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Historical trends in the grade of onset and sequence of cigarette, alcohol, and marijuana use among adolescents from 1976-2016: implications for "Gateway" patterns in adolescence*

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Abstract

Introduction: In the past decade, marijuana use prevalence among adolescents has remained relatively steady while cigarette and alcohol prevalence has declined. We examined historical trends in: average grade of onset of marijuana, alcohol, and cigarette use by 12th grade; proportion who try alcohol/cigarettes before first marijuana use, among those who use by 12th grade; and conditional probability of marijuana use by 12th grade after trying alcohol/cigarettes.

Methods: Data were drawn from 40 yearly, cross-sectional surveys of 12th grade US adolescents. A subset of students (N=246,050) were asked when they first used each substance. We reconstructed cohorts of substance use from grade-of-onset to determine sequence of drug use, as well as probability of marijuana use in the same or later grade.

Results: Average grade of first alcohol and cigarette use by 12th grade increased across time; e.g., first cigarette increased from grade 7.9 in 1986 to 9.0 by 2016 ($\beta = 0.04$, SE = 0.001, $p < 0.01$). The proportion of 12th grade adolescents who smoke cigarettes before marijuana fell below 50% in 2006. Each one-year increase was associated with 1.11 times increased odds of first cigarette in a grade after first marijuana (95% C.I. 1.11–1.12). Among those who initiate alcohol/cigarettes prior to marijuana by 12th grade, the probability of subsequent marijuana use is increasing.

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Contributors

K. Keyes drafted the manuscript and the data analytic plan. C. Rutherford conducted the data analysis and wrote parts of the manuscript. R. Miech oversees the parent study and provided critical feedback on the manuscript and analyses. All authors have read and approved the final manuscript.

Conflict of Interest

No conflict declared.

Conclusion: Marijuana is increasingly the first substance in the sequence of adolescent drug use. Reducing adolescent smoking has been a remarkable achievement of the past 20 years; those who continue to smoke are at higher risk for progression to marijuana use.

Keywords

adolescent; gateway; marijuana; tobacco; alcohol; Monitoring the Future

1. Introduction

Psychoactive substance use tends to begin in adolescence and early adulthood in a predictable sequence. Adolescents who use substances most often begin with those that are licit for adults and more readily available, such as alcohol and tobacco, and then a proportion of those will experiment with marijuana and other drugs (Kandel and Kandel, 2015; Ramo et al., 2012; Wall et al., 2018). Indeed, historically, few adolescents who use marijuana have not experimented with alcohol and cigarettes beforehand. This sequence has become known as the 'gateway hypothesis' (Kandel, 1975; Kandel and Kandel, 2015), and implies that alcohol and cigarettes may be 'gateway drugs.' Support for alcohol and cigarettes as causally related to subsequent drug use is drawn from both animal models suggesting changes in reward sensitivity (Griffin et al., 2017; Kandel and Kandel, 2014; Lee et al., 2010; Panlilio et al., 2007) as well as social mechanisms through peer group selection (Wagner and Anthony, 2002).

Yet the landscape of adolescent substance use is changing in the United States in ways that are historically unprecedented. Perhaps the most dramatic change in the last 40 years has been in the rapid declines in adolescent cigarette smoking. The prevalence of daily smoking in the US in 12th grade, for example, declined from about one third in 1977 to less than 5% in 2017 (Miech et al., 2017b). Alcohol use and binge drinking have also decreased to historic lows. In contrast, the prevalence of any marijuana use in the past year has slightly increased across the last decade, with approximately one in three adolescents using marijuana by 12th grade (Keyes et al., 2017; Miech et al., 2017b). Similar trends have been observed across a range of national and local data (Ahrnsbrak et al., 2017; CDC, 2016; Johnson et al., 2018; Mauro et al., 2018).

These trends – a stable marijuana prevalence while cigarette and alcohol use have declined – raise three research questions that this study considers. First, we examine the extent to which age of initiation in adolescence has increased for cigarette and alcohol use. Since the 1990s almost all changes in adolescent drug prevalence have begun in the younger cohorts and then become evident among older cohorts as these younger cohorts aged (Miech et al., 2017b). Consequently, the decreases in cigarette and alcohol use would be expected to reflect fewer and fewer younger adolescents using these drugs and thereby increasing the age of initiation within the adolescent time period. Increases in age of initiation have implications for long-term trends in addiction, given the robust associations between decreasing age of first use of substances and development of substance dependence (Grant and Dawson, 1998, 1997; Hingson et al., 2006).

