The Relationship Between Marijuana and Conventional Cigarette Smoking Behavior From Early Adolescence to Adulthood

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Abstract

Longitudinal analyses investigated (a) the co-occurrence of marijuana use and conventional cigarette smoking within time; and (b) bidirectional associations between marijuana and conventional cigarette use in three developmental periods: adolescence, young adulthood, and adulthood. A cross-lag model was used to examine the bidirectional model of marijuana and conventional cigarette smoking frequency from ages 13 to 33. The bidirectional model accounted for gender, school-age economic disadvantage, childhood attention problems, and race. Marijuana use and conventional cigarette smoking were associated within time in decreasing magnitude and increased cigarette smoking predicted increased marijuana use during adolescence. A reciprocal relationship was found in the transition from young adulthood to adulthood, such that increased conventional cigarette smoking at age 24 uniquely predicted increased marijuana use at age 27, and increased marijuana use at age 24 uniquely predicted more frequent conventional cigarette smoking at age 27, even after accounting for other factors. The association between marijuana and cigarette smoking was found to developmentally vary in the current study. Results suggest that conventional cigarette smoking prevention efforts in adolescence and young adulthood could potentially lower the public health impact of both conventional cigarette smoking and marijuana use. Findings point to the importance of universal conventional cigarette smoking prevention efforts among adolescents as a way to decrease later marijuana use, and suggest that a prevention

effort focused on young adults as they transition to adulthood would lower the use of both cigarette and marijuana use.

Keywords

Introduction

As marijuana legalization rolls across the United States, one of the primary concerns with legalization is how changing social norms, increased access, and use of marijuana impact other substance use behavior. In particular, marijuana's relationship with conventional combustible tobacco cigarettes is of interest due to the routinely shared mode of use (Golub, Johnson, Dunlap, & Sifaneck, 2004), similar timing of onset (Johnston, O'Malley, Miech, Bachman, & Schulenberg, 2015), and the fact that tobacco use continues to be the number one preventable cause of death in the United States (Mokdad, Marks, Stroup, & Gerberding, 2004). Although cigarette use, particularly among adolescents, has steadily decreased from 2001, when prevalence was 28.5% (Centers for Disease Control and Prevention [CDC], n.d.-b), to 2015, when current cigarette use among adolescents was 9.3% (Singh, 2016), marijuana use among adolescents has increased since 2009 (Johnson et al., 2015). As of 2012, among people age 12 years and older, 43% reported using marijuana and 62% reported using cigarettes in their lifetime (Substance Abuse and Mental Health Services Administration, 2014). Further, using cigarettes and marijuana together is common (Lanza, Vasilenko, Dziak, & Butera, 2015), raising concerns that as marijuana use increases in response to loosened restrictions (Smart, 2015), the downward trend in cigarette smoking may slow down.

Understanding the association between the two substances has large potential for public health impact. Marijuana and tobacco use independently are associated with a long list of negative health consequences, including cancer (USDHHS, 2014), mental health impairment and substance use disorders (USDHHS, 2014), and increased morbidity (Mokdad et al., 2004). More concerning is that evidence suggests that when tobacco and marijuana are used together, the health impacts of either substance can be exacerbated (Ramo, Liu, & Prochaska, 2012). Marijuana use has also been associated with an increased risk for nicotine dependence in adolescence, young adulthood, and adulthood (Wang, Ramo, Lisha, & Cataldo, 2016). Ramo and colleagues (2013) found that the using both marijuana and tobacco led to increased likelihood of chronic respiratory problems and a lower likelihood of being able to quit either substance.

Cross-sectional Within-time Use of Marijuana and Conventional Cigarettes

The co-occurring use of marijuana and cigarette smoking is well studied. Cross-sectional studies have consistently found a significant within-time association between marijuana use and cigarette smoking (Ramo et al., 2012), cigarette smoking frequency (Ramo et al., 2013), persistent cigarette smoking (Ford, Vu, & Anthony, 2002), daily cigarette consumption (Ramo et al., 2013), and nicotine addiction (Rubinstein, Rait, & Prochaska, 2014). The risk

magnitude for using both substances within time is estimated to be between 5 to 7 times greater if an individual used one substance (Agrawal et al., 2012; Ramo et al., 2012).

Recent trend analyses using nationally representative surveys found that the within-time marijuana–cigarette smoking relationship has remained consistent across nearly four decades (from 1976 to 2013; Lanza et al., 2015). For adolescents and among adults age 18 and older, co-occurring use patterns have increased steadily from 2003 – 2012, and particularly among those individuals aged 26 – 34 years and those aged 50 years or older (Schauer, Berg, Kegler, Donovan, & Windle, 2015). These findings on the consistent co-occurrence of marijuana and cigarettes at differing developmental points in the life course suggest that even with successful drug and tobacco public health efforts, the co-occurring use of these two substances persists.

Association Between Marijuana and Cigarettes Over Time

While cross-sectional studies underscore that marijuana and tobacco use often go hand in hand within a given time point, what is more difficult to extrapolate is how the use of these two substances co-vary at each point in development, a topic which is largely undocumented.

The association of marijuana and cigarette use is likely to change over time. The co-occurrence of marijuana and cigarettes appears to span multiple developmental periods, including adolescence (Rubinstein et al., 2014), young adulthood (Ramo et al., 2013), and adulthood (Agrawal, Madden, Martin, & Lynskey, 2013). There is also some suggestion in the literature that the magnitude or strength of the association between marijuana use and cigarette smoking varies developmentally. Using a longitudinal sample, Crane (2015) found that the strength of the within-time association between marijuana use and cigarette use was stronger in adolescence and decreased as the individual aged into young adulthood (20 – 21 years).

