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8. Stability and Change in Perceived Risk Associations with Binge Drinking and Marijuana Use among Young Adults in the United States: A National Study, 1990-2016

Yvonne M. Terry-McElrath, Megan E. Patrick, and Patrick M. O'Malley

Highlights

- Among adolescents and early young adults, perceiving substance use to be risky is associated with lower likelihood of use. Do these associations continue across age (through young adulthood)? Have the associations changed across historical time?
- We examined (a) how perceived risk was linked with binge drinking and marijuana use among individuals as they aged from 18 through 30, and (b) if those links appeared to have changed during the years 1990-2016.
- For both binge drinking and marijuana use, risk and use remained strongly associated from ages 18 through 30, but most strongly at age 18, indicating that prevention messaging for both forms of substance use may be most successful during early young adulthood.
- During historical years characterized by notable marijuana policy change (emerging state-level legalization), the protective association between perceived risk and marijuana use weakened significantly as individuals moved from the mid-20s through age 30. No similar change was observed for binge drinking.
- Those involved with prevention efforts should be aware of the weakened risk/use association for marijuana that may accompany marijuana policy change.

Introduction

Alcohol and marijuana are currently the most frequently used substances among youth in the United States (US) and many other countries (Australian Institute of Health and Welfare, 2017; European Monitoring Centre for Drugs and Drug Addiction, 2017; Government of Canada, 2017; Miech et al., 2017b; Substance Abuse and Mental Health Services Administration [SAMHSA], 2017). In countries where tobacco use remains higher than marijuana use among youth, marijuana remains the most frequently used illicit substance (ESPAD Group, 2016). Use prevalence for both alcohol and marijuana is highest during the developmental period of young adulthood, with peak use occurring during the early- to mid-20s (Azofeifa et al., 2016; Jackson et al., 2008; Maggs & Schulenberg, 2004/2005; Patrick et al., 2016b; Schulenberg et al., 2005, 2017; SAMHSA, 2017; Terry-McElrath & O'Malley, 2011). As a result, young adults are at high risk for negative consequences resulting from the use of alcohol or marijuana.

Heavy or high-risk use of alcohol and/or marijuana has been associated with serious individual and societal harms. Binge drinking (defined generically as 5 or more drinks per occasion or, using gender-specific cut-offs, 5 or more drinks for men and 4 or more drinks for women) is associated with unintentional injuries (e.g., motor-vehicle crashes, alcohol poisoning), violence, sexually transmitted diseases, unintended pregnancy and poor pregnancy outcomes, chronic diseases, specific cancers, memory and learning problems, and alcohol dependence (Centers for Disease Control and Prevention, 2017; Iyasu et al., 2002; Naimi et al., 2003; World Health Organization, 2014). Heavy marijuana use has been associated with cognitive impairment, reduced academic achievement and functioning, psychoses, acute and long-term negative physical health outcomes, and increased risk of injury and death, including possible driving impairment and increased motor vehicle collisions, injuries, and fatalities (Asbridge et al., 2012; Calabria et al., 2010; Compton, 2017; Hall & Degenhardt, 2009; Kelly et al., 2004; Li et al., 2012; National Academies of Sciences, Engineering, and Medicine, 2017; Ramaekers et al., 2004; Sewell et al., 2009; Volkow et al., 2014, 2016).

Efforts to prevent or reduce alcohol and marijuana use and associated negative consequences often include a focused effort to communicate the risks associated with such use, because the degree to which individuals perceive they risk harming themselves (or others)

by using a particular substance is believed to influence decisions to use or abstain. The concept that beliefs/perceptions affect behavior is central to multiple models and theories of health behavior (e.g., the Health Belief Model [Janz & Becker, 1984; Rosenstock, 1974], the Theory of Reasoned Action [Fishbein & Ajzen, 1975], and the Theory of Planned Behavior [Ajzen, 1991; Montaño & Krasprzyk, 2008]). The perceived risks of substance use involve a range of domains, including physical, emotional, social/relational, aspirational, and legal risk (CRC Health, 2015; Danesco et al., 1999). Across a range of cross-sectional studies it has been shown that higher levels of perceived risk are significantly associated with lower alcohol and marijuana use during late adolescence or young adulthood (e.g., Bachman et al., 1991; Chomynova et al., 2009; Kilmer et al., 2007; SAMHSA, 2013a), but there is scant research on the extent to which such associations change in magnitude as individuals age.

Those attempting to address young-adult binge drinking and marijuana use would be able to target their efforts better if it was clear whether or not the protective associations between perceived risk and use continued to remain significant across this developmental period, and if so, if there was an indication of when during young adulthood perceived risk had the strongest association with the likelihood of binge drinking and marijuana use. Developmental differences in the strength of association between perceptions and young-adult marijuana use have been observed for other constructs such as friends' perceived use of marijuana. Patrick and colleagues (2016a) found that the strength of the association between friends' perceived use and participants' own use of marijuana strengthened across young adulthood. There is likely a normative trajectory of association strength between perceived risk and substance use across young adulthood, but this has not been documented in the literature. A comparison of cross-sectional historical trends in perceived risk and marijuana use using data from the National Study on Drug Use and Health (NSDUH) showed the percentage of individuals perceiving great harm from monthly or weekly marijuana use decreased significantly from 2002 through 2013 among individuals aged 18 through 25, and 26 and older; however, significant increases in past-month marijuana use were observed only among those aged 26 and older (Lipari et al., 2015). These findings indicate that the marijuana perceived risk/use association may be strongest during later young adulthood (ages 26 and older).

Several researchers have identified possible weakening of cross-sectional correlations between age-specific trends in (a) risk perception and (b) young-adult binge drinking and marijuana use that may indicate either historical or cohort differences, which might result in meaningful differences in the developmental pattern of risk/use associations across young adulthood. In the past, cross-sectional population-level trends for perceived risk of alcohol and marijuana use have been closely and inversely tied to population-level trends for use prevalence of the respective substance (Azofeifa et al., 2016; Meich et al., 2017b; Schulenberg et al., 2017). In other words, when perceived risk is relatively high, substance use is relatively low and, conversely, during periods when perceived risk is lower, substance use is higher. There are indications that this close link between perceived risk and use may be weakening for both binge drinking and marijuana use. For example, NSDUH data show that the percentage of individuals aged 12 and older who perceived great risk from weekly or daily binge drinking decreased from 2002 to 2013, while the percentage of binge alcohol users remained stable (Lipari et al., 2015). A disconnect between risk and use trends for both binge drinking and marijuana use among young adults also has been observed in Monitoring the Future data (e.g., Schulenberg et al., 2017). The observed disconnects may indicate a weakening of the statistical associations between risk and use. These changes may stem from period effects (in which case, the effect should be seen during the same years for individuals of all ages) or from cohort effects (in which case the effect should be specific only to individuals from certain cohorts as they move across age). Based on the study by Lipari et al. (2015), cited above, it appears that the observed disconnects between risk and use trends are likely a function of cohort differences, because the observed changes were not observed among individuals of all ages during the specified years.