Second, we examine changes in age of initiation for cigarettes, alcohol, and marijuana relative to each other. Such relative changes could directly indicate a restructuring of the typical gateway sequence (Kandel and Kandel, 2015). As cigarettes and alcohol are now relatively uncommon, we might expect that, among adolescents who use cigarettes/alcohol and marijuana by 12th grade, fewer adolescents would use cigarettes/alcohol first in a sequence of drug use. Indeed, we might expect that cannabis will increasingly become the first substance used. Available evidence from national surveys indicate that there have been recent increases in the proportion of adolescents and young adults who use marijuana before alcohol and cigarettes from 2004 to 2014 (Fairman et al., 2018), supporting the hypothesis that the sequence has changed.

Third, while examining adolescents who use substances by 12th grade provides one vantage point in changes in the sequence, additional analyses incorporating those who both do and do not use substances by 12th grade are necessary to fully understanding changes in sequence progression. Thus, we examine changes in the probability of marijuana use given first use of alcohol and/or cigarettes. Given the declines in alcohol and cigarette use, we might hypothesis that those who use alcohol and cigarettes during times of low use may be at higher risk of progression to marijuana use than previous generations. Indeed, national data among adults with reconstructed life histories has demonstrated that adult cigarette users in more recent birth cohorts are more likely to have other drug disorders compared with previous cohorts of smokers (Talati et al., 2016, 2013), supporting the hypothesis that cigarettes users are increasingly a group selected for use of more drugs, though analyses that focus on adolescents are needed.

In summary, the decline in alcohol and tobacco use, coupled with the lack of decline in marijuana use, among adolescents portends shifts in the epidemiology of youth substance use. The present paper uses nationally representative data from 1976 through 2016, and considers historical trends in the average age of initiation of these substances during the adolescent period, the proportion of adolescents who use alcohol and tobacco prior to marijuana use among those who use by 12th grade, and the probability of subsequent marijuana use given alcohol and/or tobacco use among all adolescents.

2. Material and methods

2.1. Sample

Data were drawn from annual cross-sectional surveys of 12th grade adolescents in the 48 contiguous US states from 1976 through 2016 from the Monitoring the Future (MTF) study (Miech et al., 2017b). Schools are selected under a multi-stage random sampling design, and are invited to participate for two years. Schools that decline participation are replaced with schools that are similar on geographic location, size, and urbanicity. The overall school participation rates (including replacements of schools that decline to participate) range from 91% to 99% for all study years. Student response rates have ranged from 85.0% to 87.3%, and averaged 86.5%, with no systematic trend. Almost all non-response is due to absenteeism; less than 1% of students refuse to participate. Self-administered questionnaires are given to students. Detailed description of design and procedures are provided elsewhere (Bachman et al., 2015; Miech et al., 2017b). The present study focuses on students who

were randomized to a questionnaire that included questions regarding grade of first use of a series of substances, which was administered to approximately 38.54% of the total sample across years. The total analyzed sample size was 246,050 (ranging from 3,347 in 1976 to 8,570 in 1989).

2.2. Measures

2.2.1. Onset of substance use.—

We examined the sequence of substance use by using a subset of questions that measured the grade of onset for each substance (marijuana, cigarettes and alcohol). Each question starts with the phrase, "When (if ever) did you FIRST do each of the following things? Don't count anything you took because a doctor told you to." Follow-up questions included "smoke first cigarette" (first introduced to the survey in 1986), "smoke cigarettes on a daily basis," "try an alcoholic beverage--more than just a few sips," and "try marijuana or hashish." Answer options included "never," "grade 6 or below," "grade 7," "grade 8," "grade 9," "grade 10," "grade 11," and "grade 12." Using these variables, we estimated the overall proportion who tried each substance, dichotomizing each variable by "never used substance" versus all others. We note that the resulting estimates differ slightly from those reported in the MTF monographs (Miech et al., 2017b). These differences are due to variations in question wording as well as that we are estimating proportions in the subsample of the total MTF sample who received questionnaires with grade of onset questions. For example, the MTF monograph reports the prevalence of daily cigarette use based on the question "How frequently have you smoked cigarettes during the past 30 days?" whereas we estimate the prevalence of daily cigarette use based on those who report any grade of onset versus "never" based on the question described above.

2.2.2. Demographics.—

Analyses were stratified by adolescent-reported gender and results are available in online Supplementary Figures[1].