The social development model (SDM) hypothesizes that during each developmental domain (e.g., adolescence, young-adulthood, and adulthood), individuals are contextualized within differing social networks that provide different opportunities and social norms which influence behavior (Hawkins et al., 2007). When social norms are more positive towards a behavior, and opportunities more prevalent, the behavior is more likely. Further, the act of using one of the substances (e.g., marijuana or cigarettes) will create more opportunities and less stigma around using another substance (e.g., marijuana or cigarettes). The use of cigarettes increasing opportunities for using harder drugs such as marijuana is in line with a gateway directionality (Kandel, Yamaguchi, & Chen, 1992), while the use of marijuana increasing opportunities for conventional cigarette use is aligned with the reverse-gateway directionality (Patton et al., 2005). As opportunities and norms for marijuana and conventional cigarette use differ for adolescents compared to adults, the SDM would posit that within each developmental period changes to social norms and opportunities will result in changing patterns of use.

Though empirical investigations using longitudinal data to investigate the marijuana–cigarette smoking relationship are sparse, earlier cigarette smoking leading to later

marijuana use behavior has been found most consistently in adolescence when longitudinal studies were used (Hawkins, Hill, Guo, & Battin-Pearson, 2002; Vega & Gil, 2005) while, in young adulthood, earlier marijuana use has been more consistently linked with later cigarette smoking (Patton et al., 2005; Timberlake et al., 2007). Timberlake and colleagues (2007), looking at longitudinal data from ADD Health, a national U.S. sample study, found that among individuals who had smoked at least once in their life, baseline marijuana use (aged 17 – 21 years) had the most influence on the development of nicotine dependence and daily cigarette smoking onset 6 years later (aged 23 – 27 years). When the study sample was divided into younger and older cohorts, these relationships were not found among the younger subsample of the study who were aged 12 – 16 years at the first wave and aged 18 – 22 years at the final wave, suggesting that the reverse-gateway association between marijuana and tobacco use may be restricted to young adulthood.

It should be noted that none of the above longitudinal studies simultaneously tested the competing directional pathways, considered co-occurring within-time use or prior use of both substances, thus precluding our ability to determine if the relationship is reciprocal, unidirectional, or completely explained by prior drug use behavior. Moreover, it is not known if these relationships persist beyond young adulthood.

Potential Covariates in the Association Between Marijuana and Cigarette Use

The prevalence of cigarette and marijuana use has been shown to differ across groups, including race, socioeconomic status (SES), gender, and person-centered characteristics such as attention problems (Lanza et al., 2015). In a systematic review of the literature on the co-use of marijuana and tobacco, the only consistent factors associated with both substances were African-American ethnicity, person-centered characteristics, and school-related characteristics (Ramo et al., 2012). The inclusion of these covariates can aid in disentangling the role these factors play in the association between marijuana use and conventional cigarette smoking.

Current Study

The present study investigates the relationship between marijuana use and conventional cigarette smoking across three developmental periods: adolescence, young adulthood, and adulthood. The study extends prior work by (a) examining the within-time co-occurrence of marijuana and conventional cigarette use into adulthood; and (b) simultaneously testing directional associations across three developmental periods while accounting for potential covariates including gender, school-age SES, race, and childhood attention problems (person-centered trait). Findings regarding how marijuana and conventional cigarette smoking are associated with each other across developmental periods may aid in developing public health prevention strategies for both substances and may inform novel prevention efforts and policy.

Methods

Participants

Original Study—The Seattle Social Development Project (SSDP) sample was recruited in 1985, when students were in the fifth grade (mean age 10 years old, standard deviation 6 mos). Students were from 18 elementary schools serving high-crime neighborhoods in Seattle, Washington, and were invited to participate in a multicomponent intervention study focused on protective and risk factors. During the fall of 1985 a population of 1,053 students from these schools were approached to participate, and 808 students (76.7%) consented to participate in the longitudinal study, the 808 students constitute the ongoing SSDP sample that has been followed longitudinally over time. Retention of participants has been high: 92% at age 33. The original study sample (n=808) is gender balanced, 49% (396) are females and 51% (412) are males, and racially diverse. Nonparticipation at each assessment wave was not related to gender; lifetime use of tobacco or marijuana, nor consistently related to ethnicity. For more information on the ongoing original study see Hawkins et al. (2007).

