Perceived Ease of Access and Age attenuate the Association between Marijuana Ad Exposure and Marijuana Use in Adolescents

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Highlights

- There is an increase in adolescent marijuana ad exposure since 2014, especially via storefronts and billboards
- Ad exposure, perceived ease of access to marijuana and age are positively associated with past year marijuana use in adolescents.
- Perceived ease of access is a significantly larger predictor of marijuana use compared to ad exposure
- Its association with marijuana use is stronger for males
- Perceived ease of access moderates (augments) the positive association between ad exposure and past year marijuana use
- Age augments the moderating effect of perceived ease of access on the ad exposure and past year marijuana use association

Abstract

This study theorizes and tests moderators (perceived availability of marijuana and age group) of the association between adolescents' frequency of marijuana ad exposure and past year

marijuana use. To test this model we analyzed national survey data from 9,024 American adolescents with hierarchical regression techniques. Results showed that being a male [95% CI for unstandardized regression coefficient: 0.06;0.16] and peer pressure [0.04;0.14] increased past year marijuana use; and father education [-0.11;-0.06] reduced it. Perceived ease of access [0.18;0.22], ad exposure [0.03;0.14] and age [0.16;0.27] increased past year marijuana use. Importantly, the associations of perceived ease of access and age with past year marijuana use were significantly larger than this of ad exposure. Age [0.00;0.15] and perceived ease of access [0.01;0.07] independently strengthened the ad exposure→ use association. There was a significant three-way interaction [0.01;0.12] showing that age increases the positive influence of perceived ease of access on the marijuana ad exposure to past year marijuana use association. An exploratory analysis further revealed that male adolescents are more strongly influenced by perceived ease of access compared to females. Based on the findings we suggest that approaches for reducing perceived marijuana availability and for implementing age-specific interventions are promising avenues for prevention programs aimed at decreasing marijuana use in adolescents.

Keywords: Marijuana, Cannabis, Adolescents, Age, Ad exposure, Perceived Ease of Access

1. Introduction

Marijuana has consistently been the most prevalent illicit substance used by adolescents (Parnes, Rahm-Knigge, Smith, & Conner, 2019). While there has been a 17% decline in past year marijuana use by adolescents (12-17 years old), from 15.8% in 2002 to 13.1% in 2014 (Azofeifa et al., 2016) and to about 12% in 2016 (Substance Abuse and Mental Health Services Administration, 2017), these are still high prevalence rates, which can be associated with myriad

problems. Even though many adolescents believe that the use of marijuana is not harmful (Clark, Ringwalt, Hanley, & Shamblen, 2010), there is at least some evidence that some and more so heavy marijuana use can be a risk factor for issues such as cardio-metabolic deficits, respiratory disease and lung cancer, deficits in immune system, motor vehicle accidents, defects in offspring (e.g., lower birth weight) and pregnancy complications, cognitive impairments and reduced academic performance, developing schizophrenia or other psychoses, as well as depressive symptoms, social anxiety and suicidal ideation (National Academies of Sciences & Medicine, 2017). Other possible adverse associations of marijuana use include serving as a "gateway" drug for other substances (Hall & Lynskey, 2005), risky sexual behavior (Sun, Reboussin, Mann, Garcia, & Rhodes, 2016), and violence (Jordan et al., 2019). As such, there is a need to examine factors that are associated with marijuana use in adolescents, as a means to guide health promotion interventions and policy development efforts aimed at reducing marijuana use in adolescents.

One possible driver of marijuana use in adolescents that received recent attention is individual differences in marijuana ad exposure (Berg, Henriksen, Cavazos-Rehg, Haardoerfer, & Freisthler, 2018; D'Amico, Miles, & Tucker, 2015; D'Amico, Rodriguez, Tucker, Pedersen, & Shih, 2018; Krauss et al., 2017). Even though such advertising is lightly regulated in offline environments (e.g., restricted near schools in Colorado), it is difficult to control in online environments (Bierut, Krauss, Sowles, & Cavazos-Rehg, 2017; Pacula, Kilmer, Wagenaar, Chaloupka, & Caulkins, 2014). Exposure to such ads is further exacerbated by the increased number of US states that have legalized medical and recreational marijuana (Parnes et al., 2019). That is, not only do adolescents see pro medical and recreational marijuana content online, they can also be exposed to increased marijuana storefront and billboard advertising (D'Amico et al.,

2015; Krauss et al., 2017). This exposure may trivialize marijuana use, make it seem desirable, can change adolescents' attitude and beliefs toward marijuana use, and consequently lead to earlier onset of use and increased uptake (D'Amico et al., 2015; D'Amico et al., 2018). Accordingly, we hypothesize that the frequency of marijuana ad exposure is positively associated with past year marijuana use.

