change in emotional states or mood lability by capturing multiple randomly timed assessments of mood in real time within a day and across a number of days. Mood lability takes into account fluctuations in mood and the sequence of fluctuations, and is indicative of emotional regulation difficulties during adolescence.

A number of studies indicate that mood lability is associated with social, behavioral, and internalizing difficulties during adolescence. For example, variability in mood states (e.g., unhappy, happy, angry) was related to depression and problems with social relationships during early adolescence (Larson, Raffaelli, Richards, Ham, & Jewell, 1990). An EMA study showed that both sad and anxious mood lability were associated with victimization of peer verbal aggression (Rusby, Westling, Crowley, & Light, 2013). Another study found that negative mood lability (anger, sadness, and anxiety) was associated with depression and antisocial behavior (Silk, Steinberg, & Morris, 2003) during adolescence. Moreover, rapid mood changes were associated with the comorbidity of internalizing and externalizing problems (Stringaris & Goodman, 2009). Thus, from a prevention perspective, mood lability is a salient indicator of emotional and social difficulties for adolescents. Capturing anxious mood lability appears to be a valid and relevant measure of anxiety in adolescence.

The aim of the present study was to investigate the association between anxious mood lability and recent marijuana use during early to midadolescence. The measure for anxiety used in the present study is informed by previous work on mood lability in adolescents which suggests that mood lability is indicative of difficulties in mood regulation, which is associated with both social and internalizing problems. Low self-regulation, or disinhibition, increases susceptibility to social influences and substance use in adolescents (Zucker, Heitzeg, & Nigg, 2011). Others posit that internalizing difficulties have a role in the development of substance use (i.e., alcohol use) in adolescents (Hussong, Jones, Stein, Baucom, & Boeding, 2011). We anticipated that this is relevant for adolescents experiencing anxious mood lability, expecting to find significant associations between recent marijuana use and anxious mood lability. In addition to heightened susceptibility, adolescents with frequent fluctuations in anxious mood may use marijuana to get relief from their negative mood or to enhance positive mood. A secondary aim was to test whether gender moderated the association between anxious mood lability and recent marijuana use. Although social anxiety was associated with marijuana use in adult males, but not females (Buckner et al., 2012), such gender differences may or may not be found for adolescent anxious mood lability and marijuana use.

2. Methods

This EMA study on the social contexts of adolescent activities and emotional states is part of a larger study investigating social influences of risky behaviors during adolescence. Data collection for this study occurred from 2014 through 2017. Students completed brief randomly prompted surveys on an Apple iPod touch over four consecutive days (Thursday through Sunday) for 10 quarterly assessment waves from spring of 8th grade through the spring of 10th grade. There were 18 randomly timed surveys per assessment wave, for a total of 180 possible EMAs per participant. The randomly timed surveys occurred in a window of time when school was not in session (during adolescent's free time). Although school schedules varied, the school day ended at similar times across schools. All schools' classes had ended before the earliest start time of the EMA. Incentives were offered for participation in each EMA wave ($20–$30), with bonuses provided for answering 80% or more of the survey prompts. In addition, participating adolescents completed a brief survey on school computers in the spring of 8th grade and in fall, winter, and spring of 9th and 10th grades (7 assessment waves). This survey asked about adolescent's substance use, including lifetime and past 30 day marijuana use. All study procedures were reviewed and approved by the Institutional Review Board of the first author's institution.

2.1. Participants

Participating adolescents were from 11 middle schools in seven rural and suburban Oregon school districts. All adolescents in the 8th grade who could understand English or Spanish were eligible to participate in the social influence study (N = 1188) and were invited to participate in the EMA study. Detailed information about the study, the consents, and the assents were mailed to families (these were in English on one side and Spanish on the other). The study and consents/assents were described over the phone or in person, and informed consent (from parents) and assent (from adolescents) were obtained for participation in the EMA study. Research assistants who were bilingual in Spanish and English were available to communicate with Spanish speaking families. Consent and assent to participate in the EMA study were received via mail or in person for 466 adolescents. The EMA study involved a representative sample, as this sample did not differ from the full 8th grade population on gender, ethnicity, or substance use. Participants were 53% female, and 44% White, non-Hispanic, 38% Hispanic, and 18% other or multiple races.

