

Diffusion of Adolescent Marijuana Use in School Environments Following Recreational
Legalization

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Manuscript word count: 3216

Conflict of Interest Declaration: None

Abstract

Aim: To identify the mechanisms by which social interactions with classmates influence marijuana use in the transition into adolescence.

Design: Using four waves of longitudinal social network data collected quarterly during the school year from the spring of 8th grade to the spring of 9th grade (2014-2016), we examine how friendship ties relate to marijuana use.

Participants: 1075 adolescents were included in the present analysis. An implicit consent procedure was used: all students whose parents did not opt out of the study were eligible to participate.

Setting: Participants were drawn from 12 schools with 8th graders, from five rural and two nonrural school districts in Western Oregon.

Measurements: At each assessment wave participants reported on their marijuana use in the past 30 days. Using stochastic actor-oriented modeling, we examined whether classmates with similar marijuana use were more likely to select each other as friends, and if a classmate's marijuana use was influenced by friends' use.

Findings: Past 30-day marijuana use increased in prevalence across 9th grade. Classmates with similar marijuana use were more likely to select each other as friends, and classmates were more likely to adopt similar patterns of marijuana use as their friends. This influence effect did not depend on the friend's popularity or closeness; best friends had no more influence on marijuana use than less-close friends.

Conclusion: In the transition into high school, adolescents tend to select friends who report similar recent marijuana use, and are also more likely to adopt the marijuana use patterns of their friends regardless of how close or popular they are.

Introduction

Substance use during adolescence can increase the risk of harming the brain (1), which is still developing into the early twenties (2). Several states have legalized the sale of recreational marijuana for individuals aged 21 years or older, and this change in legislation has affected adolescents' attitudes towards using marijuana as well as likelihood of using. In Oregon, the legalization of recreational marijuana was followed by increased use in adolescents who had already begun using marijuana, but did not increase the likelihood for adolescents to initiate use (3). Following the legalization of recreational marijuana use in Washington, adolescents were more likely to use marijuana and perceive it as less harmful to use, but this pattern was not observed in Colorado (4).

The 2017 Youth Behavior Risk Survey reported that almost a quarter of youth in the U.S. have tried marijuana by 9th grade, and 13% report having used marijuana in the past 30 days (5). By 10th grade, a third have tried marijuana and 19% report recent use (5). The school environment is known to affect adolescent marijuana use; for instance, students attending high-performing charter schools reported less marijuana use in the previous 30 days compared to students attending traditional public high school (6). Feelings of school connectedness appears to protect high school students from the influence of high-status peers (7), whereas negative attitudes towards school put students at risk for receiving offers of marijuana and being influenced by friends who use (8). The present investigation goes further, addressing how peers and friends within school environments—where adolescents spend the majority of their daily lives—influence the likelihood of marijuana use in the transition into high school.

Early longitudinal social network investigations of friendship networks within school environments using the Add Health dataset demonstrated that adolescents are likely to choose

friends with a similar history of marijuana use (“selection”) (9), and that this effect is not driven by similarities in current marijuana use or associated risk factors such as school performance or delinquency (10). However, these early studies presented mixed results regarding how marijuana use affects the marijuana use of their friends (“influence”), and thus how it spreads through adolescent social networks. A study of two schools within the Add Health dataset found evidence that marijuana use spread mainly through closer (viz., reciprocated) friendships in one school, whereas the popularity status of the marijuana-using friend was an important moderator of influence in the other school (11). These investigations have provided important insight into how marijuana use might influence friendship selection and how social network characteristics can moderate the spread of marijuana use in adolescence. Modeling selection and influence simultaneously has, in particular, been an important innovation, allowing investigators to isolate social influence (behavior change based on exposure to friends’ behavior) from the common but non-generative tendency for similarly-behavior youth to affiliate.

However, these studies have been limited in several ways. Only two out of 16 Add Health schools provided suitable data, and just two waves of data were available for each school. Moreover, the Add Health dataset is now over 20 years old. Given the changing community norms and policies pertaining to marijuana use, there is a critical need to understand how social risk factors may influence marijuana use in the transition to high school using recently collected data in locations where adult recreational marijuana has been legalized. With adolescents already beginning to perceive marijuana use as less harmful (4), it is possible that peer influences will be broader, and less likely a function of closer friendships or popularity. Instead, marijuana use may show signs of having dynamics somewhat similar to alcohol, where use is relatively widespread,

attitudes are permissive, and peer influence is not typically dependent on closeness of the relationships or popularity (12,13).