Current Sample—Because the present goal of the current study was to investigate the use and co-use of marijuana and cigarettes across time inclusion into the current study was based on 1. the participant having provided at least some information on their marijuana and cigarette use from ages 10–33 years and, 2. that during their lifetime (aged 10–33 years) the participant had reported using at least one of the substances since abstention prohibits the investigation of how the substances are used and co-used. Regarding criteria 1, among the original SSDP sample of 808 participants, 769 (95%) participants provided information on their marijuana and cigarette use at some point from ages10 to 33 years. For criteria 2, among the 769 participants who had reported on their marijuana and/or cigarette use by age 33 years, 80 participants (10%) had abstained from both marijuana and cigarettes, while 689 participants (85%) reported the use of marijuana and/or had smoked a cigarette at least one time in their life. We removed the 80 individuals that had never reported using either substance at any point in their lifetime for the current study leaving us with a final sample size of 689 participants. The decision to eliminate abstainers was based on recommendations by Timberlake et al. (2007), to minimize bias from participants who were lifetime abstainers from both marijuana and cigarettes since these individuals never started a drug use trajectory, the focus of the current study. Females were more likely to be in the excluded abstainer group (n = 51, 64%) compared to males (n = 29, 36%) (Pearson's chi square: 7.47(1), p < .01). Asians (n = 32, 40%) were also more likely to report no use of marijuana or cigarettes in their lifetime compared to White, Black, or Alaska Native/American Indian participants (Pearson's chi square: 20.387(3), p < .001). No difference in the likelihood of being in the abstainer group versus user group was detected for those individuals with attention problems (Pearson's chi square: 3.806 (1), p > .05) or by school-age SES (Pearson's chi square: .842(1), p > .05). A sensitivity analysis on the 39 participants (5%) who had complete missing data from ages 13 – 33 on their marijuana and cigarette use was conducted. The analysis in which these 39 cases were included in the final models found no significant alterations of findings in which they were excluded. Based on this, a decision was made to remove the 39 cases from the present analysis to further decrease any bias, resulting in a final sample size of 689.

Among the final sample included in the present analysis (n = 689), 52.7% were males, 50.1% White, 25.8% Black, 18.4% Asian, 5.7% Native American, and 51.7% qualified for free and reduced-price lunch during the fifth, sixth, or seventh grade. Participants were assessed 12 times over the course of the original study through age 33. Ten of those assessments were used in the current analysis since marijuana use was assessed beginning in the seventh grade when participants were approximately 13 years of age. Participants were assessed yearly from ages 13–16, again at age 18, and then every 3 years after that through age 33.

Measures

Marijuana use was measured beginning at age 13. Five marijuana use items (lifetime use, past year use, past year frequency, past month use, and past month frequency) were used to create a comprehensive marijuana use variable modeled after Tucker et al. (2005). The frequency of use over the past year and past month frequency were combined, creating a five-category variable of marijuana use over time (0 = no use in the past year; 1 = < 3 times in past year; 2 = 3 – 10 times in past year; 4 = 11 or more times in past year and 6 or more times in the past month). Participants were considered abstainers if they never reported use at any of the 10 waves.

Conventional cigarette use—A similar variable, paralleling the Tucker et al. 2005 marijuana variable described above, was created for conventional cigarette use. Four conventional cigarette smoking items (lifetime use, past year, past month, and average number of cigarettes per day) were transformed into a five-category variable paralleling the Tucker et al. (2005) marijuana use variable above: (1 = no use in the past month; 2 = used in past month but less than 1 cigarette a day on average; 3 = used in past month and smoked 1 – 5 cigarettes a day on average; 4 = used in the past month and smoked, on average, half a pack a day; 5 = smoked in the past month and used a pack a day on average). Due to the higher frequency of conventional cigarette use, use over time was based upon use in the past month (compared to past year with marijuana) and amount used on an average day in the past month. Abstainers were those participants who never smoked a conventional cigarette at any assessment. If a participant abstained from both marijuana and cigarettes, they were removed from the present analysis.

Potential Covariates

Sex: participant self-report of gender. **Race:** participant self-report of race which was dummy coded with White as the referent category. Three variables were created using the dummy code: Black, Alaska Native/American Indian, and Asian. **Attention problems in fifth grade:** a dichotomous variable based upon teacher reports of attention problems exhibited by the participant during fifth grade using the Child Behavior Checklist (Achenbach & Edelbrock, 1986). **School-age socioeconomic status:** a dichotomous variable based on parent report of their children's eligibility for free and reduced-price school lunch during Grades 5, 6, or 7.

Consideration of Intervention

During the elementary grades, a portion of the sample participated in a multicomponent social development intervention. Intervention effects have been found in *level* differences in predictors and outcomes (e.g. Hawkins, Kosterman, Catalano, Hill, & Abbott, 2008). We have found little evidence of differences in relationships among variables across study conditions in etiological SSDP studies (e.g., Hill, Hawkins, Catalano, Abbott, & Guo, 2005). To address possible threats to validity and confounding effects of the intervention, the current study examined a fully constrained covariance matrix where all study variables were forced to equality across the full treatment group and control group. The fully constrained model fit the data well (χ^2 315.067 (276) p = .0528, RMSEA: .030; CFI: .996, TLI: .992), suggesting that the strengths of associations between marijuana use, cigarette smoking, and other study variables were similar across intervention conditions. Further analyses were conducted using the full sample.

Data Analysis

Bivariate correlations were run to determine if there was a correlation between marijuana use and conventional cigarette use within and across time. To establish if cross-sectional within-time associations between marijuana and conventional cigarette smoking behavior had a unique relationship after accounting for other factors, a path analysis was used to model the cross-sectional within-time associations between marijuana and conventional cigarette smoking, adjusted for time-fixed covariates (e.g., school-age socioeconomic status, ethnicity, gender, and childhood attention problems), and autoregressive pathways where previous marijuana use predicts successive marijuana use in the next time period at each of the 10 waves; a similar pathway was estimated for conventional cigarette use. Finally, to investigate the directional pathways between marijuana use and conventional cigarette use in the next wave, a cross-lag model was selected. Pathways representing a gateway directionality, where conventional cigarette use is associated with marijuana use in the next time point, and the reverse gateway pathways, captured by marijuana use being associated with conventional cigarette use at the next wave, were added to the prior model. Thus, the final reciprocal cross-lag model contained four groups of pathways that were estimated simultaneously: potential covariates, autoregressive pathways within substance, cross-sectional within-time correlations between substances, and reciprocal bidirectional pathways linking marijuana and conventional cigarette smoking across time from ages 13 – 33 years. Analyses were conducted using Mplus version 6.1, variables were treated as categorical, MLR was used to address skewness in variable distribution and Full Information Maximum Likelihood (FIML) estimation was used to address missing data.