2.2. Measures

2.2.1. Ecological Momentary Assessment of anxious mood lability

For the EMA adolescents answered questions about their current activities, moods, and social context (who they were with, their perceptions of any peers present, and where they were) during nonschool hours. The question on anxious mood was "How anxious or worried are you right now?" and a slider was used to indicate the level on a 1–9 scale from Not at all to Very. Mood lability within an assesment wave was calculated by taking the mean squared successive difference statistic across each subject's four-day, ordered session observations. For a sequence of N observations, it is given by:

$$\text{MSSD} = \frac{\sum_{i=1}^{N-1}(x_{i+1} - x_i)^2}{N-1}$$

This statistic has become the standard lability measure for EMA and other intensive longitudinal data (Anestis et al., 2010; Jahng, Wood, & Trull, 2008; Miller, Vachon, & Lynam, 2009) because it defines variability between ordered pairs of observations rather than ignoring order. A higher score reflects greater temporal instability of the mood measured.

2.2.2. Recent marijuana use

On the online survey adolescents answered questions about their marijuana use; items were from the Oregon Healthy Teens Survey (Boles, Biglan, & Smolkowski, 2006). Adolescents were asked about lifetime use, whether they used marijuana in the past 30 days, and, if so, on how many days they used marijuana in the past 30 days.

2.2.3. Analytical procedures

Descriptive statistics were run for each variable at each data time point to explore out of range values and the rates of missing data. To investigate the relationship between anxious mood lability and recent marijuana use, the analysis included only EMA of mood lability and reports of marijuana that occurred within 30 days of each other. In 4.2% of the assessments the EMA occurred more than 30 days before the marijuana report and in 4.1% of the assessments the EMA occurred more than 30 days after marijuana report; these assessment cases were excluded from the analyses. Of the assessments included in the analysis (n = 2062), 351 (17%) of EMAs occurred no more than 30 days prior to the marijuana assessments and 1711 (83%) of EMAs occurred no more than 30 days following the marijuana assessment.

Multilevel models were estimated to investigate the associations between adolescent recent marijuana use and anxious mood lability and gender moderation. Due to non-normality, anxious mood lability scores were log transformed for analysis, ln(x + 1), and back transformed, exp.(x) − 1, for reporting results to assist in interpretation. Values indicating the number of days of marijuana use in the last 30 days, were dichotomized into 0 = no recent use and 1 = 1 or more days of recent marijuana use, due to the extreme right skew of the distribution and high prevalence of zeros. We investigated whether an adolescent's anxious mood lability was greater when the adolescent reported recent marijuana use and whether this relationship varied by gender. Because adult use of recreational marijuana became legal in Oregon where the study was taking place in July 2015, we also conducted a post hoc analysis to determine whether the relationship differed pre and post legalization (35% of the EMAs occurred prior to legalization and 65% occurred after legalization).

Models accounted for the nesting of measurement occasion within the individual, using a random individual-level intercept and fixed slope. All multilevel models were run using R 3.4.3 lme4 package version 1.1–17 (Bates, Maechler, Bolker, & Walker, 2015) with linear mixed effects model fit by REML.

The unconditional model (Model 1) had 2062 measurement occasions (Level 1) and 446 adolescents (Level 2):

Level 1 (measurement occasion) $Y = \pi_0 + e$

Level 2 (adolescent) $\pi_0 = \beta_{00} + r_0$

Next, the conditional model (Model 2) was a random intercept model with a dichotomous Level 1 covariate depicting recent marijuana use (use in the past 30 days) added:

Level 1 (measurement occasion) $Y = \pi_0 + \pi_1$(Recent Marijuana Use) + e

Level 2 (adolescent) $\pi_0 = \beta_{00} + r_0$

$$\pi_1 = \beta_{10} + r_1$$

Last, Model 3 was a random intercept model with a dichotomous Level 2 moderator, gender, added:

Level 1 (measurement occasion) $Y = \pi_0 + \pi_1$(Recent Marijuana Use) + e

Level 2 (adolescent) $\pi_0 = \beta_{00} + \beta_{01}$(Gender) + r_0

$\pi_1 = \beta_{10} + \beta_{11}$(Gender) + r_1

3. Results

3.1. Descriptive statistics

EMA response rates are shown in Table 1. On average, across all assessment waves, 76% of EMA surveys were answered. Retention at each assessment wave ranged from 92% participation in the EMA at Wave 1 (spring of 8th grade) to 73% at Wave 9 (spring of 9th grade). Descriptive statistics for anxious mood lability and marijuana use are shown in Table 2. Across the assessment waves, the percent of adolescents reporting recent marijuana use ranged from 8% to 13%, representing 21 to 39 adolescents at each time point, and a total of 115 adolescents (26% of sample, 47 male and 68 females) provided at least

Table 1
Descriptive statistics: EMA completion and participation rates.

	EMA sessions completed		Participation rates	
Assessment wave	Mean	SD	*N*	%
Spring 8th grade	14.25	3.63	430	92%
Fall 9th grade	13.34	4.69	381	82%
Winter 9th grade	13.67	4.43	390	84%
Spring 9th grade	13.44	4.80	374	80%
Fall 10th grade	13.45	4.49	355	76%
Winter 10th grade	13.57	4.75	348	75%
Spring 10th grade	13.67	4.74	342	73%

Note. Total EMA sessions per wave = 18. The participation rates reflect the number of adolescents who participated in the EMA wave out of 466.

Table 2
Descriptive statistics: anxious mood lability and last 30-day marijuana use.

Anxious mood lability (MSSD)	Mean	*SD*	Min	Max
Spring 8th grade	0.36	0.38	0	1.71
Fall 9th grade	0.38	0.44	0	2.32
Winter 9th grade	0.41	0.46	0	3.30
Spring 9th grade	0.35	0.38	0	2.83
Fall 10th grade	0.40	0.48	0	2.62
Winter 10th grade	0.37	0.43	0	2.94
Spring 10th grade	0.34	0.41	0	2.27

Past 30 Day Marijuana Use	*n*	Percent	Min	Max
Spring 8th grade	38	12%	0	1
Fall 9th grade	23	8%	0	1
Winter 9th grade	32	10%	0	1
Spring 9th grade	39	13%	0	1
Fall 10th grade	21	8%	0	1
Winter 10th grade	35	12%	0	1
Spring 10th grade	38	13%	0	1

one report of recent marijuana use.

3.2. Multilevel models: anxious mood lability and recent marijuana use moderated by gender

Results of the multilevel models are reported in Table 3. Average anxious mood lability score (MSSD) was 0.46 (95% CI = [0.42, 0.50]). The unconditional model (Model 1) attributed 24% of the variance in anxious mood lability to the individual and 76% to the measurement occasion, with the average adolescent mood lability score varying by 0.23 points (95% CI = [0.20, 0.26]). Although most of the variability in anxious mood lability depends on factors associated with the assessment occasion, there is also a significant proportion associated with individual tendencies or characteristics.

The results of Model 2 show that the anxious mood lability (MSSD) at a measurement occasion without recent marijuana use was 0.44 (95% CI = [0.40, 0.48]). With all other factors constant, average measurement occasions in which recent marijuana use occurred had anxious mood lability scores 0.15 (95% CI = [0.08, 0.22]) greater than measurement occasions without recent marijuana use reported ($p < .001$).

Table 3
Multilevel models: anxious mood lability (MSSD), recent marijuana use, and gender moderation.