Extending this view, we note that ad exposure represents "promotion" (i.e., how marijuana is promoted to adolescents) in the marketing mix (i.e., the 4 Ps: product, price, place, and promotion, see Kotler & Keller, 2006). What may also be important in driving marijuana use using the 4Ps framework are price and placement (i.e., the cost of marijuana and locations through which people can gain access to marijuana), which can together manifest in perceived ease of access to marijuana. That is, when marijuana is perceived to be too expensive and difficult to obtain (e.g., sellers are unknown or are out of reach, cannot obtain marijuana from friends, stores check identification and refuse to sell marijuana to adolescents), adolescents are likely to perceive low ease of access to marijuana. Consistent with social cognitive theories of behavior (Bandura, 1989), such perceived barriers should deter plans to acquire and/or use marijuana. As such, we hypothesize that low perceived ease of access to marijuana is associated with reduced past year marijuana use.

Age is another important individual differences in this context. Being older adolescent increases the odds of marijuana use and frequency of use. Lifetime use of marijuana in 2018 was 13.9% in 8th grade and 32.6% in 10th grade, and past year use prevalence increased from 10.5% in 8th grade to 27.5% in 10th grade (The National Institute on Drug Abuse, 2019). This may be attributed to reduced beliefs about marijuana risks as adolescents grow (Roditis & Halpern-Felsher, 2015), the naturalization of marijuana use as adolescents grow (Peretti-Watel, 2003),

and/or reduced parental monitoring as adolescents grow (DiClemente et al., 2001). Accordingly, we hypothesize that adolescent age is positively associated with past year marijuana use.

Extending this direct associations view, we seek to examine moderators of the association between marijuana ad exposure and marijuana use. Knowing under what circumstances ad exposure is more or less efficacious in driving marijuana use has important health promotion and risky behavior prevention implications. It is reasonable to expect that individual differences in perceived ease of access to marijuana and age serve as such moderators. Specifically, ad exposure alone (e.g., in a high socio-economic-status neighborhood) cannot drive marijuana use, if marijuana sources (friends, dealers, stores) are out of reach. That is, the association between ad exposure and marijuana use is contingent on availability: low availability can deter the translation of positive attitudes (as often instilled by marijuana ads) into behavior (Smith & Swinyard, 1983). This is consistent with emerging literature that shows that availability and realistic use opportunities can explain marijuana use trajectories (Burdzovic Andreas & Bretteville-Jensen, 2017; Hines et al., 2016; Wagner & Anthony, 2002). This interaction can further depend on age. Specifically, even if ad exposure is high and marijuana is perceived to be easy to access, younger adolescents do not naturalize, trivialize and perceive marijuana use as safe compared to older adolescents (Peretti-Watel, 2003; Roditis & Halpern-Felsher, 2015), and are more supervised by parents (DiClemente et al., 2001). Hence, being younger, and presumably more supervised, and having stronger marijuana risk perceptions and anti-marijuana sentiment, can further reduce the translation of marijuana ad exposure, including under high perceived ease of access to marijuana conditions, into marijuana use. Accordingly, we propose a three-way interaction. We hypothesize that age will augment the positive interaction of perceived ease of access to marijuana and marijuana ad exposure, and will further strengthen the

association between marijuana ad exposure and past year marijuana use. We expect this association to be stronger for older adolescents.

2. Methods

2.1 Study Population

We used secondary data from 8th and 10th grade students who participated in the 2014, 2015 and 2017 Monitoring the Future studies[1]. See study details in Miech et al. (2018). Responses were fully anonymized and the study procedures were approved by the University's Institutional Review Board. Number of schools, number of students, and response rates stratified by age (with school grade serving as a proxy) as reported in Miech et al. (2018), are given on the left side of Table 1. The right side of the table reports analytic sample details. The analytic sample was created through list-wise deletion of records of students who did not complete relevant study sections, had missing values for the model's variables, or reported to have used prescribed medical marijuana (102 students in 2017).

--Table1 Here--

2.2 Study Measures

The outcome variable was past year (last 12 months) marijuana use, which was self-reported on a 1-7 scale (1="0 Occasions", 2="1-2 Occasions", 3="3-5 Occasions", 4="6-9 Occasions", 5="10-19 Occasions", 6="20-39 Occasions", and 7="40 or More".) The independent variables were perceived ease of access to marijuana, marijuana ad exposure, and age. Perceived ease of access was self-reported in response to a question asking about ease of getting marijuana on a 1-5 scale

[1] The 2016 data did not include marijuana ad exposure variables, so it was not included in the analyses.