Given the changing community norms and policies pertaining to marijuana use, however, there is a critical need to understand how social risk factors may influence marijuana use in the transition to high school using recently collected data in locations where adult recreational marijuana has been legalized. The present investigation includes four waves of data collected in the last five years, in a state where marijuana was legalized for adult recreational purposes during data collection. Although the sample size is comparable with the above-noted Add Health studies, our data included twice the number of observations during the one-year time span, and three times as many distinct communities.

Methods

Participant Recruitment

Participants were drawn from 12 schools with 8th graders, within seven school districts in Oregon. Two cohorts of 8th grade students from these communities were recruited for study participation. Cohort 1 was recruited from seven schools in three school districts in spring 2014 and Cohort 2 was recruited from five schools in four school districts in spring 2015. One school district from Cohort 1 was excluded from the present study because the large number of changes in affiliation between middle school and high school impacted our ability to accurately estimate network effects; therefore, only six total school districts were included in the analyses presented here. Participants were required to be able to read in English or Spanish. Families of all 8th grade students enrolled in participating schools received information about the study and a postage-paid opt-out card to request that their teenager not be included in the study. All students for

whom no opt-out card was received were eligible to participate. Students provided their assent prior to completing each survey and could opt out of any survey at any time. Of 1358 eligible participants over all four waves of data collected from spring of 8th grade to spring of 9th grade, 1075 (79%) completed at least two surveys and were included in the present analysis. Of participating youth, 50% were female and 39% were Latino/Hispanic. The research protocol was reviewed and approved by the Oregon Research Institute Institutional Review Board.

Data Collection

Online questionnaires were completed online at school during the spring of each cohort's 8th grade year (wave 1), and again in the fall (wave 2), winter (wave 3), and spring (wave 4) of the 9th grade year. Data included in the present analysis were collected between March 15 and June 15, 2014 for cohort 1, and between the same dates in 2015 for cohort 2. Research assistants were present to monitor survey completion. Students were not compensated. Participants reported on their own marijuana use and social relationships. Ethnicity and gender were obtained at the student's initial assessment. Newly-enrolled students were recruited at each assessment wave using the same recruitment procedures.

Measures

Network studies can include variables applying not only to individuals, but also to the set of all network ties. Ties may have various characteristics, referred to as "dyadic" variables. The network itself is a dyadic variable, as it captures the presence or absence of some type of relationship (friendship) between all dyads. Other social network measures can also be defined (e.g., popularity).

Friendship network. Network ties were based on participants' selections of up to 25 grade-mates they "spent free time with" in the previous 30 days from a complete list of eligible participants. At each wave, participants were asked several additional questions about each of these free-time relationships. These included a checkbox to indicate whether the selected individual was "...one of my best friends" (maximum of 10), which we refer to as a friendship tie.

Best friend. If a participant selected any other student as "one of my best friends", he or she was then given the option to select one of them as a "...very best friend". To avoid confusion, we refer only to this singular nomination as the "best friend" of the participant. This measure is used to define a closer network linkage than simple friendship.

Unsupervised time. The survey included several questions about participants' friend nominations. One asked how many days out of the previous 30 the participant had spent with the nominated friend when "...no adults were present for some or all of the time." This frequency measure was recoded into three categories numbered 0 (no days), 1 (1–9 days), and 2 (10 or more days) when used as an average characteristic of each individual (days averaged across friends).

Lifetime and recent marijuana use. At each wave, participants reported whether they had previously used marijuana in their lives and, if so, the number of days out of the previous 30 in which they had used marijuana. This individual frequency measure was recoded into three ordered categories of 0 (no lifetime use reported, or no reported use in the last 30 days), 1 (1–9 days), or 2 (10 or more days).

Same sex. On their first survey, participants were asked to self-identify as "female" or "male". This information was used to create a dyadic "same sex" variable at each wave.

Same ethnicity. Participants were asked how they would describe their ethnicity (Non-Latino/Hispanic or Latino/Hispanic) on their first survey. This information was used to create a dyadic “same ethnicity” variable at each wave.