A decoupling of perceived risk and use might result in decisions to revise the focus of efforts to prevent the use of alcohol and marijuana. If the strength of risk/use associations has weakened among young adults (either across the entire developmental period, or for a specific age-range), allocation of limited prevention resources to addressing deficiencies in knowledge regarding the risks of binge drinking and/or marijuana use would have lower priority (Terry-McElrath et al., 2017). Observed disconnects between trends in marijuana perceived risk and use among US adolescents (Miech et al., 2017b; SAMHSA,

2013a) led to recent research to examine whether perceived risk was no longer a strong protective factor against marijuana use among 12th-grade students in the US. Results indicated that association strength has continued to be robust across time (Terry-McElrath et al., 2017), and that the observed trend disconnects can be explained by historical decreases in cigarette use, which have led to lower numbers of adolescents taking up marijuana use following initiation of cigarette use (Miech et al., 2017a). Among adolescents, the fact that perceived risk remains a strong protective factor against marijuana use supports continued and possibly increased allocation of prevention resources to address deficiencies in knowledge regarding risks of marijuana use, given the overall decreasing prevalence of perceived risk (Terry-McElrath et al., 2017). However, the same may or may not be true for risk/use associations for binge drinking or marijuana use from ages 18 through 30.

The current study contributes to the substance-use epidemiology literature through two research aims: (1) to describe the developmental patterns of association between perceived risk and both binge drinking and marijuana use across young adulthood, and (2) to test the extent to which the observed developmental patterns have changed across recent young-adult cohorts.

Methods

Design

Analyses used data from the Monitoring the Future (MTF) study; detailed methodology is available elsewhere (Bachman et al., 2015; Miech et al., 2017b; Schulenberg et al, 2017). Briefly, nationally-representative samples of approximately 15,000 12th-graders (modal age 18) from about 130 schools in the contiguous 48 states of the US have been surveyed annually since 1975. Students complete self-administered surveys, typically during a normal class period. A sub-sample of about 2,400 12th-graders is selected from each annual sample for longitudinal follow-up (with oversampling of drug users). A randomly selected half of the follow-up sample begins biennial follow-up one year after their senior year (modal age 19), while the other half begins biennial follow-up two years after their senior year (modal age 20). Mailed questionnaires are used to collect data at six follow-up time points: modal ages 19/20, 21/22, 23/24, 25/26, 27/28, and 29/30. The

resulting data include responses at all modal ages from 18 through 30 (although individual respondents provide data at a maximum of 7 modal ages). A University of Michigan Institutional Review Board approved the study.

Participants

To enable examination of change across cohorts but focus on the most recent data, analysis was limited to the most recent 15 cohorts that had the opportunity to complete all baseline and follow-up surveys through age 29/30. Thus the analytic sample was limited to 12th-grade cohorts from 1990–2004 (age 29/30 data were collected from 2001 through 2016). Perceived risk of both binge drinking and past 30-day marijuana use were asked for all relevant years on three of the six randomly distributed MTF questionnaire forms. A total of 18,390 individuals who were selected for follow-up participation filled out the three relevant forms during the 12th-grade survey. Cases were limited to the 13,910 respondents (75.6%) who participated in at least one of the six follow-up data collection efforts. Of these respondents, 13,866 provided data on both binge drinking risk and use on at least one occasion; 13,876 provided data on both marijuana risk and use on at least one occasion. The mean number of surveys per respondent in the resulting analytic dataset was 4.97 (range of 1–7). Attrition adjustments are discussed below.

Measures

Binge drinking in the past 2 weeks was measured by asking, "Think back over the last two weeks. How many times have you had five or more drinks in a row?" Responses were dichotomized as any binge drinking (1) versus none (0). Marijuana use in the past 30 days was measured by asking, "On how many occasions (if any) have you used marijuana or hashish during the last 30 days?" Responses were dichotomized as any marijuana use (1) versus none (0). Perceived risk was asked as, "How much do you think people risk harming themselves (physically or in other ways) if they…Smoke marijuana regularly? …Have five or more drinks once or twice each weekend?" Responses (originally including no risk, slight risk, moderate risk, or great risk) were dichotomized as perceiving moderate or great risk (1) versus no or slight risk (0) in order to distinguish between levels of risk perception likely to lead to behavior change versus those that were not. Cohort (indicating year of 12th-grade baseline survey)

was coded into three five-year groups of 1990–1994, 1995–1999, and 2000–2004. Modal age per survey in years (hereafter referred to simply as age) was coded continuously from 18 (at 12th-grade baseline) to 30.

Statistical Analysis

Analyses were conducted using the analysis software SAS (v. 9.4). Modeled age-varying prevalence and regression estimates were obtained using time-varying effect modeling (TVEM). TVEM is a regression-based method of modeling relationships between one or more covariates and an outcome over continuous time; no assumptions regarding the association's parametric form are made (Lanza et al., 2014; Tan et al., 2012). In TVEM it is assumed only that the regression estimates change over time in a smooth manner (Li et al., 2015). For the purposes of the current analyses, time was operationalized as modal age in years. The SAS macro %WeightedTVEM (v. 2.6.0) (Dziak et al., 2014; Weighted TVEM SAS Macro, 2017) was used to fit TVEM models as shown (here predicting the log odds of any past 30-day marijuana use for individuals perceiving moderate/great risk in regular marijuana use (vs. no/slight risk) as a continuous, flexible, smoothed function of age from 18 to 30):

$$In\left(\frac{P(MJUSE_i = 1)}{1 - P(MJUSE_i = 1)}\right) = \beta_o(t) + \beta_1(t)PerceivedGreat/ModerateRisk_i$$

where β_0 is the intercept, *t* indicates continuous age, and β_1 is the slope function describing the age-varying association between perceived risk (referent=no/slight risk) and the outcome. Figures present coefficient functions in the form of odds ratios (ORs) or adjusted odds ratios (AORs) and point-wise 99% confidence intervals (CIs) for each point along a smoothed curve by continuous age (analyses used the default TVEM setting of 100 points). For points when CIs do not contain 1.0, coefficients are significant at $p < 0.01$ ($p < 0.01$ was selected as appropriate given the large sample size). Comparisons of pseudo-likelihood AIC and BIC values from unpenalized B-splines were used to select the optimal number of knots (corresponding to smoothness) for each coefficient function.