2.3. Statistical analysis

Analyses proceeded in three steps. First, we examined trends over time in the average grade of onset of alcohol, cigarettes, and marijuana. Spline regression was used to fit a model through the year data points to summarize trends. We also estimated the overall linear trend in average grade of onset using regression with year as the independent variable and grade of onset as the dependent variable (controlling for the questionnaire version received by the student). Second, we examined the proportion of students who had either used both alcohol and marijuana by 12^{th} grade or both cigarettes and marijuana by 12^{th} grade. Among these subgroups, we estimated three percentages: the proportion who used alcohol/cigarettes in a grade before marijuana use, the proportion who used alcohol/cigarettes the same grade as marijuana, and the proportion who used alcohol/cigarettes in a grade after marijuana. Again, spline regression as used to summarize the trends. Further, polytomous regression was used to summarize the overall trend, with a generalized logit link function; year was the independent variable and the outcome was three levels (use of substance in a grade before marijuana, same grade as marijuana, or grade after marijuana). Finally, we estimated the conditional probability of later marijuana use given alcohol or cigarette use. We did this by

[1]Supplementary material can be found by accessing the online version of this paper at http://dx.doi.org and by entering doi:...

constructing conditional proportions based on age of onset, by year. We describe our approach for cigarette use, and a similar approach was done for daily smoking and alcohol use. If an individual used cigarettes in 6th grade, for example, they were in the numerator for the conditional probability if they used marijuana in 6th through 12th grade. If an individual used cigarettes in 7th grade, they were in the numerator for the conditional probability if they used marijuana in 7th through 12th grade. Future grade of first cigarette use were coded similarly. The denominator included all adolescents who used cigarettes minus cigarette users who used marijuana before cigarettes (as those adolescents were not 'at risk' of marijuana use after cigarette use). Taken together, this collective proportion provides an estimate, retrospectively constructed, of the conditional probability of concurrent or future marijuana use given first cigarette use in any particular grade. All analyses were stratified by gender in supplementary analyses, and conducted in SAS version 9.4 as well as R software.

3. Results

3.1. Average onset of substance use

Average reported grade of onset has increased across time for first cigarette, onset of daily smoking, and alcohol use (Figure 1).

3.1.1. Alcohol.—The average grade of first alcohol use increased from 9.1 in 1976 to 9.5 in 2016. On average from 1976 through 2016, each additional year was associated with a 0.02 grade increase in onset of alcohol use (SE = 0.001, $p < 0.01$).

3.1.2 First cigarette.—The largest increase in grade was observed for first cigarette, which increased from average grade 7.9. in 1986 to 9.0. in 2016. On average from 1976 through 2016, each additional year was associated with a 0.04 grade increase in onset of cigarette use (SE = 0.001, $p < 0.01$).

3.1.3 Daily smoking.—Daily smoking increased from average grade 9.1. in 1976 to 9.9. in 2016. On average from 1976 through 2016, each additional year was associated with a 0.03 grade increase in onset of daily smoking (SE = 0.001, $p < 0.01$).

3.1.4 Marijuana.—Marijuana use has not considerably increased in average grade of onset across time at approximately 9.4 average grade of first use, with the exception of decrease in age from 1976 to 1989 (from 9.6 to 9.2) and a briefly observed increase in average grade of use in 1992 (to 10.0 in 1995). On average from 1976 through 2016, year was not associated with a change in the grade of onset of marijuana use ($\beta = 0.0003$, SE = 0.001, $p = 0.71$).

Supplementary Figure 1[2] provides grades of onset stratified by gender; no substantial gender differences emerged.

[2]Supplementary material can be found by accessing the online version of this paper at http://dx.doi.org and by entering doi:...

3.2. Trends in first substance used

Figure 2 graphs the proportion who reported first alcohol use in a grade before first marijuana use, smoking first cigarette in a grade before first marijuana use, and daily smoking in a grade before first marijuana use, among who used both substances by 12th grade. In supplementary Figures 2–4[2], we provide the proportion who used both substances in the same grade, and the proportion who used marijuana in a grade before each substance.

3.2.1. Alcohol.—Among 12th grade students who have used both alcohol and marijuana, the proportion who tried alcohol before marijuana has exhibited non-linear trends (Figure 2). Trying alcohol before marijuana peaked in 1995, the year in which 69.4% of adolescents reporting alcohol in a grade before marijuana use. This proportion fell rapidly by 1999 to 47.4%. Proportion trying alcohol in a grade before marijuana use remained relatively stable, between 44.5% and 50.9% until 2013, when the proportion significantly annually declined, to 39.0% in 2016. Overall, from 1976 through 2016, each year increase is associated with 1.05 times the odds of trying alcohol in a grade after marijuana, compared to a grade before marijuana (95% C.I. 1.04–1.05).