Statistical Analysis

Modeling approach

Stochastic actor-oriented modeling (SAOM (14)) was applied to the data from each school district, using the R package *RSiena* (v.1.2-4 (15)). SAOM simultaneously models the probabilities of changes in ties within a single social network, along with probabilities of changes in some behavior (in this case, recent marijuana use) of each individual who is a member of that network. The network change and behavior change parts of a model are estimated jointly and interdependently, allowing us to disentangle influence effects from selection effects.

Analytical Procedures

To address our questions regarding friend influence effects on recent marijuana use, we developed a SAOM containing a suite of hypothesis-related effects, as well as additional control effects that help rule out alternative causal interpretations (these include known fundamental endogenous network dynamics, such as tendencies for ties to be reciprocated, to be extended to friends of friends, etc.). Our network equation predictors included recent marijuana use similarity, same sex, and same ethnicity. We addressed the following influence predictors of recent marijuana use: influence of exposure to marijuana using friends, influence of best friend’s marijuana use, how popularity might increase the likelihood of adopting the marijuana use

patterns of friends, and the influence of spending unsupervised time with friends.

A SAOM applies to a single network; there are several methods available for combining results from multiple networks. In this study, we defined the different school districts as sub-groups, which were then combined into one multi-group analysis. The multi-group approach allowed different rates of change in both friendships and marijuana use by district and wave, thus improving model estimation. Other parameters (such as the impact of being the same sex or ethnicity on friend selection) were constrained to be the same, in order to identify average effects common to all districts. Further technical details are available in (16) and the RSiena manual (15).

Results

Descriptive Statistics

Participation rates (surveys completed among all survey-eligible students) for each of the four survey waves were 88%, 87%, 80%, and 82%, respectively. Of the 1075 study participants (539 [50.1% female]; mean age \pm SD at enrollment: 13.9 \pm 0.36 years), 423 (39.3%) identified as Latino. The prevalence of recent marijuana use was 13.8% in the sample across all four waves. Percent of participants reporting ever using marijuana increased from 15% to 35% over the four waves. For students with any reported marijuana use during this time ($n=379$), the median recent marijuana use varied across waves from 5 to 8 days. The average number of days in the past 30 that participants reported spending unsupervised time with friends ranged from 1.59 to 5.13 days when summarized by district and wave.

Table 1 gives descriptive statistics for the sample as a whole, and for each of the individual participating school districts, numbered 1 through 6. The smaller districts (1-4) had

between 81 and 103 participants each, and the two larger-districts (5-6) ranged from 342 to 359 participants. Participation per wave was 980 to 1059, comprising 1075 unique individuals. Both network density and average number of friendship selections decreased between the spring of 8th grade and spring of 9th grade, whereas percent of reciprocated friendships did not change with time. The Jaccard index of friendship stability (number of unchanging ties as a percentage of all possible ties) ranged from 0.149 to 0.319.

Modeling

Our objective was to examine friend influence on recent marijuana use in adolescents transitioning into high school, and whether characteristics of the friendship impact the likelihood of use. We did so by developing models that included different influence parameters and comparing the impact of these parameters on friend selection and marijuana use. These models are shown in Table 2 and described below. Models differ only in terms of the different predictors of recent marijuana use frequency. Not all combinations of these effects could be modeled simultaneously because of resulting model convergence issues, usually resulting from data that do not distinguish clearly among them; we address this limitation in our conclusions.

Network dynamics. Predictors of friendship formation and change are described in the network dynamics section of Table 2. Most of these effects are needed for control purposes; only the marijuana use similarity effect is relevant to our hypotheses.

“Rate” effects (the expected number of latent tie changes by district and wave) are not shown in Table 2, but can be found in (Table S1). Rate effects serve a weighting role for estimating substantively relevant parameters. The median rate is about 8 (ranging from 3.5 to 22.2), and the distribution of these estimates is slightly right-skewed. Table 2 shows the average

network dynamic effects common across school districts.

Control variable effects typical of adolescent friendship networks were observed: individuals with a greater number of friendship selections were less likely to select more individuals as friends (negative outdegree); friendships tended to be reciprocated (positive reciprocity); individuals who share friends were more likely to be friends themselves (positive transitive triplets); and status hierarchies were evident (negative 3-cycles). Adolescents were more likely to select each other as friends if they share the same gender ($b = 0.58 \pm 0.03$) and ethnicity ($b = 0.18 \pm 0.03$).

There was a tendency for youth with similar frequencies of recent marijuana use to select each other as friends ($b = 0.56 \pm 0.10$), further suggesting an important role of this behavior in structuring friendship networks.