(1="Probably Impossible" 2="Very Difficult" 3="Fairly Difficult" 4="Fairly Easy" 5="Very Easy".) Marijuana ad exposure was operationalized as an average of responses to the question "About how often have you seen advertisements for marijuana " (a) on storefronts, (b) on billboards, (c) on screens[2], and (d) on the radio, which were self-reported on a 1-6 scale (1="Not at all", 2="Less than once a month", 3="1-3 times per month", 4="1-3 times per week", 5="Daily or almost daily", and 6="More than once a day"). These items were reliable in capturing overall marijuana ad exposure (Cronbach's $\alpha = 0.812$.) Age group was captured with school grade (0="younger adolescents, 8th grade" and 1="older adolescents, 10th grade"). Interaction terms were operationalized as products of mean centered variables.

We also controlled for (a) survey year, to account for possible trend effects (The National Institute on Drug Abuse, 2019), (b) individual differences including sex and peer pressure to use marijuana (Harakeh & Vollebergh, 2012; Studer et al., 2016), to account for possible innate and social influences on marijuana use, and (c) family variables, including father and mother education levels, to indirectly account for possible socio-economic differences (White, Bechtold, Loeber, & Pardini, 2015). Year was operationalized as two dummy variables ("Is 2014?" and "Is 2017?"), with 2015 being the reference year. Sex was coded as 0="female" and 1="male". Peer pressure to use marijuana was captured with self-reported levels of pressure to use marijuana one feels from friends and schoolmates, on a 1-4 scale (1="None", 2="A little", 3="Some", and 4="A lot"). Father and mother education levels were self-reported on a 1-6 scale (1="Completed grade

[2] Whereas the 2017 round of data collection focused on all screens together, the 2014-15 data captured Internet and TV separately. These items (TV and Internet) were therefore averaged into a single item that was somewhat equivalent to the 2017 item in that it captures general screen time. It was decided to average and not add TV and Internet exposure given the Likert scales used, and the blurring lines between these two media (e.g., watching TV over the Internet).

school or less", 2="Some high school", 3="Completed high school", 4="Some college", 5="Completed college", and 6="Graduate or professional school after college").

Zero-order correlations among study variables are reported in the Appendix A.

2.3 Statistical Analysis

First, descriptive statistics for the sample, analyses of variance (ANOVA) and charts that visualize changes over time were generated with SPSS 26. Based on Cumming (2009), non-overlapping confidence intervals or distances from upper/lower bound to the estimate point that had less than 50% overlap were deemed indicative of significant ($p<0.05$) differences between variables and between years. Second, we estimated the hypothesized model with hierarchical regression procedures in SPSS 26, with the first block containing controls, the second containing main associations, the third containing two-way interactions, and the fourth containing the three-way interaction. The models were estimated with bootstrapping with 5,000 re-samples as a means to generate bias-corrected 95% confidence intervals for estimates, to avoid distributional assumptions, to improve robustness, and to afford comparisons of regression coefficients. Third, the three-way interaction was further analyzed and plotted with tools in http://www.jeremydawson.co.uk/slopes.htm (Dawson & Richter, 2006).

3. Results

Descriptive characteristics [mean (standard deviation)] of the sample stratified by age group and sex are outlined in Table 2. Older students (10th grade) reported significantly stronger peer pressure to use marijuana, perceived ease of getting marijuana, exposure to marijuana ads on screens, and past year marijuana use, compared to younger students (8th grade). They also reported lower ad exposure on billboards, compared to younger students. Males reported higher

perceived ease of getting marijuana and higher levels of past year marijuana use, compared to females. They reported lower marijuana ad exposure on screens, compared to females. There were no significant differences in overall marijuana ad exposure between the age groups or sexes. Trends in sources of marijuana ad exposure are described in Table 3. The table demonstrates a significant 2014 to 2017 decline in screen exposure to marijuana ads, a significant increase in storefront and billboard exposure, and no change in radio exposure during the same period. The overall exposure to marijuana ads increased between 2014 and 2017, perceived ease of access did not change, and past year marijuana use has slightly decreased during this period.

--Tables2&3 Here--

Hierarchical regression results explaining past year marijuana use are given in Table 4. The first block shows that peer pressure and being male are positively associated with past year marijuana use, while father education is negatively associated with past year marijuana use. The second block shows that perceived ease of access to marijuana, ad exposure and age (grade) are positively associated with past year marijuana use. The third block demonstrates that perceived ease of access and age independently increase the association between ad exposure and past year marijuana use; and that age increases the association between perceived ease of access to marijuana and past year marijuana use. The fourth block supports the three-way interaction[3]. This is probed in the next paragraph.

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[3] The model was also tested with 30 day marijuana use as the DV. It produced very similar results with significant direct effects (all with p=0.000), significant two-way interaction between perceived ease of access and exposure, and between perceived ease of access and age (both with p=0.000), and a significant three-way interaction (p=0.048).