Supplementary Figure 2[3] provides the overall trend in trying alcohol, and the proportion who used both alcohol and marijuana in the same grade. Trying alcohol has declined across time, and the proportion trying alcohol and marijuana in the same grade has increased, which was 39.4% of the sample in 2016.

3.2.2. First cigarette.—Among 12th grade students who have tried both cigarettes and marijuana, the proportion who used cigarettes in a grade before marijuana has significantly and substantially declined. In 1995, 74.7% of 12th grade students who tried both cigarettes and marijuana used cigarettes in a grade before marijuana; by 2016, the proportion has fallen to 39.5%, indicating that the majority of adolescents now use marijuana in the grade during or before cigarettes. Of note, the trend in proportion trying cigarettes first is aligned closely with the proportion of 12th grade adolescents who reported trying cigarettes at all (Supplementary Figure 3[3]), which has also substantially declined over time. Concomitantly, the proportion who reported trying cigarettes in the same grade as marijuana has increased, from 20.1% in 1994 to 32.1% in 2016. Overall, from 1976 through 2016, each year increase is associated with 1.11 times the odds of trying cigarettes in a grade after marijuana, compared to a grade before marijuana (95% C.I. 1.11–1.12).

3.2.3. Daily smoking.—Among adolescents who used cigarettes daily by 12th grade and tried marijuana, the proportion who smoked daily before trying marijuana has declined more than 60%, from 38.5% in 1976 to 14.6% in 2016 (Figure 2). This decline is coincident with the decline in using cigarettes daily overall, which as of 2016 was 8.14% of the sample (Supplementary Figure 4[3]). As the proportion of adolescents who used cigarettes daily in a grade before marijuana has declined, starting daily smoking in the same grade as marijuana use has remained relatively steady, ranging from 23.4% in 2016 to 38.3% in 1989. Overall, from 1976 through 2016, each year increase is associated with 1.07 times the odds of

[3]Supplementary material can be found by accessing the online version of this paper at http://dx.doi.org and by entering doi:...

beginning to smoke daily in a grade after marijuana, compared to a grade before marijuana (95% C.I. 1.07–1.08).

Supplementary Figure 5[4] provides gender-stratified trends; no substantial gender differences emerged.

3.3. Conditional probability of marijuana use in the same or a later grade as alcohol and cigarette use

Figure 3 shows the conditional probability of marijuana in the same or later grade as alcohol and cigarette use, as well as the overall prevalence of trying marijuana in each panel for comparison. The probability of marijuana use, contingent on first using alcohol and cigarettes, has exhibited trends, especially since approximately 1999.

3.3.1. Alcohol.—The proportion of adolescents who use marijuana the same grade or after first trying alcohol closely overlapped the overall proportion of those who tried marijuana through the 1970s and 1980s, given that the proportion of the sample who tried alcohol by 12th grade was nearly ubiquitous. From the mid-1990s onward, the conditional probability of using marijuana in the same grade or after trying alcohol increased compared to the overall proportion who tried marijuana; by 2016, 56.4% of adolescents who tried alcohol would try marijuana in the same or a later grade, compared with 42.9% of the total sample.

3.3.2. First cigarette.—In 1999, 66.6% of students who tried cigarettes also tried marijuana in the same or a later grade, compared with 48.2% of the total sample. By 2016, 74.9% of student who used cigarettes use marijuana in the same or a later grade, compared with 42.9% of the total sample.

3.3.3. Daily smoking.—The proportion of daily smokers who initiate marijuana in the same or a later grade as daily smoking has averaged between 58.2% (1992) and 81.2% (2011).

4. Conclusions

Trends in adolescent substance use are rapidly evolving, and changing the historically predictable sequence of alcohol and cigarettes before marijuana use. The present study has three novel findings. First, the average grade at first use alcohol, cigarettes, and commence daily smoking is increasing during the adolescent period, especially in the last decade. In contrast, marijuana use onset is remaining relatively stable during adolescence. Second, marijuana is increasingly displacing alcohol and cigarettes as the first substance used among adolescents who use multiple substances. Compared to trends in the 20th century, only a minority (< 50%) of high school seniors tried cigarettes in a grade before trying marijuana since 2006, and the proportion of cigarette before marijuana users has been declining rapidly since then. Similar declines are evident for daily smoking before marijuana use. Trends in the sequence of alcohol and marijuana use are less apparent, with about half of adolescents

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trying alcohol in a grade before marijuana, and a large proportion trying alcohol and marijuana in the same grade. Third, the risk of marijuana use given first use of cigarettes is increasing during adolescence. That is, among all adolescents, the probability of using marijuana in the same grade or after initiation of smoking has increased. Currently, about three quarters of adolescents who try smoking will use marijuana in the same or a later grade, whereas less than half of adolescents overall will try marijuana at all.