Behavior dynamics. Social network and individual-level predictors of recent marijuana use are described in the behavior dynamics section of Table 2. Latent change estimates by district across wave pairs ranged from about 0.5 to 5.5, with a mean of 2 and a median of 1.6 (see Table S1). Adolescents with friends who report more recent marijuana use were more likely to increase their frequency of recent marijuana use (Model 1; $b = 0.52 \pm 0.14$). Adolescents were likely to adopt similar recent marijuana use patterns of their best friend (Model 2; $b = 0.37 \pm 0.15$); however, the influence of the best friend was non-significant once use by all friends was included (Models 3 and 4). Model 5 included a term that conditioned the influence of friends' recent marijuana use on friends' popularity. Such a model would normally also include (unconditional) friend use, to allow an interpretation that the conditional effect was not simply due to its friend use component alone. Models with both of these terms did not converge, but nevertheless the conditional effect was not statistically significant, consistent with friend

popularity status not being a moderator of the friend use effect. Unsupervised time with friends did not seem to influence recent marijuana use differently than total time spent (Model 6).

To address the possibility that the above marijuana-related effects did not simply represent a correlated but more general substance-using effect, we examined whether including recent alcohol use in our network and behavior models would absorb the variance captured by recent marijuana use (Table S2). Results demonstrate that the recent alcohol use of friends explains unique variance in friendship selection as well as influence on adolescents' marijuana use patterns, but does not reduce the magnitude of associations found for recent marijuana use.

Discussion

We applied a longitudinal social network approach to identify the mechanisms by which social interactions within the school environment influence marijuana use in 1075 adolescents transitioning into and across the first year of high school. Our results demonstrate that adolescents tend to select friends who report similar recent marijuana use, and are also more likely to adopt the marijuana use patterns of their friends regardless of how close or popular they are. The likelihood of using marijuana over the past month was not influenced by the amount of unsupervised time spent with friends. Taken together, these results point to an increasing acceptance of marijuana use during adolescence.

The marijuana-related social dynamics observed in this study are similar to those observed for adolescent alcohol use, and differ from social processes previously observed for adolescent marijuana use. This could portend a national shift in social dynamics regarding adolescent marijuana use as more states begin to legalize recreational marijuana use for adults. Our work adds to mounting evidence that pediatricians and clinicians should take a similar approach to discouraging adolescent patients' marijuana use as they do for alcohol (17). This

means sending a clear, consistent message against the use of marijuana by those under age 21 years and providing anticipatory guidance to adolescents on marijuana use as part of routine care. Providing educational materials to families regarding the impact of marijuana use on adolescent health and discussing how family members' marijuana use and perceptions of marijuana use can impact adolescents' decision to use marijuana are likely needed to mitigate widespread peer influences on marijuana use.

Results also suggest that a broad approach may be effective in reducing marijuana use through peer influence. Perhaps interventions that address how increased commercialization of marijuana use takes advantage of younger consumers, similar to approaches adopted by healthy-eating campaigns (18), would be an effective approach to take within the school setting to reduce marijuana use during adolescence.

Limitations

The current study, while inclusive of several school districts sampling rural and suburban areas of Western Oregon, is limited in geographic scope, and does not qualify as a nationally representative sample. Therefore, it is unclear how generalizable these findings are for other states that have legalized recreational marijuana use for adults, as well as states that have not. The current study is unable to parse between the influences of shifting cultural norms around marijuana use, increased commercialization, and recreational legalization of marijuana use. Also, our models did not always provide clear answers to questions regarding the effect of friends' marijuana use independent of correlated behaviors such as alcohol use. Such questions might be answered by larger studies, or meta-analysis-based pooling of existing data across studies.

Conclusions

Recent changes in public policy may be responsible for a pattern of marijuana use diffusion through adolescent social ecologies that resembles the diffusion of alcohol use. In recent decades, marijuana has become a socially acceptable recreational drug for adults, but studies have found that, like alcohol, its use among still-developing adolescents is dangerous and ill-advised. Pediatricians and other health care workers serving this population thus are in a position to leverage existing strategies designed for discouraging use of other substances, particularly alcohol, to reduce the spread of marijuana use among adolescents.