--Table4 Here--

The significant three-way interaction is examined in Figure 1. It depicts the association between marijuana ad exposure and past year marijuana use, at different levels of perceived ease of access to marijuana (-/+ 1SD) and at the different age groups (grades 8th or 10th). The figure shows that marijuana ad exposure is marginally associated with marijuana use when access to marijuana is perceived to be low (lines #3 and 4) or at younger ages (line #2). The association becomes steeper and more noticeable only in older adolescents (10th grade) and when access to marijuana is perceived to be high (line #1). The differences between the slopes of lines 1 and 2 (p<0.001), lines 1 and 3 (p<0.000), lines 1 and 4 (p<0.000), lines 2 and 4 (p<0.010), and lines 3 and 4 (p<0.000) were statistically significant. The difference between the slopes of lines 2 and 3 (p<0.291) was not statistically significant.

--Figure1 Here—

In Table 2, compared to boys, girls had a slightly higher exposure to marijuana while reporting lower perceived ease of getting marijuana. While differences in means do not imply differences in association with marijuana use, the study ventured to see if sex attenuates the associations of ad exposure and perceived ease of access with marijuana use with same hierarchical regression techniques used for the main study. Results are given in Appendix B.

4. Discussion

With the growing numbers of states that legalize marijuana use for medical and/or recreational purposes, and the limited regulation of marijuana advertising, teenagers are increasingly exposed to marijuana advertisements. Our data (Table 3) supported this notion by showing a significant

increase in overall marijuana ad exposure of students in 8th and 10th grade, from 2014 to 2017. This increase, though, is not across all advertising channels; it rather represents a change in the mix of advertisement outlets. While there was a significant decrease in screen (Internet, TV) exposure, teenagers have been significantly increasingly exposed to storefronts and billboards that advertise marijuana. This increase overshadows the decrease in exposure to marijuana ads via electronic media channels. The new mix of advertising channels and the increased exposure of youth to marijuana ads emphasize the need for research in this area. This study makes first strides toward deepening the understanding of the implications of this trend. It is specifically aimed at understanding the conditions under which marijuana advertisement exposure is associated with increased marijuana use in adolescents. More specifically, in line with recent works on the roles of realistic use opportunities and availability in affording marijuana use (Burdzovic Andreas & Bretteville-Jensen, 2017; Hines et al., 2016; Wagner & Anthony, 2002), we sought to examine whether perceived ease of access to marijuana and age can attenuate the association between marijuana ad exposure and past year marijuana use.

Our descriptive findings (Table 2) demonstrate that older teenagers (10th grade, typically 15-16 years old) experience stronger peer pressure to use marijuana, believe that it is easier for them to get marijuana, and report more past year instances of marijuana use, compared to younger students (8th grade, typically 13-14 years old). This illuminates the importance of studying age (or school grade as a proxy for age) as a predictor of marijuana use attitudes and behaviors, and to the possible limited generalizability from studies done in one age group to another. It also emphasize the need to start substance use programs (Clark et al., 2010; Ghosh-Dastidar, Longshore, Ellickson, & McCaffrey, 2004; Porath-Waller, Beasley, & Beirness, 2010; Ringwalt et al., 2009) early in adolescence, before peer pressure and ease of access perceptions grow.

Interestingly, there were no significant differences in overall, storefront and radio marijuana ad exposure between the age groups, but younger students reported higher billboard and lower screen exposure. This points to a possible shift in the exposure mix as adolescents mature. For example, all students may be driven to and from school or to after school activities, and in this route they may be exposed to similar numbers of storefronts that advertise marijuana. However, they may change the websites they use and TV shows they watch such that older students are exposed to more mature content, including more marijuana advertisements. Such explanations and the implications of changes in the exposure mix require further research.

The hierarchical regression results shed light on several correlates of past year marijuana use in teenagers. All blocks consistently show that males report more instances of marijuana use compared to females, which is consistent with past findings (Cuttler, Mischley, & Sexton, 2016). They also show that peer pressure significantly increase marijuana use in teenagers, which is consistent with prior research on the role of peers in promoting risky behaviors (Jordan et al., 2019), including marijuana use (Ali, Amialchuk, & Dwyer, 2011). Lastly, they show that father education reduces instances of marijuana use, but mother education does not. This may be explained through differences in the ways mothers and fathers shelter adolescents from substance use (Brook, Brook, Arencibia-mireles, Richter, & Whiteman, 2001).