Predictors	Model 1: unconditional model	Model 2: conditional model	Model 3: moderator added
Fixed effect estimates			
Intercept- anxious mood lability	0.46 (0.01)***	0.44 (0.01)***	0.49 (0.02)***
Marijuana use		0.15 (0.03)***	0.11 (0.04)*
Gender			−0.08 (0.03)**
Marijuana use × Gender			0.08 (0.06)
Variance components			
Level 2:			
Individual anxious mood lability	0.23	0.22	0.21
Goodness-of-fit			
Deviance	2175.47	2162.11	2160.85
AIC	2198.36	2170.11	2172.85
BIC	2198.36	2192.63	2206.61
Pseudo R^2			
Within person variance explained		0.00	0.00
Between person variance explained		0.06	0.10

Note. Coefficients are shown for the fixed effect estimates with standard errors in parentheses.
* $p < .05$.
** $p < .01$.
*** $p < .001$.

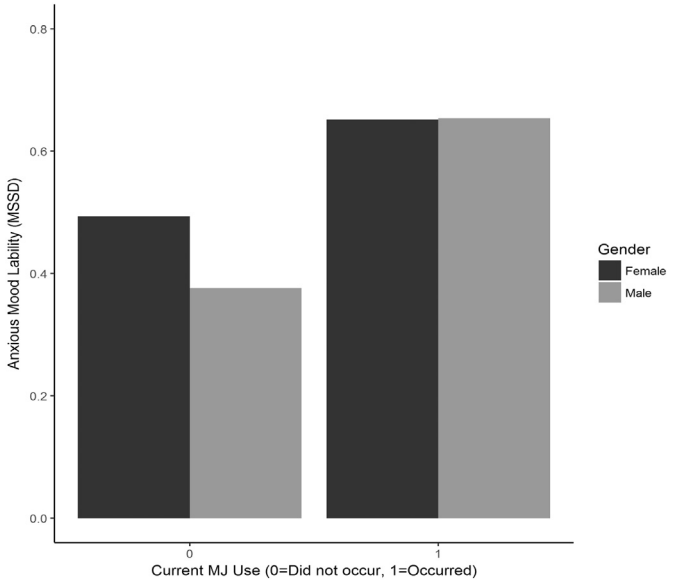

Fig. 1. Anxious mood lability and recent marijuana use by gender.

Model 3 examined gender differences in the relationship between recent marijuana use and anxious mood lability. Conditional effects of recent marijuana use ($p = .015$) and gender ($p = .002$) on anxious mood lability (MSSD) were detected. Average anxious mood lability (MSSD) for females at a measurement occasion without recent marijuana use was 0.49 [0.44, 0.55], and was 0.11 higher ($p = .015$, 95% CI = ([0.02, 0.20]) on occasions where recent marijuana use was reported. On average, anxious mood lability (MSSD) without recent marijuana use was −0.08 (95%CI = [−0.13, −0.03]) smaller for males than females ($p = .002$). Gender differences in the relationship between recent marijuana use and anxious mood lability was not detected 0.09 (95% CI = [−0.04, 0.23]), $p = .197$. Fig. 1 illustrates the association between anxious mood lability and recent marijuana use for females and males.

A post hoc model was performed to explore the influence of assessment order on the relationships of interest. Significant relationships were not detected between assessment order (EMA before v. after marijuana report) and anxious mood lability ($p = .577$) nor between assessment order and the relationship between recent marijuana use and anxious mood lability ($p = .728$). Post hoc analyses were also conducted to investigate a potential effect for legalization of adult recreational marijuana use on the relationship between adolescent marijuana use and anxious mood lability, and no influence for legalization on the relationship was detected ($p = .473$).