Acknowledgements

This research was supported by grant R01DA034062 from the National Institute on Drug Abuse. The funder had no role in the design and conduct of the study; collection, analysis, or interpretation of the data; or preparation, review, or approval of the manuscript. Authors wish to recognize an excellent assessment team: Cathy Milchak, Kristina Hulegaard, Cynthia LaMorticella, Robin Ware, and Katherine Bravo Aguayo.

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Table 1

Descriptive Statistics of District Networks and Students by Wave

		Overall	<i>District 1</i>	<i>District 2</i>	<i>District 3</i>	<i>District 4</i>	<i>District 5</i>	<i>District 6</i>
Number of participants	<i>W</i> ₁	980	81	78	88	85	338	310
	<i>W</i> ₂	1048	90	79	100	94	349	336
	<i>W</i> ₃	1059	91	81	101	96	359	331
	<i>W</i> ₄	1045	88	80	101	94	349	333
Density: Number of outgoing friend nominations as % of max possible	<i>W</i> ₁	27.4%	25.3%	23.6%	25.0%	23.3%	27.5%	30.7%
	<i>W</i> ₂	22.3%	21.9%	24.4%	26.6%	17.4%	16.9%	27.7%
	<i>W</i> ₃	15.6%	14.3%	13.8%	15.7%	14.2%	12.3%	20.3%
	<i>W</i> ₄	13.9%	16.6%	14.3%	15.3%	11.5%	9.4%	18.1%
Percent reciprocated ties	<i>W</i> ₁	38.2%	43.9%	38.0%	45.5%	35.4%	32.8%	41.1%
	<i>W</i> ₂	32.6%	41.6%	41.5%	41.4%	23.2%	22.0%	34.8%
	<i>W</i> ₃	30.5%	44.6%	17.9%	37.7%	30.9%	23.1%	33.0%
	<i>W</i> ₄	31.4%	41.1%	26.3%	34.8%	33.3%	20.7%	34.5%
Average outdegree	<i>W</i> ₁	2.65	2.53	2.33	2.50	2.33	2.75	3.07
	<i>W</i> ₂	2.21	2.16	2.44	2.63	1.69	1.69	2.75
	<i>W</i> ₃	1.53	1.43	1.42	1.54	1.37	1.23	1.98
	<i>W</i> ₄	1.35	1.60	1.41	1.50	1.09	0.91	1.76
Jaccard Indices: Change in ties from previous wave ^a	<i>W</i> ₁	-	-	-	-	-	-	-
	<i>W</i> ₂	-	0.229	0.261	0.272	0.195	0.149	0.242
	<i>W</i> ₃	-	0.292	0.230	0.308	0.186	0.192	0.237
	<i>W</i> ₄	-	0.255	0.256	0.319	0.202	0.200	0.227
Percent participants who have ever used marijuana	<i>W</i> ₁	15.3%	16.5%	16.0%	11.7%	23.2%	13.4%	15.8%
	<i>W</i> ₂	25.2%	31.9%	23.5%	24.3%	34.3%	23.1%	23.7%
	<i>W</i> ₃	30.5%	34.1%	27.2%	30.1%	39.4%	28.4%	30.1%
	<i>W</i> ₄	35.3%	39.6%	28.4%	35.0%	47.5%	32.3%	35.4%
Median prior 30-day	<i>W</i>	2	1	0	15	3	2	1

marijuana use, given onset	<i>W</i> ₁							
	<i>W</i> ₂	1.5	1	0	2.5	1	2	1
	<i>W</i> ₃	1	1	0	2	1	2	1
	<i>W</i> ₄	2	2	0	2	1	2	2
Average days unsupervised (across friends) in past 30 days	<i>W</i> ₁	3.59	2.48	5.00	2.72	2.91	3.95	3.64
	<i>W</i> ₂	3.83	4.43	4.08	5.13	3.05	3.04	4.29
	<i>W</i> ₃	2.82	2.25	2.21	2.77	2.62	2.48	3.56
	<i>W</i> ₄	2.48	1.90	2.60	3.48	2.04	1.59	3.38

^aJaccard index is a measure of change in ties in relation to total number of ties that could have changed.