The hierarchical regression results also supported the hypothesized predictors of past year marijuana use in adolescents. The second block revealed that marijuana ad exposure, perceived ease of access to marijuana and age are positively associated marijuana use. These findings are in line with social cognitive theories of behavior (Bandura, 1989), theories of attitude change via advertisement (Rossiter & Percy, 1980), and common explanations of age association with marijuana use (Roditis & Halpern-Felsher, 2015). Importantly, these findings present a more

integrative view of the associations between several elements of the marketing mix (specifically price and placement, as captured by perceived availability; and promotion, as captured by ad exposure) and marijuana use. Prior research has focused mostly on marijuana use promotion through ads (Berg et al., 2018) and/or intervention programs aimed at changing pro-marijuana beliefs (Clark et al., 2010; Ghosh-Dastidar et al., 2004; Longshore, Ellickson, McCaffrey, & St Clair, 2007). Interestingly, the validated integrative view suggests that perceived ease of access and age are significantly larger predictors of past year marijuana use compared to ad exposure (based on confidence intervals). Extending the direct associations view, the interaction blocks provide insights regarding moderators of the ad exposure→use association. The two-way interaction block suggests that age and perceived ease of access independently increase the ad exposure→use association with statistically indistinguishable magnitudes (as per the confidence intervals). Furthermore, the three-way interaction block showed that age strengthens the positive influence of perceived ease of access on the marijuana ad exposure to marijuana use association.

The exploratory analysis reported in Appendix B is also informative. It shows that while the association between ad exposure and marijuana use does not differ between the sexes, the association between perceived ease of access and marijuana use is stronger for males than for females. That is, male adolescents may be more influenced by ease of access perceptions compared to females.

These findings point to important implications. First, they imply that in parallel to the focus on regulating and/or minimizing adolescent exposure to marijuana ads, research and policy makers should conceive ways to reduce perceived ease of access to marijuana, especially among male adolescents (i.e., consider a targeted intervention). Second, the findings imply that older adolescents are at a higher risk for more frequent marijuana use. Older adolescents report

stronger peer pressure, perceived ease of getting marijuana and screen exposure to marijuana ads, compared to younger users. Hence, these can be considered as intervention targets for reducing marijuana use among older adolescents. Ultimately, the findings confirm a need for comprehensive policies and interventions that prevent youth access (and perceived access) as well as advertising exposure, rather than only advertising exposure.

Several limitations of this study are noteworthy. First, data each year were self-reported and cross-sectional. Thus, the reciprocal effects of ad exposure and use could not be examined (Tucker, Miles, Amp, Apos, & Amico, 2013); and caution should be exercised regarding interpreting causality. In addition, it is unclear how far self-reports are from objective measures (e.g., marijuana intake). Second, even though the variety of marijuana products and consumption methods (e.g., vaping, edibles, smoking) has increased, we lumped all forms of marijuana use together. Third, the sample represents primarily non-prescribed use of marijuana, but it is impossible to fully rule out that very few people did not report prescribed use and/or blurred the lines between prescribed and non-prescribed use. Future research should more closely examine differences between prescribed and non-prescribed marijuana use. Fourth, it is possible that ad exposure influences ease of access perceptions. While the correlation between the variables was small and positive (they share about 2.1% of the variance), we call for future research to examine the cross-influence possibility. Lastly, we assumed that certain processes are associated with age (e.g., declining parental supervision), but did not directly account for such processes. These limitations serve as fruitful areas for future research.

5. Conclusions

This study shows that (1) adolescents' marijuana ad exposure is on the rise; it may counteract efforts exerted by prevention programs to change pro-marijuana attitudes, (2) marijuana ad

exposure, perceived marijuana availability, and age jointly predict marijuana use in adolescents, (3) age and perceived ease of access interact and increase the positive association between marijuana ad exposure and past year marijuana use, and (4) ease of access perceptions are more potent correlates of marijuana use in males than in females. We call for future research to focus on multiple elements of the marketing mix of marijuana, and examine approaches for reducing perceived marijuana availability in adolescents.

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Tables

Table 1: Analytical Sample Characteristics

		Sample			Analytic Sample		
Year	Age (Grade)	schools	Students	Response Rate	Male	Female	Total
2014	8th	141	15,195	90%	650	722	1,372
	10th	114	13,341	88%	797	779	1,576
2015	8th	142	15,015	89%	654	750	1,404
	10th	110	16,147	87%	900	943	1,843
2017	8th	131	16,010	87%	616	746	1,362
	10th	106	14,171	85%	689	778	1,467
Total		744	89,879	87.7%	4,306	4,718	9,024