For descriptive purposes (overall developmental change from ages 18 through 30 in use and perceived risk), intercept-only TVEM mod-

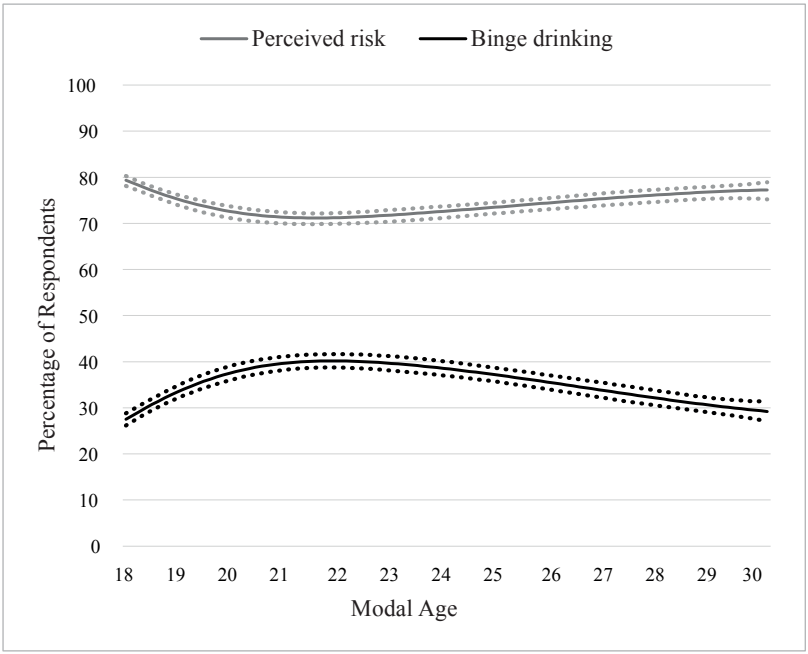
els were fit to model prevalence across age. (For comparison purposes, observed prevalence estimates were obtained using SURVEYFREQ.) To describe the developmental patterns of association between perceived risk and both binge drinking and marijuana use (research aim [RA] 1), TVEM models regressed use on the relevant perceived risk measure (all cohort groups combined). To test the extent to which the observed developmental patterns changed by cohort (RA 2), TVEM models regressed use on the relevant perceived risk measure, dichotomous cohort group terms, and perceived risk/cohort group interaction terms (models were first run using 1990–1994 as the referent cohort group, and then repeated using 2000–2004 as the referent group). If significant cohort interactions were observed, then cohort-group specific TVEM models were used to regress use on perceived risk across age. All analyses accounted for clustering of repeated measures within individuals. In addition, all analyses were weighted using follow-up specific attrition weights, calculated as the inverse of the probability of responding at each age based on covariates measured at age 18 (sex, race/ethnicity, college plans, high-school grades, number of parents in the home, religiosity, parental education, alcohol use, cigarette use, marijuana use, region of country, cohort, and sampling weight correcting for over-sampling of age 18 substance-users).

Results

Descriptive Developmental Change in Use and Perceived Risk

Figure 8.1 presents the modeled estimates of past 2-week binge drinking and perceived risk prevalence averaged across all 1990–2004 cohorts from ages 18 through 30 (observed estimates are reported in Appendix Figure 8.1). Modeled binge drinking prevalence rose from a minimum of 27.5% at age 18 to a maximum of 40.2% at age 22, and then decreased across the remainder of young adulthood, reaching 29.2% by age 30. Modeled perceived risk of binge drinking decreased from a maximum of 79.4% at age 18 to a minimum of 71.2% at ages 21 and 22, but then increased thereafter, reaching 77.3% at age 30.

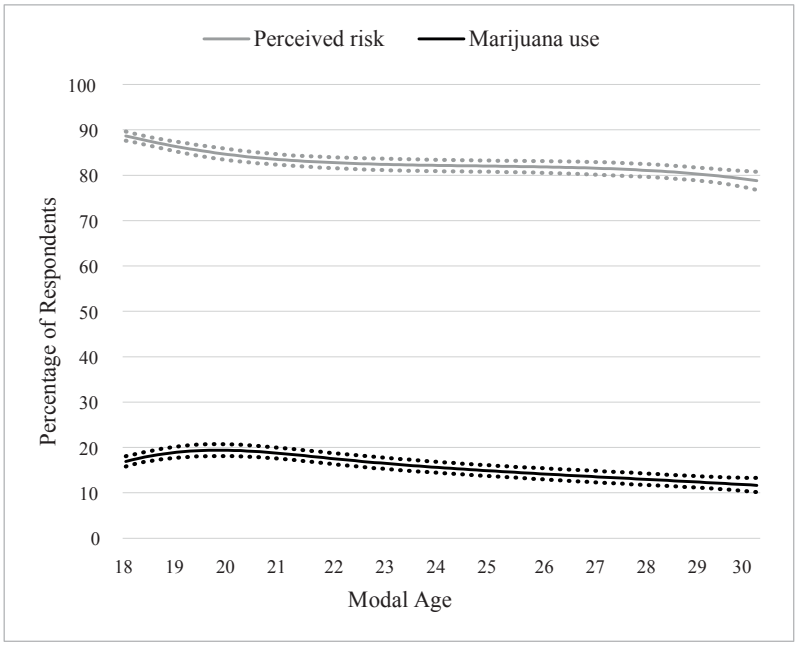
Figure 8.1 Modeled prevalence of moderate/great perceived risk of weekend binge drinking and any past 2-week binge drinking among US young adults ages 18 through 30



Notes: N(unwtd.) = 68,932 time points from 13,866 individuals. Estimates obtained from time-varying effect models. Dotted lines indicate 99% confidence intervals. Binge drinking defined as having 5 or more drinks per occasion.

Figure 8.2 presents the modeled estimates of past 30-day marijuana use and perceived risk prevalence averaged across all cohorts from ages 18 through 30 (observed estimates are reported in Appendix Figure 8.2). The modeled prevalence of any marijuana use in the past 30 days rose from 16.9% at age 18 to a maximum of 19.4% at age 20, and then decreased across the remainder of young adulthood, reaching a minimum of 11.7% by age 30. The modeled prevalence of perceived risk of marijuana use decreased from a high of 88.6% at age 18 to 83.0% at age 22, and then continued to decrease (but at a slower rate) through age 30, reaching 78.8%.

Figure 8.2 Modeled prevalence of moderate/great perceived risk of regular marijuana use and any past 30-day marijuana use among US young adults ages 18 through 30