Results

Descriptive Statistics

Of the 689 individuals in the current study the majority had reported using both marijuana and cigarettes (n = 539, 78%) at some point in their life, while a smaller proportion had used only marijuana (n = 34, 5%) or only cigarettes (n = 81, 12%) and not the other substance. The current sample, similar to the original study sample, was gender balanced, with 363 males (53%) and 326 females (47%), and was composed of Whites (345, 50%), African

Americans (178, 26%), Asian Americans (127, 18%), and Native Americans (39, 6%). About half the sample (356, 52%) qualified for free and reduced-price lunch during the fifth, sixth, or seventh grade, and about 12% (n = 81) reached the upper tertile of attention problems in the fifth grade. Descriptive information on sample demographics can be found in Table 1.

The prevalence of current marijuana use across time ranged from 4% at age 13 (Grade 7 in 1988), peaking at age 21 (year = 1996) with 48%, and declining to 26% by age 33 in 2008. Conventional cigarette use in the past month showed a similar curve, with 10% of seventh graders in 1988 reporting current cigarette smoking in the past month, peaking at 43% by age 21 (year = 1996), and declining to 29% by age 33 in 2008. Prevalence rates of marijuana and cigarette use at each of the 10 assessment points can be found in Table 1.

Bivariate Relationships Between Marijuana and Cigarette Smoking Across Time

Bivariate correlations between marijuana and cigarette use across 10 assessments from age 13 to age 30 are available online. Bivariate correlations among marijuana use across assessments were strong proximally (e.g., r = .84 from age 30 to age 33), and weaker, but often still significant, distally (e.g., r = .10 from age 13 to age 30). Bivariate relationships among conventional cigarette smoking measures showed similar proximal and distal patterns, but with more consistent significance between early adolescence and cigarette smoking in the 30s. Marijuana use was significantly correlated with conventional cigarette smoking behaviors at each time point at p < .05 and ranged from .19 to .72 in strength, with the strongest correlations within time, becoming less strong the more distal the two measures were. On the bivariate level, correlations where cigarette smoking is lagged one year before marijuana use, in the gateway directionality, ranged from .20 to .58, and correlations in a reverse-gateway process ranged from .19 to .50. The strength of the relationship between the two substances decreased, but remained significant over time in all three scenarios.

To determine if the cross-sectional bivariate correlations between marijuana and tobacco use persisted after accounting for other factors, we next modeled cross-sectional within-time associations between marijuana use and cigarette smoking from age 13 (seventh grade) to age 33 using a path analysis adjusting for covariates. The model (Figure 1) included autoregressive pathways within substance, where earlier marijuana use predicted later marijuana use and earlier conventional cigarette use predicted later cigarette use, while controlling for race, school-age SES, childhood attention problems, and gender of the participant. Due to low sample prevalence of marijuana and conventional cigarette smoking at age 13 (seventh grade) and to preserve time ordering, time-fixed covariates (e.g., sex, race, childhood attention problems, and school-age SES) were regressed onto eighth-grade cigarette smoking and marijuana use in the model, and seventh-grade substance use was treated as a covariate to capture any variance associated with early onset. The model fit the data well (χ^2 473.703 (224) p < .000, RMSEA: .04; CFI: .984, TLI: .980). As expected, autoregressive pathways were the strongest predictors of future substance use for both marijuana (standardized coefficients ranged from .27 to .88) and conventional cigarette use (standardized coefficients ranged from .39 to .92). During adolescence, the within-time

cross-sectional association between the two substances remained significant but decreased in magnitude over time, such that from age 14 – 18 the strength of the cross-sectional associations went from .62 to .32. Within-time associations were for the most part not found in young adulthood and adulthood at ages 21, 24, 30, and 33. In adulthood, a single within-time association at age 27, between marijuana use and conventional cigarette smoking, remained significant (β = .48, p < .001) after accounting for other factors.

Directionality, Strength, and Association Between Marijuana and Cigarettes

We next tested a cross-lag model of the association between marijuana and cigarettes over time. In this model (Figure 2), pathways where we lagged conventional cigarette smoking in predicting the following assessment-point marijuana use behavior and pathways where earlier marijuana use predicted later conventional cigarette smoking behavior were added to the above model (Figure 1) simultaneously. When cross-lag pathways were added to the model, the model fit remained stable and continued to fit the data well (χ^2 490.471 (208) p < .000, RMSEA: .04; CFI: .981, TLI: .975). In adolescence, conventional cigarette smoking behavior in 7th grade predicted 8th-grade marijuana use (β = .17, p < .01), and 9th-grade cigarette smoking predicted 10th-grade marijuana use (β = .16, p < .05). Smoking in young adulthood (age 24) also predicted marijuana use in adulthood (age 27) (β = .10, p < .05). Interestingly, in the transition to adulthood marijuana use at age 24 predicted increased cigarette smoking at age 27 (β = .11, p < .01).