4. Discussion

The purpose of this investigation was to examine how marijuana and anxious mood were associated during the developmental period from early adolescence to midadolescence. We used anxious mood lability scores collected via EMA as indicators of anxious mood difficulties. Multilevel models showed that most of the variance in anxious mood lability was due to the measurement occasion (within-person), but substantial differences between individuals were also found. Recent marijuana use was associated with significantly greater anxious mood lability. These findings are similar to results based on trait anxiety and marijuana use (Dorard et al., 2008) except with a much larger sample

size and a more precisely defined developmental period. The assessment period of the present study occurred when youth were in 8th grade through 10th grade, a potentially risky developmental period when youth tend to use marijuana for their first time and marijuana use tends to accelerate (Johnston et al., 2018), and thus, an ideal time for preventing onset and escalation. Additionally, although females had significantly higher average anxious mood lability than boys, the association between anxious mood lability and recent marijuana use did not differ by gender. This finding implies that prevention efforts addressing anxious mood and marijuana use are relevant for both boys and girls.

The present study adds to the research aimed at understanding anxiety in youth by pinpointing the link between rapid changes in feelings of anxiety and recent marijuana use. There is a growing concern regarding anxiety problems in youth given that about one third of adolescents are estimated to have an anxiety disorder (Merikangas et al., 2010) and the prevalence is steadily increasing (e.g., Bitsko et al., 2018). Simultaneously, attitudes about marijuana are changing and marijuana use by adolescents appears to be recently increasing (Johnston, O'Malley, Miech, Bachman, & Schulenberg, 2014). Addressing healthy ways to deal with feelings of anxiety may be applicable for preventing onset and acceleration of marijuana use during this period. It is also possible that efforts to decrease marijuana use may be helpful in reducing anxiety disorders in youth.

4.1. Limitations

Causal inferences cannot be drawn about the relationship between marijuana use and anxiety during adolescence from this study. The results, on the other hand, demonstrate that anxious mood lability and recent marijuana use are associated during this important development period when youth are prone to try marijuana.

This study utilized a representative sample of youth from participating schools; however, it is limited to youth who live in rural and suburban communities, and results may not generalize to an urban population. Participants also were predominantly White and/or of Hispanic/Latino ethnicity, possibly limiting relevance for youth of other races.

We have chosen to use a measure of anxious mood lability as an indicator of difficulties with anxiety during adolescence. High anxious mood lability does not necessarily mean that anxiety is interfering with the individual's life progress (such as academic achievement or the quality of social relationships), and the measure has not been validated as a clinical measure (to our knowledge, no clinical scores for mood lability have been systematically identified). Nevertheless, negative mood lability is a risk factor, as it has been found to be associated with social, emotional, and behavioral difficulties during adolescence (e.g. Rusby et al., 2013; Silk et al., 2003) and to predict trait anxiety during early adulthood (Stringaris & Goodman, 2009). This study's use of EMA of anxious mood lability offers a rich data set with many assessments in a relatively large sample of adolescents, and has less bias than retrospective self-report questionnaire data (e.g., Gorin & Stone, 2001).

4.2. Summary and future directions

Study results show an association between difficulties with anxious mood and marijuana use for adolescent boys and girls, indicating that attention to both anxiety and marijuana use is needed, as well as further investigations regarding predictors and moderators of these associations. Efforts are needed to identify whether anxiety leads to adolescent marijuana use (self-medication as an effort to relieve anxious feelings), marijuana use leads to greater feelings of anxiety, or a dynamic process takes place. A dynamic process in which marijuana provides temporary relief from anxiety, leading to an escalation of marijuana use and dependence on marijuana to achieve that temporary relief is plausible. Note that Pardee, Colder, and Bowker (2014) explored dynamic processes in youth ages 11 to 15, finding that anxiety symptoms and alcohol use changed simultaneously with lower decreases in anxious symptoms associated with increased alcohol use. On the other hand, there may be a subgroup of adolescents for which anxiety and marijuana use grow simultaneously over time and another group for which this is not the case. For example, in young adult marijuana users, greater psychological problems were found for those who used marijuana to cope with stress than for those who used marijuana socially for recreational purposes (Brodbeck, Matter, Page, & Moggi, 2007). Further, marijuana users with recreational motives were similar on levels of distress as nonusers. Similar subgroups may be found for adolescents who use marijuana. Pinpointing such motivators of marijuana onset and use during adolescence will contribute to the identification of relevant mechanisms to address for prevention.

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