Table 2: Descriptive Characteristics of Sample by Age Group (Grade) and Sex

	Younger Adolescents (8th Grade)		Older Adolescents (10th Grade)			Difference between age groups* [*p*-value]	Difference between sexes* [*p*-value]
Variable	Female	Male	Female	Male	Total		
Peer Pressure to Use Marijuana	1.23 (0.65)	1.26 (0.68)	1.42 (0.80)	1.37 (0.75)	1.33 (0.73)	0.000	0.418
Mother Education	4.25 (1.41)	4.30 (1.33)	4.35 (1.34)	4.39 (1.30)	4.32 (1.35)	0.002	0.083
Father Education	3.99 (1.43)	4.04 (1.39)	4.08 (1.43)	4.12 (1.40)	4.06 (1.41)	0.004	0.090
Marijuana Ad Exposure**	1.55 (0.82)	1.49 (0.85)	1.55 (0.78)	1.54 (0.80)	1.53 (0.81)	0.120	0.055
- *Storefront*	*1.43 (0.91)*	*1.41 (0.99)*	*1.41 (0.89)*	*1.41 (0.92)*	*1.41 (0.92)*	*0.717*	*0.542*
- *Billboard*	*1.38 (0.89)*	*1.35 (0.90)*	*1.32 (0.79)*	*1.32 (0.80)*	*1.34 (0.84)*	*0.014*	*0.384*
- *Screens*	*1.96 (1.23)*	*1.86 (1.25)*	*2.10 (1.30)*	*2.02 (1.30)*	*1.99 (1.28)*	*0.000*	*0.001*
- *Radio*	*1.41 (0.98)*	*1.35 (0.94)*	*1.38 (0.94)*	*1.41 (0.99)*	*1.39 (0.96)*	*0.596*	*0.478*
Perceived Ease of Getting Marijuana	2.86 (1.44)	2.92 (1.47)	3.83 (1.27)	3.87 (1.25)	3.41 (1.44)	0.000	0.011
Past Year Marijuana Use	1.27 (0.92)	1.34 (1.14)	1.74 (1.51)	1.89 (1.77)	1.54 (1.29)	0.000	0.000

* Between-group differences were examined with Analysis of Variance (ANOVA)
** Ad exposure by channel is presented below the total ad exposure (*italicized*)

Table 3: Trends in Key Variables

	2014*	2015*	2017*	2015 vs. 2014**	2017 vs. 2015**	2017 vs. 2014**
Peer Pressure to Use Marijuana	1.36 (0.77) [1.33-1.39]	1.30 (0.70) [1.28-1.33]	1.32 (0.72) [1.30-1.35]	**0.040** ↓	0.338	0.060
Marijuana Ad Exposure***	1.52 (0.81) [1.49-1.55]	1.51 (0.76) [1.48-1.53]	1.58 (0.86) [1.55-1.61]	0.459	**0.000** ↑	**0.005** ↑
- *Storefront*	*1.35 (0.86) [1.32-1.38]*	*1.34 (0.82) [1.31-1.37]*	*1.57 (1.07) [1.53-1.61]*	*0.764*	***0.000*** ↑	***0.000*** ↑
- *Billboard*	*1.29 (0.78) [1.26-1.32]*	*1.28 (0.75) [1.26-1.31]*	*1.46 (0.98) [1.43-1.50]*	*0.862*	***0.000*** ↑	***0.000*** ↑
- *Screens*	*2.02 (1.26) [1.98-2.07]*	*2.01 (1.24) [1.97-2.06]*	*1.93 (1.33) [1.88-1.98]*	*0.770*	***0.016*** ↓	***0.008*** ↓
- *Radio*	*1.43 (1.03) [1.39-1.46]*	*1.38 (0.95) [1.35-1.42]*	*1.36 (0.91) [1.32-1.39]*	*0.094*	*0.257*	*0.060*
Perceived Ease of Getting Marijuana	3.44 (1.44) [3.39-3.49]	3.40 (1.44) [3.34-3.44]	3.40 (1.42) [3.35-3.46]	0.214	0.770	0.360
Past Year Marijuana Use	1.62 (1.47) [1.57-1.68]	1.56 (1.41) [1.51-1.61]	1.55 (1.37) [1.50-1.60]	0.080	0.763	**0.047** ↓

* Cell include the mean (standard deviation) and [95% confidence interval for the mean].
** Between-year changes were examined with Analysis of Variance (ANOVA). The table reports Least Significant Difference (LSD) post-hoc analysis *p*-values; bolded text and arrows indicate trend of change for significant differences.
*** Trends in ad exposure by channel are presented below the total ad exposure (*italicized*).