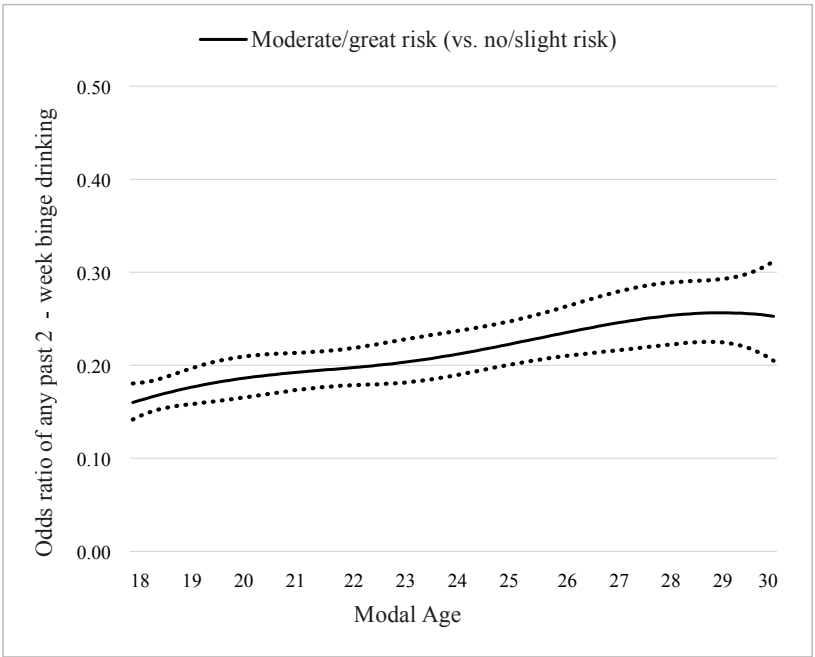


Notes: N(unwtd.) = 69,039 time points from 13,876 individuals. Estimates obtained from time-varying effect models. Dotted lines indicate 99% confidence intervals.

Overall Developmental Patterns of Association between Risk and Use (RA 1)

Figure 8.3 presents the results of the model regressing past 2-week binge drinking on perceived risk of weekend binge drinking (cohorts combined). The association was significant at all ages of young adulthood, with individuals who perceived moderate/great risk in weekend binge drinking reporting significantly lower odds of any binge drinking in the past two weeks from ages 18 through 30. The association was strongest at age 18 (OR 0.16, 99% CI 0.14, 0.18). The association weakened (i.e., odds ratios moved closer to 1.0) through age 29 (reaching OR 0.26, 99% CI 0.22, 0.30), and remained generally stable from ages 29 through 30.

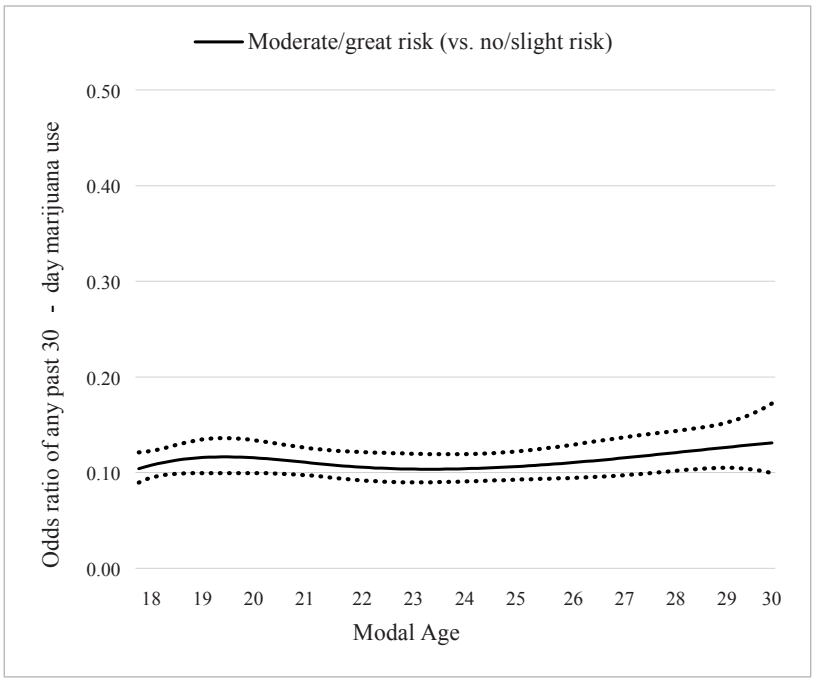
Figure 8.3 Time-varying bivariate associations between perceived risk of weekend binge drinking and any past 2-week binge drinking among US young adults from ages 18 through 30



Notes: N(unwtd.) = 68,932 time points from 13,866 individuals. Estimates obtained from logistic time-varying effect models. Dotted lines indicate 99% confidence intervals.

Results of the model regressing past 30-day marijuana use on perceived risk of regular marijuana use (cohorts combined) are shown in Figure 8.4. Again, the association was significant and protective at all ages of young adulthood (18 through 30): among individuals who perceived moderate/great risk in regular marijuana use, the odds of any past 30-day marijuana use were much lower than among individuals who perceived no/slight risk. The association was strongest at ages 18 and 23 through 24 (OR 0.10, 99% CI 0.09, 0.12). Between ages 18 and 23 through 24, the association weakened very slightly to OR 0.12 (99% CI 0.10, 0.14) at age 20. Following age 24, the association again weakened slightly to 0.13 (99% CI 0.10, 0.17) by age 30.

Figure 8.4 Time-varying bivariate associations between perceived risk of regular marijuana use and any past 30-day marijuana use among US young adults from ages 18 through 30



Notes: N(unwtd.) = 69,039 time points from 13,876 individuals. Estimates obtained from logistic time-varying effect models. Dotted lines indicate 99% confidence intervals.

Cohort Change in Associations between Use and Risk (RA 2)

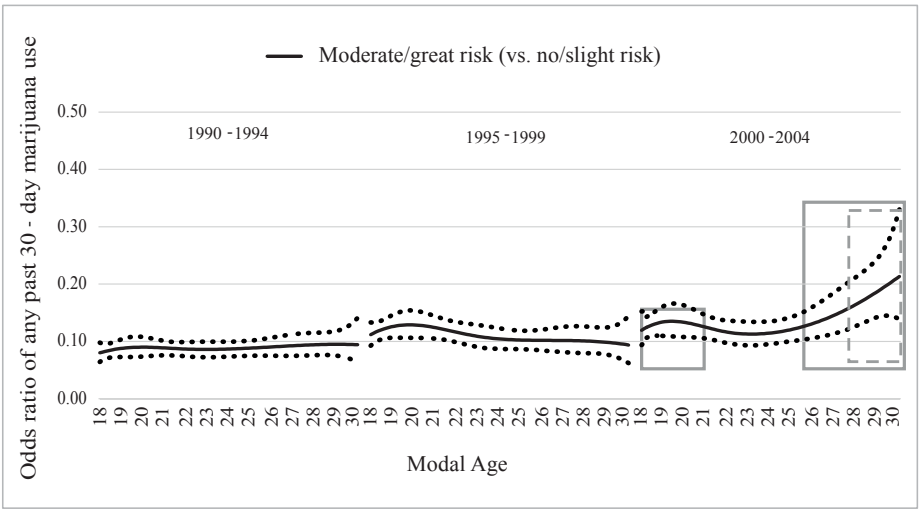
In the model regressing binge drinking prevalence on perceived risk, cohort groups, and perceived risk*cohort group interactions, at no point were 99% CIs for the interaction terms either fully above or below 1.00 (see Appendix Figures 8.3 and 8.4), indicating no significant interactions between perceived risk and cohort group on the odds of past 2-week binge drinking at any age. Thus, the age-varying associations between binge drinking and perceived risk of binge drinking did not vary significantly across cohort groups.