Table 2. Model results for network and behavior dynamic effects on past 30-day marijuana use

	Model 1			Model 2		
	<i>Mean Parameter</i>			<i>Mean Parameter</i>		
	<i>Estimate</i>	<i>SE</i>	<i>T stat</i>	<i>Estimate</i>	<i>SE</i>	<i>T stat</i>
Network dynamics						
Outdegree	-3.68	0.04	-90.09	-3.68	0.04	-91.15
Reciprocity	2.33	0.05	48.12	2.34	0.05	49.32
Transitive triplets	1.47	0.06	25.26	1.47	0.06	25.98
3-Cycles	-0.47	0.05	-9.58	-0.47	0.05	-9.71
Same Gender	0.58	0.03	18.26	0.57	0.03	18.88
Same Ethnicity (Latino)	0.18	0.03	5.20	0.18	0.03	5.22
Marijuana Use Similarity	0.56	0.10	5.61	0.55	0.10	5.38
Behavior dynamics						
Marijuana Use linear shape	-3.23	0.15	-20.91	-3.31	0.16	-20.91
Marijuana Use quadratic shape	1.60	0.12	13.41	1.71	0.11	14.96
Marijuana Use Total Friend	0.52	0.14	3.78	-	-	-
Marijuana Use Influence from Best Friend	-	-	-	0.37	0.15	2.46
Marijuana Use Total Friend x Best Friend	-	-	-	-	-	-
Marijuana Use Total Friend x Popularity	-	-	-	-	-	-
Marijuana Use Influence from Average Days Unsupervised with Friends	-	-	-	-	-	-
<hr/>						
	Model 3			Model 4		
	<i>Mean Parameter</i>			<i>Mean Parameter</i>		
	<i>Estimate</i>	<i>SE</i>	<i>T stat</i>	<i>Estimate</i>	<i>SE</i>	<i>T stat</i>
Network dynamics						
Outdegree	-3.68	0.04	-87.10	-3.68	0.04	-88.54
Reciprocity	2.34	0.05	49.95	2.33	0.05	46.68
Transitive triplets	1.47	0.06	25.73	1.47	0.06	24.78
3-Cycles	-0.47	0.05	-9.85	-0.47	0.05	-9.32
Same Gender	0.58	0.03	18.50	0.58	0.03	18.31
Same Ethnicity (Latino)	0.18	0.03	5.22	0.18	0.03	5.30
Marijuana Use Similarity	0.56	0.10	5.50	0.56	0.10	5.68
Behavior dynamics						
Marijuana Use linear shape	-3.23	0.16	-20.34	-3.23	0.16	-19.97
Marijuana Use quadratic shape	1.60	0.12	13.22	1.60	0.12	13.13
Marijuana Use Total Friend	0.51	0.15	3.36	0.50	0.17	2.96

Marijuana Use Influence from Best Friend	0.02	0.21	0.09	-	-	-
Marijuana Use Total Friend x Best Friend	-	-	-	0.00	0.01	0.17
Marijuana Use Total Friend x Popularity	-	-	-	-	-	-
Marijuana Use Influence from Average Days Unsupervised with Friends	-	-	-	-	-	-

	Model 5			Model 6		
	<i>Mean Parameter</i>			<i>Mean Parameter</i>		
	<i>Estimate</i>	<i>SE</i>	<i>T stat</i>	<i>Estimate</i>	<i>SE</i>	<i>T stat</i>
Network dynamics						
Outdegree	-3.68	0.04	-89.82	-3.65	0.04	-93.75
Reciprocity	2.33	0.05	44.89	2.35	0.05	51.14
Transitive triplets	1.46	0.06	23.72	1.47	0.06	25.97
3-Cycles	-0.46	0.05	-9.43	-0.47	0.05	-9.68
Same Gender	0.58	0.03	18.10	0.57	0.03	18.77
Same Ethnicity (Latino)	0.18	0.04	5.07	0.15	0.03	5.10
Marijuana Use Similarity	0.57	0.11	5.25	0.55	0.10	5.71
Behavior dynamics						
Marijuana Use linear shape	-3.87	0.50	-7.80	-3.32	0.16	-20.35
Marijuana Use quadratic shape	2.13	0.34	6.34	1.74	0.11	15.16
Marijuana Use Total Friend	-	-	-	-	-	-
Marijuana Use Influence from Best Friend	-	-	-	-	-	-
Marijuana Use Total Friend x Best Friend	-	-	-	-	-	-
Marijuana Use Total Friend x Popularity	0.62	0.38	1.62	-	-	-
Marijuana Use Influence from Average Days Unsupervised with Friends	-	-	-	-0.02	0.07	-0.26