Table 4: Hierarchical Regression Results*, **,***

Predictor	Block 1 (controls)	Block 2 (main effects)	Block 3 (2-way interactions)	Block 4 (3-way interaction)
Year2014	0.04 (0.274) [-0.03;0.11]	0.04 (0.220) [-0.03;0.11]	0.03 (0.370) [-0.04;0.10]	0.03 (0.362) [-0.04;0.10]
Year2017	-0.02 (0.533) [-0.09;0.05]	-0.02 (0.516) [-0.09;0.04]	-0.03 (0.411) [-0.09;0.04]	-0.03 (0.443) [-0.09;0.04]
Sex [1=Male]	***0.14 (0.000) [0.08;0.20]***	***0.11 (0.000) [0.06;0.17]***	***0.11 (0.000) [0.06;0.16]***	***0.11 (0.000) [0.06;0.16]***
Peer Pressure	***0.25 (0.000) [0.21;0.30]***	***0.10 (0.000) [0.05;0.15]***	***0.09 (0.000) [0.04;0.14]***	***0.09 (0.000) [0.04;0.14]***
Mother Education	-0.01 (0.396) [-0.04;0.02]	-0.01 (0.291) [-0.04;0.02]	-0.02 (0.198) [-0.04;0.01]	-0.02 (0.198) [-0.04;0.01]
Father Education	***-0.10 (0.000) [-0.13;-0.07]***	***-0.08 (0.000) [-0.11;-0.05]***	***-0.08 (0.000) [-0.11;-0.06]***	***-0.08 (0.000) [-0.11;-0.06]***
Perceived Ease of Access		***0.29 (0.000) [0.27;0.30]***	***0.20 (0.000) [0.18;0.22]***	***0.20 (0.000) [0.18;0.22]***
Ad Exposure		***0.15 (0.000) [0.11;0.19]***	***0.08 (0.001) [0.03;0.14]***	***0.08 (0.002) [0.03;0.14]***
Age (Grade)		***0.22 (0.000) [0.17;0.28]***	***0.23 (0.000) [0.17;0.28]***	***0.22 (0.000) [0.16;0.27]***
Exposure x Ease			***0.06 (0.000) [0.04;0.09]***	***0.04 (0.022) [0.01;0.07]***
Exposure x Age			***0.10 (0.006) [0.01;0.18]***	***0.08 (0.037) [0.00;0.15]***
Ease x Age			***0.19 (0.000) [0.15;0.23]***	***0.19 (0.000) [0.15;0.23]***
Ease x Exposure x Age				***0.06 (0.009) [0.01;0.12]***
R^2	0.032	0.144	0.157	0.158
p-Value ΔR^2		*0.000*	*0.000*	*0.009*

* The dependent variable is past year (12 month) marijuana use instances.