In the model regressing marijuana use prevalence on perceived risk, cohort groups, and perceived risk*cohort group interaction

terms, the interactions were significant at specific ages (see Appendix Figures 8.5 and 8.6). In the model using the 1990-1994 cohort group as the referent, the perceived risk*1995–1999 interaction term was significant and above 1.00 very briefly around age 18 (i.e., 18.2–18.5 years), but this is not interpreted due to the very short-lived effect. The perceived risk*2000–2004 interaction term was significant and above 1.00 at ages 18 through 21 and 26 through 30. Given that the adjusted odds ratios for the direct effect of perceived risk on marijuana use obtained from the model were negative at all age points (ranging from 0.08 [99% CI 0.06, 0.11] to 0.09 [99% CI 0.06, 0.15]), the interaction term results indicated that the risk/use association was significantly weaker at ages 18 through 21 and 26 through 30 for individuals in the 2000–2004 cohorts compared with those in the 1990–1994 cohorts. In the model using 2000–2004 as the referent group, the perceived risk*1995–1999 interaction term was significant and below 1.00 at ages 28 through 30, indicating that, at these ages, the risk/use association was significantly stronger for individuals in the 1995–1999 cohorts than for individuals in the 2000–2004 cohorts.

The association between marijuana use and perceived risk was modeled separately for the 1990-1994, 1995-1999, and 2000-2004 cohort groups (see Figure 8.5). Results showed that, for all cohort groups, the association was significant at all ages of young adulthood, with individuals who perceived moderate/great risk in regular marijuana use (vs. no/slight risk) reporting significantly lower odds of any marijuana use in the past 30 days from ages 18 through 30. For individuals in the 1990-1994 cohorts, the risk/use association remained consistent across young adulthood (OR range 0.08 [99% CI 0.06, 0.11] to 0.09 [99% CI 0.06, 0.15]). For individuals in the 1995–1999 cohorts, the risk/use association also remained generally consistent across young adulthood. For individuals in the 2000–2004 cohorts, the association was not consistent across young adulthood; instead, the association weakened from ages 18 through 19, remained somewhat stable during ages 19 through 20, strengthened through age 23, and then weakened steadily from ages 24 through 30. For the 2000–2004 cohort group, the strength of the risk/use association reached a maximum OR of 0.11 (99% CI 0.09, 0.14) at age 23; the weakest association was observed at age 30 (OR 0.21; 99% CI 0.13, 0.34).

Figure 8.5 Time-varying bivariate associations between perceived risk of regular marijuana use and any past 30-day marijuana use among US young adults from ages 18 through 30 by cohort groups



Notes: N(unwtd.) = 69,039 time points from 13,876 individuals. Estimates obtained from logistic time-varying effect models. Dotted lines indicate 99% confidence intervals. Solid grey rectangles identify statistically significant ($p < 0.01$) differences in associations using 1990-1994 as the referent group (ages 18 through 21 and 26 through 30 for 2000–2004 vs. 1990–1994 cohorts). Dotted grey rectangle indicates statistically significant ($p < 0.01$) differences in associations between 1995–1999 and 2000–2004 cohorts (ages 28 through 30).

Discussion

Using longitudinal data from a national survey of young adults in the US, the authors of this study found that perceived risk of harm remained significantly and negatively associated with both binge drinking and marijuana use at all ages of young adulthood (18 through 30), with moderate/great perceived risk (compared with no/slight perceived risk) associated with markedly lower odds of binge drinking or marijuana use. The association between binge drinking perceived risk and use was strongest at age 18, and then weakened from ages 19 through 30 for all cohort groups. In contrast, the age-varying association between marijuana perceived risk and use differed significantly

across cohort groups. For individuals in the earliest and middle cohort groups, the association between risk and marijuana use generally was consistent across ages 18 through 30, but for individuals in the most recent (2000–2004) cohort group, the association weakened during mid- to later-young adulthood. These results suggest that perceived risk remains protective against both binge drinking and marijuana use throughout young adulthood; however, the association between risk and marijuana use appears to have changed for the more recent cohort group.

Findings from the present study clearly indicate that perceived risk remained significantly associated with lower odds of both binge drinking and marijuana use across young adulthood. Research on perceived risk and both binge drinking and marijuana use among young adults clearly shows that non-users, compared to users, perceive higher levels of risk (e.g., Kilmer et al., 2007; Pearson et al., 2017; Sartor et al., 2017). While some studies among young adult and general adult users of alcohol and/or marijuana indicate that perceptions of risk are not associated with either the frequency of use or the actual experience of drug-related consequences (e.g., Kilmer et al., 2007), other research provides evidence of significant and protective risk/use associations. Among a national sample of Australian drinkers, low-risk drinkers (risk level defined based on the Alcohol Use Disorders Identification Test) were more likely than high-risk drinkers to be aware of a range of short- and long-term consequences of alcohol use (Coomber et al., 2017). One question that arises from results such as those from the current study and the literature cited above is, are differences in young adult risk perceptions causing differences in use, or are they the result of different use experiences (this question has been raised in prior studies, such as by Grevenstein et al., 2015)? The idea that as individuals obtain knowledge about the risks of a particular behavior, they may be motivated to change behavior or engage in protective measures to avoid behavior is referred to as the motivational hypothesis (Brewer et al., 2004; Grevenstein et al, 2015). In contrast, the idea that individuals may change their perceptions of risk associated with a particular behavior as a result of their own personal experience with that behavior is referred to as the risk reappraisal hypothesis (Brewer et al., 2004; Grevenstein et al, 2015).

In regard to alcohol and marijuana use, there is support in the literature for both the motivational and the risk reappraisal hypotheses. Examples of support for the motivational hypothesis can be found in work by Grevenstein et al. (2015), Salloum et al. (2018), Shadur et al. (2015), and Stephens et al. (2009). Higher risk-perceptions at baseline were associated with a slower increase in alcohol use over a 4-year period among young adolescents (Shadur et al., 2015). Higher perceptions of risk at ages 14-15 were significantly and negatively associated with both alcohol and marijuana use frequency two years later among a small sample of German adolescents (Grevenstein et al., 2015); however, these associations were not consistently observed across the 10-year study that reached into young adulthood. A larger high-school-based study found that perceptions of harm for both alcohol and marijuana held during 9th grade had no direct effect on use of either substance by the 11th grade, but a significant indirect effect was observed whereby 9th grade risk-perceptions were positively associated with 10th grade intentions not to use the substances, which in turn were significantly and negatively associated with use at 11th grade (Stephens et al., 2009). In addition, among a national sample of US young adults, auto-regressive cross-lagged panel analyses indicated significant associations between higher risk perceptions and lower subsequent cannabis use (Salloum et al, 2018).