The implications of the more prominent role of marijuana in the early stages of drug use sequences are important to continue tracking. There has been long-standing debate over whether the sequence of drug initiation is indicative of one drug causing use of another drug (Kandel and Kandel, 2015, 2014), or whether there is a common liability to drug use more generally (van Leeuwen et al., 2011; Vanyukov et al., 2012). If drug use arises principally from a common liability model, then the initiation of marijuana use would be expected to be associated with subsequent other drug use. Further, marijuana initiation could initiate a sequence to later drug use through social mechanisms, in that drug use portends a different social milieu and more opportunities for diverse substances. Marijuana initiation may also affect subsequent drug use through similar biological mechanisms that have been proposed for other substances; emerging evidence from animal models suggests that THC exposure early in adolescence influences reward sensitivity to other drugs including nicotine (Dinieri and Hurd, 2012; Panlilio et al., 2013; Pistis et al., 2004), and that adult marijuana use who initiated in adolescence have impairments in memory and prefrontal as well hippocampal volume (Batalla et al., 2013; Filbey and Yezhuvath, 2013). Existing epidemiological data suggest that marijuana use increases the risk of subsequent cigarette initiation, supporting the hypothesis that marijuana could be causally associated with subsequent polysubstance use (Nguyen et al., 2018).

During a historical time in which the traditional gateway sequence is changing, with marijuana increasingly accounting for the first substance used among adolescents, those who do engage in alcohol and cigarette use are increasingly a high-risk group for marijuana use. National data among adults with reconstructed life histories has demonstrated similar findings among today's cohorts of cigarette users, in that they are also more likely to have psychiatric disorders and other drug disorders compared with previous cohorts of smokers (Talati et al., 2016, 2013). Such findings are in line with hypotheses about 'hardening' of drug users, which has mixed existing empirical support (Chassin et al., 2007; Little et al., 2008), in that as a particular substance becomes more socially sanctioned, the increasingly small number of users have a higher total liability for other risk factors as well. Overall, from a public health perspective, successes in reducing adolescent smoking have been a remarkable achievement of the past 20 years, yet those who continue to smoke may represent an increasingly higher risk group for poly-substance use, and the changes in the historically-typical sequence may portend new trajectories of problem substance users.

There has been substantial interest in adolescent marijuana use in recent years, given changes in the legality of marijuana for adults. Indeed, available data indicate that marijuana use has been increasing among adults for the past decade (Grucza et al., 2016; Hasin et al., 2015; Kerr et al., 2007), yet no similar increases have been observed for adolescents (Martins et al., 2016; Miech et al., 2017b). Marijuana use has increased more among adults

in states that have legalized marijuana for medical use (Hasin et al., 2017; Martins et al., 2016; Pacula et al., 2015; Sevigny et al., 2014), but not among adolescents (Sarvet et al., 2018a). Available data indicate that adolescents increasingly view marijuana as posing little risk to health (Miech et al., 2017a; Sarvet et al., 2018b); given that perceived risk is historically strongly inversely correlated with the prevalence of marijuana use (Miech et al., 2017a; Sarvet et al., 2018b), we would expect increases in use among adolescence. The role of cigarette smoking is key to understanding these diverse patterns. Miech et al. (2017a) documented that marijuana use has increased among adolescents when trends are stratified by adolescent smoking; because smoking is a risk factor for subsequent marijuana use, the marked and rapid decline of smoking in adolescence has substantially decreased the denominator of the high-risk group of smokers, leading to the observation of no substantial change in marijuana use when smokers and non-smokers are combined. Indeed, this observation is linked fundamentally to the gateway hypothesis; if smoking is causally related to subsequent marijuana use, then the declines in smoking in the past two decades have directly influenced the lack of increase in marijuana use despite relaxed legal sanctions as well as decreased perceived risk.