It should be noted that the unique cross-lagged effects were detected even in the continued presence of very high autoregressive pathways and controlling for potential covariates. Conventional cigarette smoking in an earlier time period was the strongest predictor of future cigarette smoking (conventional cigarette smoking–regressive paths ranged from β range: .40 to .91, increasing over time). Marijuana use in an earlier period was also the strongest predictor of future marijuana use behavior (β range: .30 to .86, also increasing over time). Further, each covariate predicted early engagement in both substance-using behaviors by the eighth grade in the expected direction. Low school-age SES was a strong predictor of engaging in both marijuana and cigarette smoking pathways (SES–cigarette smoking, β = .19, p < .001) and (SES–marijuana, β = .19, p < .001). Women were less likely to engage in conventional cigarette smoking (β = -.14, p < .05) or marijuana use (β = -.12, p < .05) pathways. Higher attention problems in the fifth grade predicted increased eighth-grade conventional cigarette smoking (β = .11, p < .05) and increased use of marijuana (β = .13, p < .05) and compared to other racial groups, being White significantly predicted both cigarette smoking (β = -.16, p < .05) and marijuana use (β = -.22, p < .01) starting in the eighth grade.

Discussion

The goal of this study was to further the understanding of the longitudinal relationship between marijuana use frequency and conventional cigarette smoking frequency from adolescence to adulthood. Findings suggest that even after controlling for potential confounders: (a) a link exists between marijuana use and conventional cigarette smoking

both within and across time and (b) the directionality of this relationship changes across developmental periods.

Co-occurrence of Marijuana and Conventional Cigarette Use Into Adulthood

After accounting for autoregressive pathways and potential covariates (gender, school age SES, race, childhood attention problems), only the within-time associations between marijuana and conventional cigarette use in adolescence (i.e., 13 – 18 years) and one time point in adulthood (age 27), remained significant. The strength of these within time associations declined over adolescence, such that the strongest within-time relationship occurred at age 14, decreased to age 18, and became non-significant by age 21. Our within time findings support prior cross-sectional work that links marijuana and conventional cigarette use in adolescence. The relative absence of within-time association during young adulthood and adulthood is contrary to other cross-sectional work set in young adulthood and adulthood (Schauer et al., 2015) but supports other longitudinal such as Crane et al. (2015) who found that among men, but not women, cigarette use frequency was more strongly associated with increased marijuana use frequency in adolescence compared to young adulthood.

Our findings that the within-time co-occurring association of marijuana and cigarettes was strongest in early adolescence and progressively diminished as the individual aged may be due to the fact that, developmentally, adolescence is a time of co-occurring use of multiple substances, including marijuana and cigarettes, while substance specialization is more likely as an individual ages (Lanza et al., 2015). A second possibility is that the decreasing strength of association and the relative lack of significant within-time associations after age 18 is a statistical consequence of the high autoregressive continuity across time for both marijuana use and conventional cigarette smoking. With autoregressive pathways ranging from .30 to .91, there simply may not have been enough variance in young adulthood and adulthood left to be explained at the older age points. A third possibility is that the stronger within-time association in adolescence is reflective of the low prevalence of use of either substance in our sample during so that the stronger associations are reflective of the higher numbers of nonusers.

Pathways Between Marijuana Use and Conventional Cigarette Smoking Across Time

This work identified developmentally important directional pathways in the relationship between marijuana use and cigarette smoking. Our study, similar to Vega and Gil (2005) and Hawkins et al. (2002), found that the gateway directional relationship, where earlier cigarette smoking predicted increased marijuana use, was most consistently found in adolescence. Adolescence is a critical time of substance use due to increased sensitivity and vulnerability to the influence of drugs both biologically and socially (Viveros, Marco, & File, 2006). That more frequent cigarette use in adolescence predicted higher frequency marijuana use at later time points could be due to several factors. Early conventional cigarette use has been found to biologically prime adolescents for marijuana use (Viveros et al., 2006). It may also reflect the higher level of availability of cigarettes, and differing social norms for cigarette and marijuana use among adolescents in the 1990's, a time when cigarettes were more commonly used among adolescents compared to marijuana (CDC, n.d.-a, n.d.-b). The fifth

assessment of the current sample, when the sample mean age was 18 years, was collected in 1993—a year in which 17.7% of U.S. high school students used marijuana and 30.5% smoked cigarettes.

In the transition from young adulthood to adulthood, a developmentally distinct period that is normally associated with a decrease in substance use, our study found a reciprocal relationship between increased cigarette smoking and marijuana use frequency. A bidirectional relationship was found, where increased cigarette smoking at age 24 predicted increased marijuana use at age 27; interestingly, a unique reverse-gateway directional association between increased marijuana use at age 24 and increased cigarette smoking frequency at age 27 was similar to findings by Patton et al. (2005) and Timberlake et al. (2007), who also found that increased marijuana use in adolescence and early young adulthood led to increased cigarette smoking outcomes in young adulthood. The consistency of detecting a reverse-gateway directional pathway at this critical developmental period of young adulthood is particularly noteworthy and warrants further investigation.