Examples of support for the risk reappraisal hypothesis can be found in work by Grevenstein et al. (2015) and Salloum et al. (2018). Grevenstein and colleagues (2015) found increasing frequency of marijuana use was significantly and negatively associated with perceived risk of marijuana use two years later among a small sample of German adolescents in early young adulthood. Salloum et al. (2018) found that past-year cannabis use was significantly associated with lower subsequent risk perception. It may well be that findings in this study that there are significant perceived risk/use associations for both binge drinking and marijuana at all ages of young adulthood reflect both motivational and risk reappraisal functions.

Given the support in the literature for the motivational hypothesis, the results of the current study indicate consideration should be given to continued efforts to provide accurate and credible information to young adults on the risks associated with binge drinking and marijuana use. Yet, prevention and use-reduction programs targeting these behaviors by (at least in part) providing risk information have not

proven to be reliably successful (e.g., Foxcroft & Tsertsvadze, 2011; Knight & Norman, 2016; Sloboda et al., 2009). The best way to convey risk is still debated and not fully understood, and the best population subgroups to target with risk-related information are not known. In one particularly well-known study involving a large randomized field trial of an adolescent universal substance-abuse prevention program (which included providing information on consequences of substance use) beginning in 7th grade it was shown that when students reached the 11th grade, the intervention was associated with increased alcohol and cigarette use and showed no effect on marijuana use (Sloboda et al., 2009). However, among students who were already marijuana users at baseline, decreased marijuana use at 11th grade was observed, mediated by change in marijuana-related normative beliefs and refusal skills (Teasdale et al., 2009). The study authors concluded that their findings underscored the importance of not relying solely on a universal prevention intervention approach, but instead possibly focusing on key subgroups defined by specific substance-using behaviors (Sloboda et al., 2009). The results from the current study indicate that one type of key subgroup may be defined by age during young adulthood. The risk/use association for binge drinking was strongest during very early young adulthood, while the risk/use association for marijuana use was strongest during both the very early and middle years of the developmental period. Young adult alcohol and marijuana prevention and intervention efforts involving provision of risk-related information may be particularly successful at these ages.

The changes observed in the current study of developmental patterns of risk/use associations supported cohort, not period, effects. To illustrate, the years during which individuals were aged 19 and 20 among the more recent cohort group were 2001 through 2006; during these calendar years, the second cohort group was aged 24 and 25, and the first cohort group was aged 29 and 30. If the observed changes in the developmental risk/use associations were period effects, the same type of risk/use associations could be expected to be seen at the specified ages in different cohort groups. Yet this was not the case. The weakening in the marijuana risk/use association at ages 19 and 20 for the most recent cohort group was not observed at ages 24 and 25 for the second cohort group or ages 29 and 30 for the first cohort group. Furthermore, during 2001 through 2006, individuals in the more recent cohort group were exhibiting stronger binge drinking risk/use

associations at ages 19 and 20 than were observed at ages 24 and 25 in the second cohort group, or at ages 29 and 30 for the first cohort group.

Results from the current study indicated that the developmental pattern for young adult marijuana risk/use associations changed significantly across cohort groups. In sharp contrast to the essentially stable marijuana risk/use associations observed among the earlier cohorts, among the more recent cohorts, the association was strongest at age 18, but then weakened during later young adulthood. What might be causing the risk/use association to weaken during late young adulthood among more recent cohorts? One possible factor may be related to the dramatically changing policy landscape for marijuana. The cohorts included in the current study (12th grade classes of 1990 through 2004) witnessed dramatic change in local and state marijuana policy and also in enforcement of federal marijuana policy. As summarized by McBride et al. (2017), in the 1980s marijuana policy was for strong prohibition; the 1990s saw the first state-court-confirmed medical necessity defense for personal marijuana use and state-level ballot initiatives for medical marijuana; in the 2000s there were dramatic state-to-state differences in marijuana scheduling and penalties combined with state legislature-introduced medical marijuana policies; in the 2010s state-level legalization of adult recreational marijuana use began to emerge. No attempt has been made in the current study to model the changes in the marijuana risk/use association based on changes in marijuana policy, but the fact that the 2000–2004 cohorts (which reached ages 29 and 30 during 2011 through 2016) were the first to show a weakening of the risk/use association during late young adulthood is notable given that this coincided with initial state legalization of recreational marijuana use.

Why might a changing policy landscape affect the risk/use association? The policy landscape for marijuana is becoming similar to that for other substances that are regulated for legal adult use in the US, such as alcohol. It is of interest that the developmental pattern of the risk/use association for marijuana among the more recent cohorts now somewhat resembles that for binge drinking: strongest at age 18, with weakening occurring during later young adulthood. The perceived risk measure used in the current analysis did not specify types of risk of harm (the wording was "physically or in other ways"); thus, the risks being evaluated may include physical, emotional, social/rela-

tional, aspirational, and legal domains (CRC Health, 2015; Danesco et al., 1999). The legal risks of marijuana use (risks of arrest, prosecution, and severity of penalty assessed) for those over age 21 are arguably much lower for individuals in the more recent cohort group than for those in earlier cohort groups. In addition, as marijuana use has become more socially accepted, the social/relational risks of use may also have decreased, particularly for older young adults. Thus, the nature of the risks associated with marijuana use have changed. These changes may have resulted in the overall association between "risk" and use for marijuana weakening during later young adulthood. Future analyses that can incorporate a multi-dimensional measure of perceived risk may able to test these hypotheses and the degree to which different forms of risk may remain strongly associated with use throughout young adulthood and beyond.

The results of the current study indicate that at least for the developmental period of young adulthood, early young adulthood appears to offer the ages/period of development of strongest risk/use associations for both binge drinking and marijuana use. Prevention efforts focused on risk perceptions that target this age might show the strongest effects. The current study was limited to young adulthood and did not examine associations among adolescents or middle-aged or older adults. Risk perceptions may be more protective during adolescence than at age 18, and may continue to weaken into later adulthood, possibly reaching a point where the risk/use association is no longer significant. Future research that is able to use a broader age-range is needed to clarify these developmental patterns.

Limitations

The results of the current study should be considered within their limitations. Results may not generalize to individuals who drop out of high school prior to 12th grade; lower educational attainment is associated with higher marijuana and other substance use (SAMHSA, 2013b). Furthermore, all data were based on self-reports, which have been found to be reasonably reliable and valid under conditions which the MTF study strives to provide (Brenner et al., 2003; Miech et al., 2017b; O'Malley et al., 1983). Finally, the analyses presented were focused purposively on the developmental pattern of bivariate associations; a range of important covariates are associated with perceived risk and substance use and it would be useful to evaluate them in

future research (Bachman et al., 2002; Miech et al., 2017a; Terry-McElrath et al., 2017; Zimmerman & Farrell, 2017). These limitations notwithstanding, the current study contributes significantly to available knowledge on associations between perceived risk and both binge drinking and marijuana use among young adults in the United States.

Conclusions

Perceived risk remains a strong protective factor throughout young adulthood for both binge drinking and marijuana use, although the association for marijuana changes across cohorts. Among individuals in the most recent cohorts, risk/use associations are strongest during early young adulthood for both binge drinking and marijuana use.