These declines in alcohol and cigarette use should be considered within the broader context of declines in delinquent behavior and conduct problems overall in adolescence. Indeed, juvenile arrests as well as adolescent reports of crime and deviance have declined in the past decade (Keyes et al., 2018), in addition to a broader array of adolescent behaviors such as dating, working, and obtaining a driver's license (Twenge and Park, 2017). Yet the lack of decline in marijuana use, and its increasing prominence in the sequence of substance use during adolescence, suggests that marijuana is, and will continue to be, a key target of drug use prevention efforts. Hypotheses about the decline in adolescent alcohol and cigarette use have focused on the impressive efforts at regulatory changes that restrict access to adolescents, including minimum legal drinking ages (Jager et al., 2015), and tobacco sales and advertising restrictions directed at adolescents (Farrelly et al., 2003). Similar regulatory considerations focused on youth should be strongly in place as marijuana becomes more available for adults (Orenstein and Glantz, 2018).

Limitations of the present study are important to consider. A large portion of students report that their first use of substances is in the same grade. For those students, we do not have information on which substance was used first. Further, our data are right-censored at the 12^{th} grade; thus, the ages of onset reported, and the conditional risk of progression to marijuana use, would change were we able to observe adolescents into adulthood. Thus, these analyses should be considered as reporting on secondary school patterns only, rather than overall drug use patterns in the population at large. All responses are based on self-report, and students are retrospectively reporting on the grade of first use. However, we have no reason to believe that there are trends over time in the ability to report retrospectively on onset of use, thus while the estimates may be measured with some error, the trends should be stable. We did not have a measure of grade of onset of e-cigarette use or vaping, and consequently the results of this study may underestimate the continued role of nicotine in the drug use sequence. Use of e-cigarettes in the past 30 days increased among high school students from an estimated 1.5% in 2011 to, most recently 13% of high school seniors (Miech et al., 2017b). Even as the reductions in cigarette use underlie historical trends in the

common sequence of drug use among adolescents, the inclusion of new tobacco products in the market may once again portend changes to sequences of drug use. Further, Monitoring the Future is a school-based sample, and thus does not include high school dropouts who may be at higher risk for substance use than school-attending youth (Bachman et al., 2007). However, drop-out has generally declined in the US over the past several decades (Chapman et al., 2011), suggesting that the observed declines in substance use are not attributable to changes in sample composition. Further, the overall trends in substance use in Monitoring the Future mirror those in the National Household Survey on Drug Use and Health, which does include high school drop-outs.

In summary, the timing of substances in the "gateway" sequence is changing, as public perceptions about drugs of abuse change. Previous studies have documented that individuals who use marijuana before cigarettes are historically more likely to be Black and minority youth and have more life adversity (Green et al., 2016); as marijuana before cigarettes becomes the norm, these demographic associations may also shift. Marijuana use prior to first cigarette and daily smoking is becoming more normative, whereas the use of alcohol prior to or during the same grade as marijuana use is holding steady. Continuing to understand the social ecology of adolescents and the ways in which substances are perceived, used, and transitions to other substances are made will continue to be an important public health surveillance and intervention effort.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Author Disclosures

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Highlights

- Grade of first use of alcohol/cigarettes increasing, onset of marijuana use stable
- Majority of adolescent use marijuana in a grade prior to or same as cigarettes
- Marijuana displaces alcohol/cigarettes as 1st substance among users of >1 substance