The reciprocal relationship between marijuana and conventional cigarette smoking found in the transition from young adulthood to adulthood in the current study could be due to several underlying causes. It could be that in the transition to adulthood, when faced with new life roles, young adult marijuana users adopt cigarette smoking as a means of amplification or compensation of drug effects. Young adults have reported using cigarettes when marijuana is not available or using cigarettes to offset the effects of marijuana (Highet, 2004). It may also be that the bidirectional relationship between marijuana and cigarette smoking in young adulthood to adulthood is reflective of individuals who do not perceive use as risky. One study by Resnicow et al. (1999) found that heavy users of either substance (marijuana or cigarettes) had lower perceptions of risk for using the other substance regularly. Finally, it is important to consider that the use of marijuana and cigarette smoking over time, beginning in adolescence, impacts biological pathways (e.g., dopamine functioning). (Viveros et al., 2006). In particular, the gateway directionality seen in adolescents may be due to nicotine exposure. Chronic nicotine administration has been shown to induce changes in cannabinoid receptor density and endogenous cannabinoid levels in the hippocampus and amygdala. In experimental tests, nicotine pre-treatment enhanced several responses to cannabis, in particular, heart rate and reports of being "stimulated" on the visual analogy scales (Viveros, et al., 2006), thereby increasing an individual's vulnerability to engaging in marijuana use behavior.

Limitations

One limitation of this study is that the observed relationships may be due to other preexisting or potential confounding factors not tested here. While we sought to control for person-centered biological risk through the inclusion of variables such as early attention problems, it may be that other individual or social factors were underlying the relationship between marijuana and cigarette use such as antisocial behavior or peer influence. In addition, the stronger within time associations found in adolescence may be reflective of the lower rates of substance use versus later in development when the prevalence of use, both of marijuana and cigarettes, was higher. We were also unable to test for simultaneous use of

marijuana and cigarettes which may represent important further study. Finally, the SSDP sample is a Seattle-based community sample of which 10% were excluded for their abstention from using either marijuana or cigarettes. Generalization of study findings should be conducted with caution, and replication of study findings in other data sets conducted in other populations would be helpful.

Collins and Graham (2002) point out that there is no clear optimal length of time between assessments in longitudinal studies of tobacco. Interval length and the effect of that length on findings can vary based on the constructs under consideration. In the current study we have more rapid assessments/shorter intervals during adolescence (1 year), a slightly longer interval in young adulthood (2 years), and 3-year intervals in adulthood. Adolescent substance use is a time of increased variability and change compared to adult substance use behavior. Increased variability would suggest that shorter assessment intervals are optimal while longer assessment intervals may be more appropriate for more stable behavior, such as adult substance use. The longer intervals in adulthood however may impact the effect size coefficients in adulthood by reducing the strength of the association (Collins & Graham, 2002). Thus our findings of the association between marijuana and cigarettes in adulthood are likely conservative.

Implications for Policy and Practice

It is probable that changing marijuana legislation will affect the use of marijuana and tobacco individually, as well as their co-use (Patton, Coffey, Carlin, Sawyer, & Lynskey, 2005). States with legalized medical marijuana have higher rates of marijuana use and marijuana dependence among adults (Wen, Hockenberry, & Cummings, 2015) and adolescents (age 12 – 17) (Smart, 2015; Wen et al., 2015) compared to those states without legalized medical marijuana. Similarly, increased use of marijuana among adolescents has been found in states with legalized recreational marijuana legalization. A preliminary exploratory analysis of Washington State adolescents pre-post legalizing recreational use, in addition to legalized medical marijuana, found a higher prevalence of marijuana use after recreational legalization (6.8% vs 11.8%), though the difference was not statistically significant between cohorts (Mason et al., 2016). The study also found that conventional cigarette smoking significantly decreased among adolescents at the post-marijuana legalization assessment; co-use was not assessed. A separate study found that the co-use of marijuana and cigarettes was significantly higher in states with legalized medical marijuana (Wang et al., 2016).

While the current analysis was not able to investigate the impact of legalization, our finding that higher levels of marijuana use increased the likelihood of engaging in more frequent conventional cigarette use in young adulthood is concerning in light of the increased use of marijuana seen in states with legalized marijuana. Since the legal age for recreational marijuana use has been set at 21 in young adulthood, our finding that increased marijuana use in young adulthood (age 24) increased conventional cigarette use in adulthood suggest that an unintended consequences of legalizing marijuana during young adulthood may be the increased use of cigarettes. Increased cigarette smoking as a result of marijuana use has serious implications since marijuana use has been associated with persistent long-term

cigarette smoking (Ford et al., 2002), and nicotine dependence (Patton et al., 2005), all behaviors associated with negative health outcomes and mortality (USDHHS, 2014).

In addition to marijuana use increasing the risk of conventional cigarette smoking we must also consider that increased marijuana use may impact other tobacco products. A recent study by Cohn et al. (2015), using a single wave of a national longitudinal sample in the U.S., found that among young adults age 18 – 24, current marijuana users were significantly more likely to have used e-cigarettes, hookahs, and little cigars/cigarillos in their lifetime. While we were not able to investigate e-cigarettes and hookahs in the current analysis, the findings of Cohn et al. (2015), suggest that the relationship between marijuana and emerging tobacco products, is also intertwined. Further research is needed to investigate the relationship between marijuana and emerging tobacco products, like e-cigarettes, using longitudinal data.