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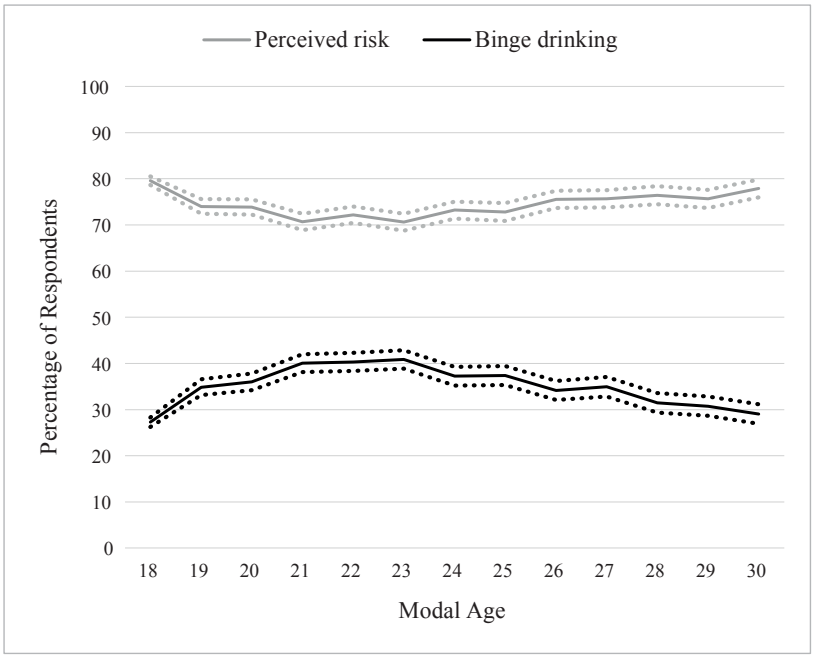
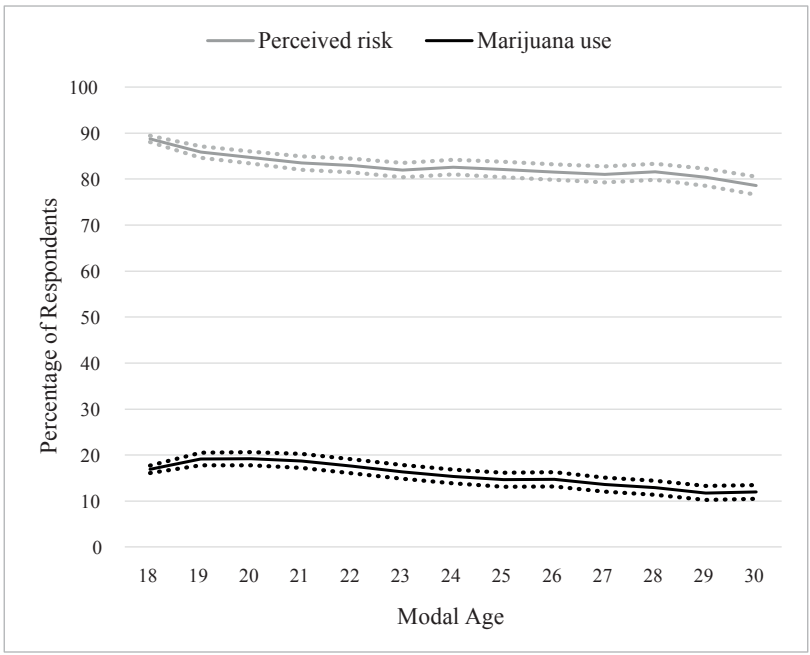
Appendix

Appendix Figure 8.1. Observed prevalence of moderate/ great perceived risk of weekend binge drinking and any past 2-week binge drinking among US young adults ages 18 through 30



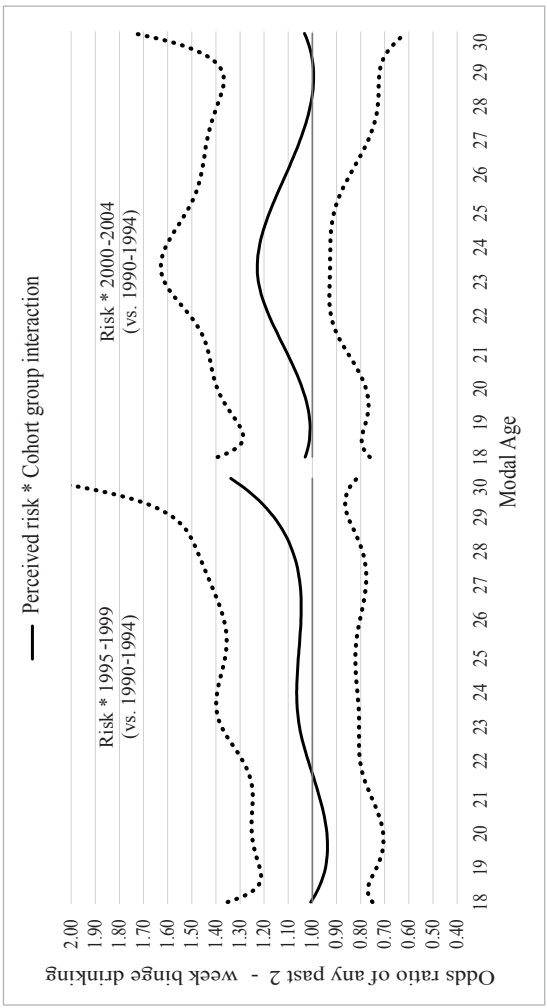
Notes: N(unwtd.) = 68,932 time points from 13,866 individuals. Dotted lines indicate 99% confidence intervals. Binge drinking defined as having 5 or more drinks per occasion.

Appendix Figure 8.2. Observed prevalence of moderate/great perceived risk of regular marijuana use and any past 30-day marijuana use among US young adults ages 18 through 30



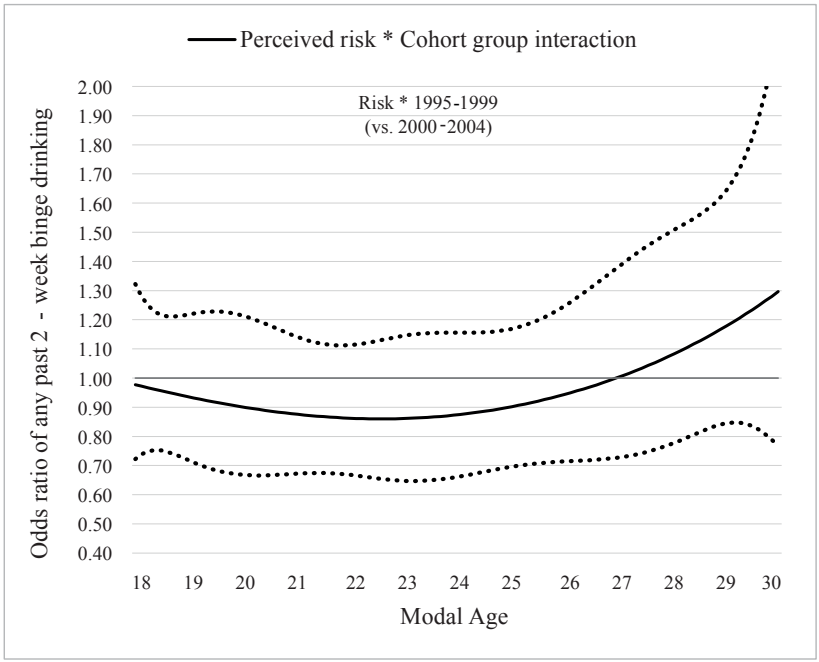
Notes: N(unwtd.) = 69,039 time points from 13,876 individuals. Dotted lines indicate 99% confidence intervals.