** Cells report unstandardized coefficients, (p-values), and [bias corrected 95% confidence intervals].

*** Significant values (at least $p<0.05$) are bolded and italicized.

Figures

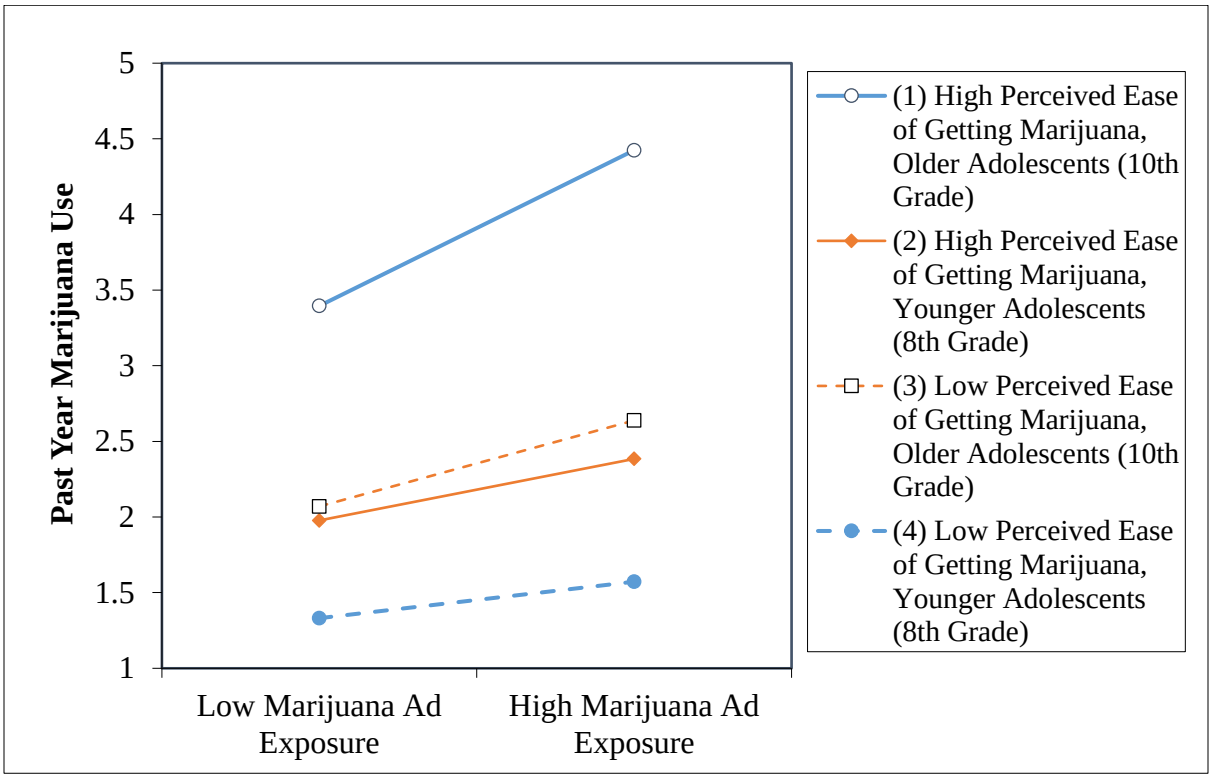

Figure 1: Three-Way Interaction Plot

Appendix

A. Zero-Order Correlations

Table A1: Zero-order correlations among study variables

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) Age (Grade)									
(2) Perceived Ease of Access to Marijuana	0.332**								
(3) Marijuana Ad Exposure	0.016	0.146**							
(4) past year (12 month) marijuana use	0.179**	0.344**	0.142**						
(5) Year2014	-0.010	0.013	-0.011	0.023*					
(6) Year2017	-0.031**	-0.003	0.039**	-0.013	-0.471**				
(7) Sex [1=Male]	0.024*	0.027*	-0.020	0.045**	0.019	-0.021*			
(8) Peer Pressure to Use Marijuana	0.101**	0.208**	0.148**	0.135**	0.029**	-0.005	-0.009		
(9)Mother Education Level	0.033**	-0.032**	-0.057**	-0.071**	-0.022*	-0.011	0.018	-0.033**	
(10) Father Education Level	0.031**	-0.058**	-0.073**	-0.108**	-0.013	-0.015	0.018	-0.040**	0.576**

B. Exploratory Model

Table B1: Hierarchical Regression Results- Sex moderation*, **,***

Predictor	Block 1 (controls)	Block 2 (main effects)	Block 3 (2-way interactions)	Block 4 (3-way interaction)
Year2014	0.06 (0.099) [-0.01;0.13]	0.04 (0.196) [-0.03;0.10]	0.04 (0.236) [-0.03;0.10]	0.04 (0.240) [-0.03;0.10]
Year2017	-0.00 (0.983) [-0.07;0.07]	-0.02 (0.504) [-0.08;0.04]	-0.02 (0.506) [-0.08;0.04]	-0.02 (0.509) [-0.08;0.04]
Age (Grade)	***0.49 (0.001) [0.43;0.54]***	***0.22 (0.001) [0.16;0.28]***	***0.22 (0.001) [0.16;0.28]***	***0.22 (0.001) [0.16;0.28]***
Peer Pressure	***0.22 (0.001) [0.17;0.27]***	***0.10 (0.001) [0.05;0.15]***	***0.10 (0.001) [0.05;0.15]***	***0.10 (0.001) [0.05;0.15]***
Mother Education	-0.02 (0.274) [-0.04;0.01]	-0.01 (0.328) [-0.04;0.01]	-0.01 (0.303) [-0.04;0.01]	-0.01 (0.303) [-0.04;0.01]
Father Education	***-0.10 (0.001) [-0.13;-0.08]***	***-0.08 (0.001) [-0.10;-0.05]***	***-0.08 (0.001) [-0.11;-0.06]***	***-0.08 (0.001) [-0.11;-0.06]***
Perceived Ease of Access		***0.29 (0.001) [0.27;0.30]***	***0.26 (0.001) [0.24;0.28]***	***0.26 (0.001) [0.24;0.28]***
Ad Exposure		***0.15 (0.001) [0.11;0.19]***	***0.10 (0.001) [0.05;0.15]***	***0.10 (0.001) [0.06;0.16]***
Sex (Male=1)		***0.11 (0.001) [0.06;0.17]***	***0.11 (0.001) [0.06;0.17]***	***0.10 (0.001) [0.05;0.16]***
Exposure x Ease			***0.07 (0.001) [0.05;0.10]***	***0.06 (0.001) [0.03;0.09]***
Exposure x Sex			0.06 (0.169) [-0.02;0.14]	0.05 (0.191) [-0.03;0.12]
Ease x Sex			***0.06 (0.001) [0.03;0.10]***	***0.06 (0.001) [0.03;0.10]***
Ease x Exposure x Sex				0.03 (0.239) [-0.02;0.08]
R^2	0.058	0.144	0.149	0.149
p-Value ΔR^2		*0.000*	*0.000*	*0.215*

* The dependent variable is past year (12 month) marijuana use instances.
** Cells report unstandardized coefficients, (p-values), and [bias corrected 95% confidence intervals].
*** Significant values (at least $p<0.05$) are bolded and italicized.