Collectively, our findings along with others, set within a context of expanding marijuana legalization underscore the importance of early prevention for conventional cigarette use and co-occurring marijuana use particularly among adolescents and young adults, a focus that has been identified as important areas for cessation and reducing the burden of tobacco-related disease (Agrawal, Budney, & Lynskey, 2012). Findings point to the importance of universal conventional cigarette smoking prevention efforts among adolescents as a way to decrease later marijuana use, and suggest that a prevention effort focused on young adults as they transition to adulthood would lower the use of both cigarette and marijuana use. Historically, prevention efforts for adolescent marijuana use and conventional cigarette smoking have been conducted separately; however, findings from the current study support a joint public health effort to prevent adolescent use of both substances in order to lower the public health burden of both substances in the changing context of marijuana legalization.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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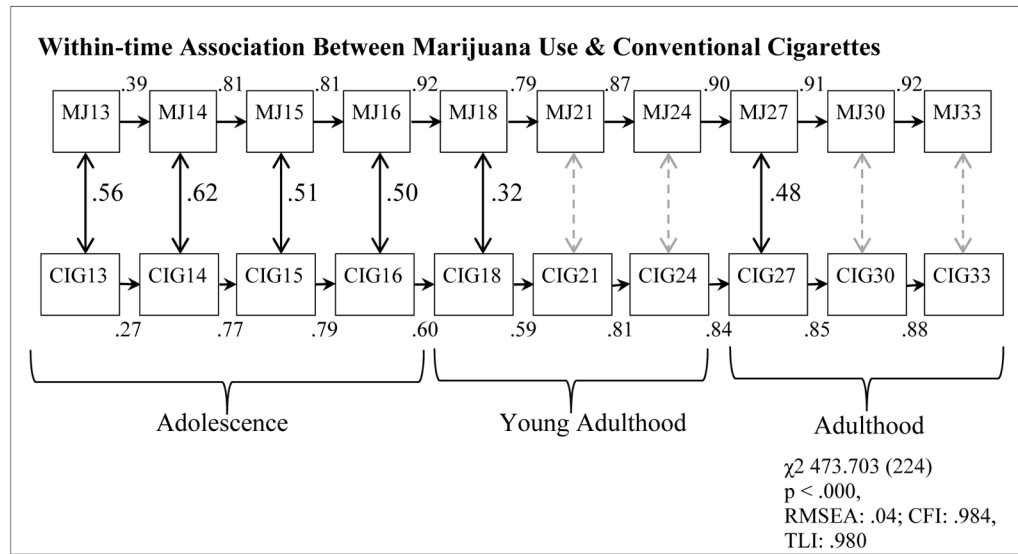
Figure 1.
Adjusted within-time associations between marijuana and cigarette use across three developmental periods. Full sample.

MJ(#) = Marijuana Use Frequency (Age); **CIG (#)** = Conventional Cigarette Smoking Frequency (Age)

Note: All presented standardized coefficients were significant at p < .05*. *Included, but not depicted in the model, were time-fixed covariates: childhood attention problems, gender, race, socioeconomic status in childhood.*
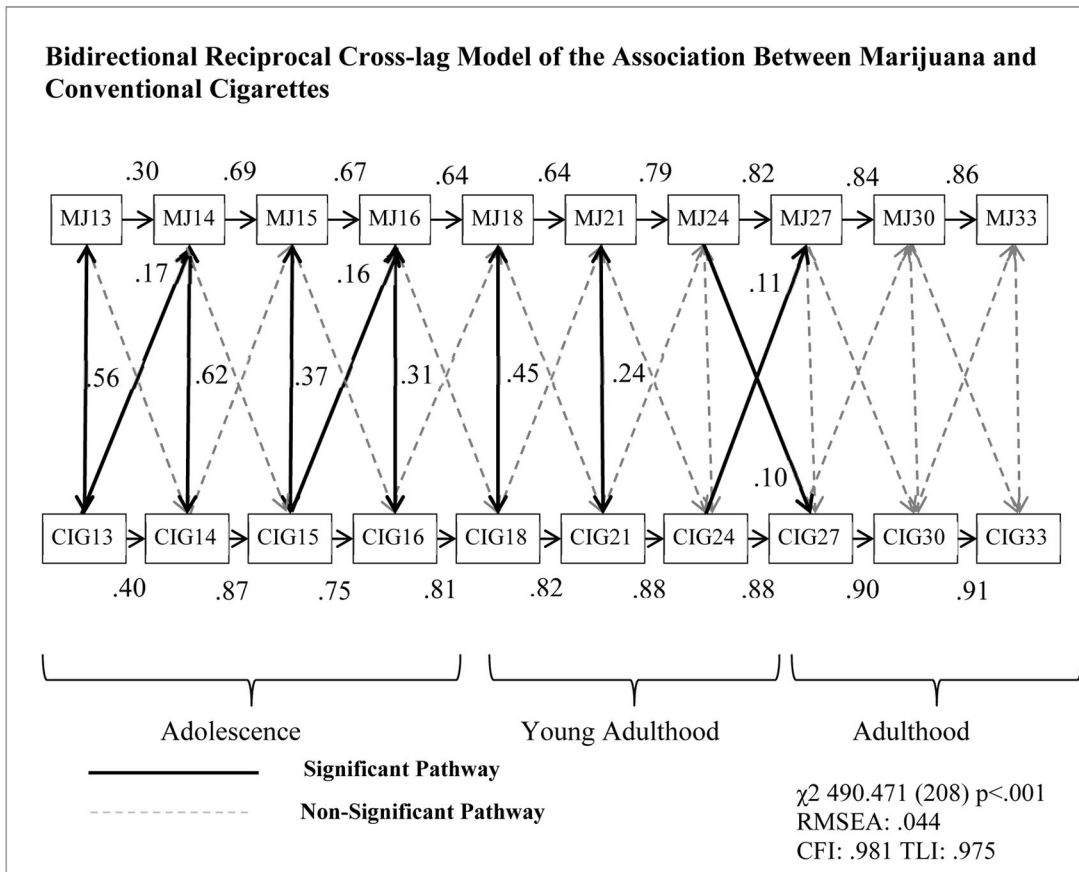
Figure 2.
Bidirectional reciprocal cross-lag model of marijuana and cigarette use across three developmental periods. Full sample.