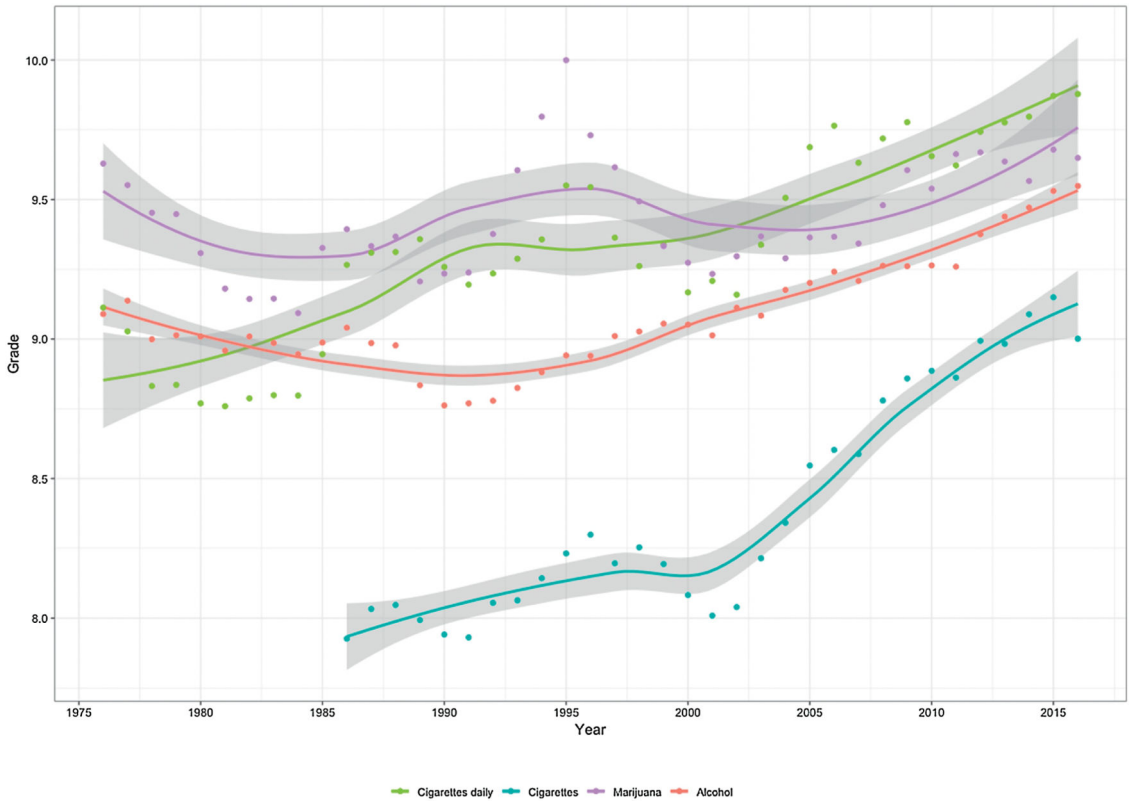

Figure 1.

Average grade of onset of cigarette, marijuana, and alcohol use among those who used by 12th grade in the United States, 1976–2016.

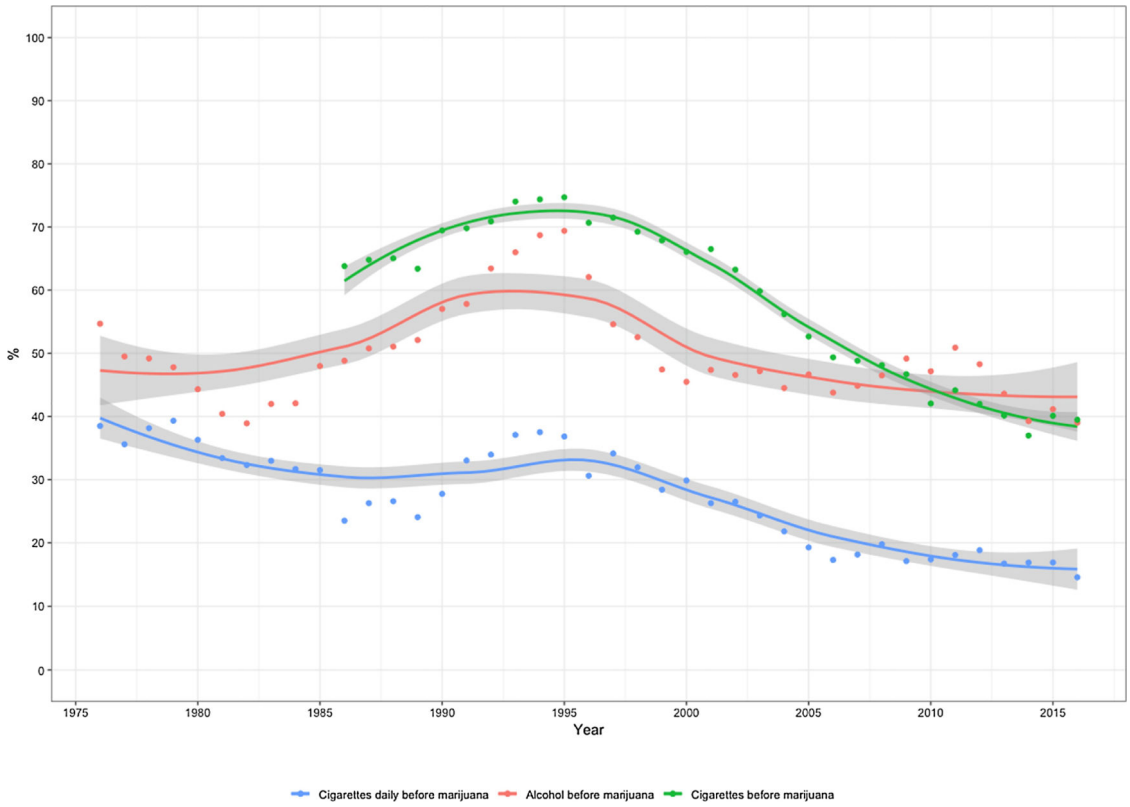

Figure 2.