Appendix Figure 8.3. Associations between perceived risk*cohort group interaction terms and any past 2-week binge drinking among US young adults ages 18 through 30: Referent group = 1990–1994



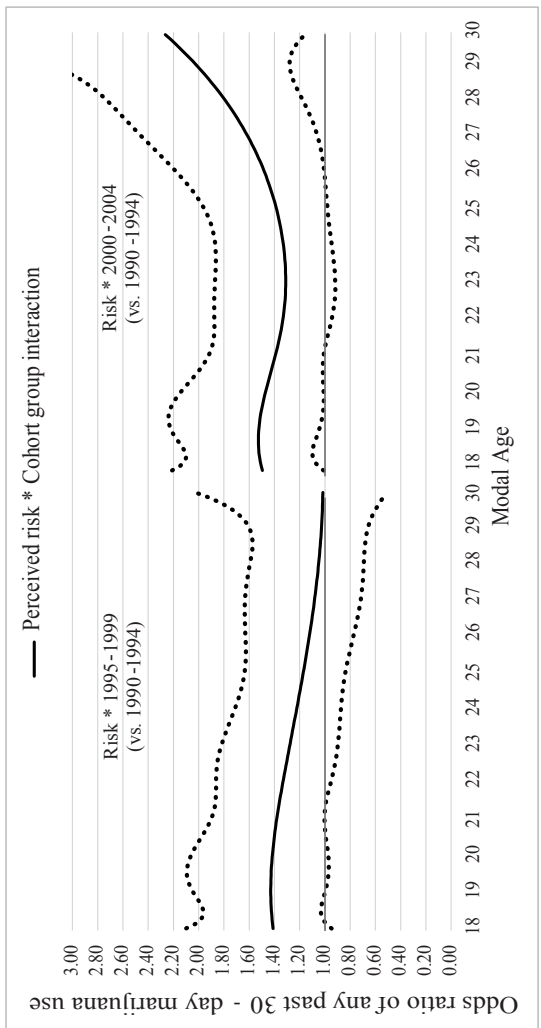
Notes: N(unwtd.) = 68,932 time points from 13,866 individuals. Estimates obtained from logistic time-varying effect models. Dotted lines indicate 99% confidence intervals. Binge drinking defined as having 5 or more drinks per occasion. Regression model simultaneously controlled for perceived risk, cohorts 1995–1999, cohorts 2000–2004, risk*1995–1999 cohorts, risk*2000–2004 cohorts.

Appendix Figure 8.4. Associations between perceived risk*cohort group interaction terms and any past 2-week binge drinking among US young adults ages 18 through 30: Referent group = 2000–2004



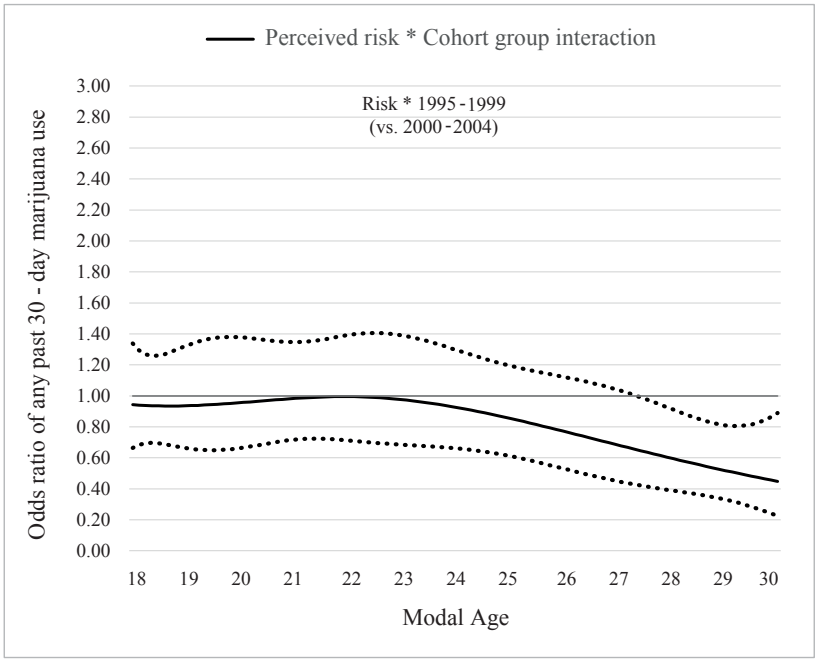
Notes: N(unwtd.) = 68,932 time points from 13,866 individuals. Estimates obtained from logistic time-varying effect models. Dotted lines indicate 99% confidence intervals. Binge drinking defined as having 5 or more drinks per occasion. Regression model simultaneously controlled for perceived risk, cohorts 1990-1994, cohorts 1995-1999, risk*1990–1994 cohorts, risk*1995–1999 cohorts. Interactions for risk*1990–1994 cohorts not shown.

Appendix Figure 8.5. Associations between perceived risk*cohort group interaction terms and any past 30-day marijuana use among US young adults ages 18 through 30: Referent group = 1990–1994



Notes: N(unwtd.) = 69,039 time points from 13,876 individuals. Estimates obtained from logistic time-varying effect models. Dotted lines indicate 99% confidence intervals. Regression model simultaneously controlled for perceived risk, cohorts 1995–1999, cohorts 2000–2004, risk*1995–1999 cohorts, risk*2000–2004 cohorts.

Appendix Figure 8.6. Associations between perceived risk*cohort group interaction terms and any past 30-day marijuana use among US young adults aged 18 through 30: Referent group = 2000–2004



Notes: N(unwtd.) = 69,039 time points from 13,876 individuals. Estimates obtained from logistic time-varying effect models. Dotted lines indicate 99% confidence intervals. Regression model simultaneously controlled for perceived risk, cohorts 1990–1994, cohorts 1995–1999, risk*1990–1994 cohorts, risk*1995–1999 cohorts. Interactions for risk*1990–1994 cohorts not shown.

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