MJ(#) = Marijuana Use Frequency (Age); **CIG (#)** = Conventional Cigarette Smoking Frequency (Age)

Note: All standardized coefficients were significant at $p < .05*$. *Included, but not depicted in the model, were time-fixed covariates: childhood attention problems, gender, race, socioeconomic status in childhood.*

Table 1

Demographics and Prevalence of Marijuana & Conventional Cigarettes Across Time (n=689)

	(%)	(n)
Gender (Male)	52.7	363
Qualified for School Age Free & Reduced Lunch in 5,6 or 7th grade	51.7	356
Ethnicity		
White	50.1	345
Black	25.8	178
Asian	18.4	127
Native American	5.7	39
Highest Tertile of Attention Problems in Childhood	11.8	81

Marijuana & Conventional Cigarette Use Prevalence from Age 13–33

	7th Grade	8th Grade	9th Grade	10th Grade	12th Grade	Age 21	Age 24	Age 27	Age 30	Age 33
Mean Age at Assessment	13	14	15	16	18	21	24	27	30	33
Year Assessed	1988	1989	1990	1991	1993	1996	1999	2002	2005	2008
Marijuana Use in Past Month	4%	11%	20%	24%	39%	48%	36%	35%	29%	26%
Conventional Cigarette Use in Past Month	10%	12%	20%	25%	31%	43%	38%	35%	33%	29%

Table 2

Bivariate Correlations Between Marijuana and Cigarette Use Across Time: Ages 13 – 33. Full Sample.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.
1. MJ13	1																			
2. MJ14	**.40**	1																		
3. MJ15	**.30**	**.75**	1																	
4. MJ16	**.20**	**.57**	**.75**	1																
5. MJ18	**.11**	**.38**	**.52**	**.60**	1															
6. MJ21	.09	.10	**.19**	**.29**	**.54**	1														
7. MJ24	**.12**	.09	**.16**	**.28**	**.48**	**.73**	1													
8. MJ27	**.11**	.13	**.16**	**.25**	**.49**	**.68**	**.79**	1												
9. MJ30	**.10**	**.15**	**.18**	**.18**	**.41**	**.63**	**.68**	**.77**	1											
10. MJ33	**.10**	.14	**.20**	**.25**	**.37**	**.60**	**.63**	**.78**	**.84**	1										
11. CIG13	**.44**	**.35**	**.28**	**.25**	**.18**	.08	**.10**	.08	.10	.07	1									
12. CIG14	**.31**	**.72**	**.55**	**.51**	**.22**	.12	.13	.12	.09	.14	**.43**	1								
13. CIG15	**.26**	**.50**	**.61**	**.58**	**.25**	.12	.07	.07	.06	.07	**.41**	**.77**	1							
14. CIG16	**.20**	**.41**	**.50**	**.62**	**.37**	.15	.09	.15	.11	.16	**.33**	**.64**	**.78**	1						
15. CIG18	**.20**	**.37**	**.47**	**.45**	**.47**	**.22**	**.16**	**.23**	**.18**	**.21**	**.28**	**.55**	**.66**	**.78**	1					
16. CIG21	.11	**.25**	**.26**	**.33**	**.32**	**.29**	**.22**	**.24**	**.19**	**.18**	**.16**	**.43**	**.47**	**.59**	**.70**	1				
17. CIG24	.09	**.28**	**.24**	**.30**	**.26**	**.19**	**.19**	**.20**	**.15**	**.17**	**.16**	**.41**	**.47**	**.57**	**.67**	**.79**	1			
18. CIG27	**.15**	**.18**	**.27**	**.28**	**.26**	**.18**	**.21**	**.28**	**.24**	**.25**	**.17**	**.35**	**.43**	**.50**	**.61**	**.76**	**.84**	1		
19. CIG30	**.13**	**.32**	**.31**	**.26**	**.22**	**.16**	**.24**	**.24**	**.29**	**.27**	**.17**	**.40**	**.43**	**.55**	**.61**	**.70**	**.78**	**.84**	1	
20. CIG33	**.18**	**.33**	**.28**	**.29**	**.25**	**.17**	**.22**	**.29**	**.25**	**.29**	**.19**	**.40**	**.40**	**.47**	**.62**	**.72**	**.78**	**.84**	**.87**	1

Note. All **Bold** Standardized Coefficients were * p < .05; MJ(#): Marijuana Use in Prior Month (Age); CIG(#): Smoked in Prior Month (Age)

☐ **Within-Construct Correlations**

▨ **MJ-CIG Within-Time Correlations**

▨ **Gateway CIG- > MJ Correlations**

▨ **Reverse-Gateway MJ- > CIG Correlations**

Note: MJ = marijuana; CIG = cigarettes