Proportion trying cigarettes, using cigarettes daily, and trying alcohol in a grade before marijuana use, among users of both substances by 12th grade in the United States, 1976–2016.

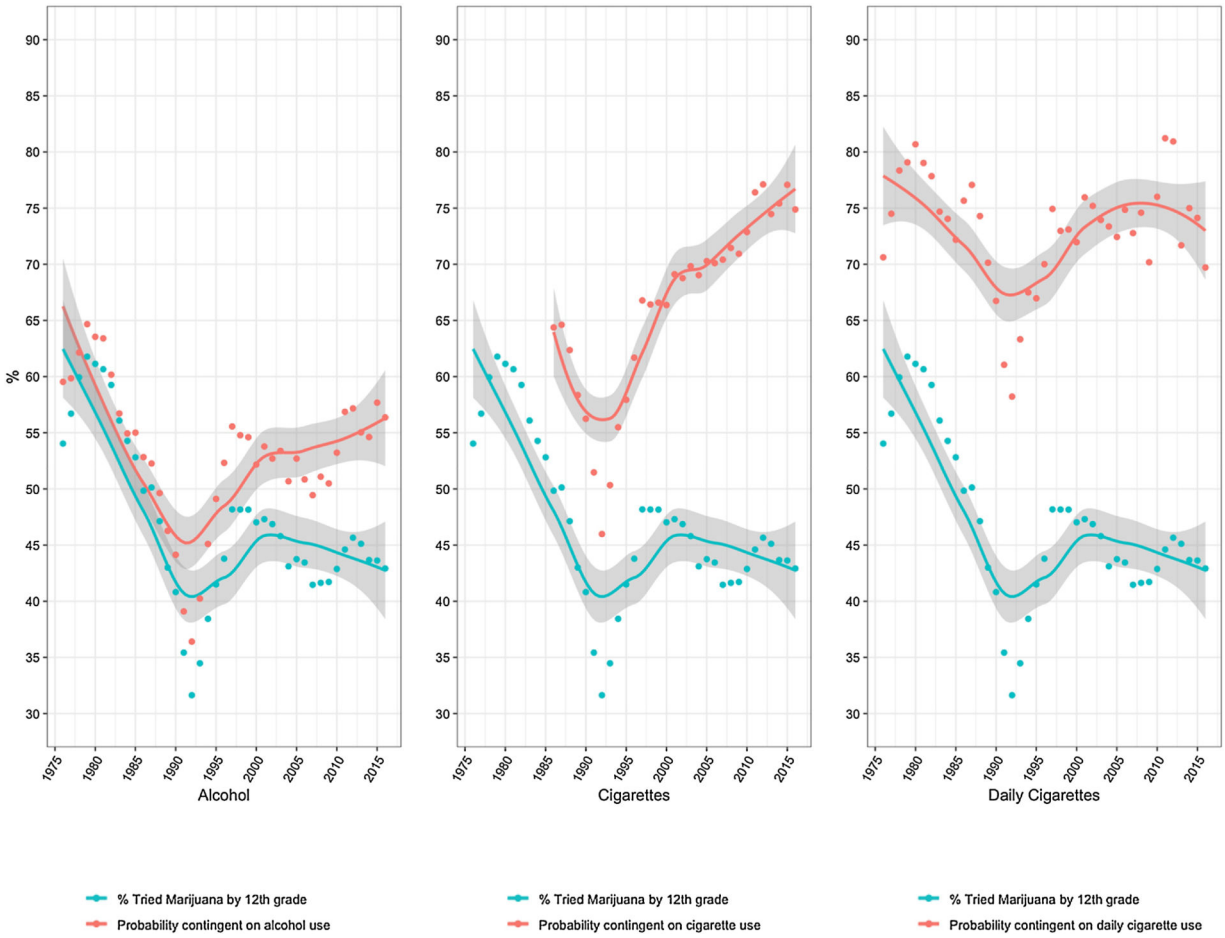

Figure 3.

Probability of using marijuana by 12th grade (blue line) and conditional probability of marijuana use in the same grade or later as first cigarette, onset of daily smoking, and first drink (red line) among adolescents in the United States, 1976–2016.