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Selection and Influence Mechanisms Associated With Marijuana Initiation and Use in Adolescent Friendship Networks

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Abstract

Friends are thought to influence adolescent drug use. However, few studies have examined the role of drugs in friendship selection, which is necessary to draw sound conclusions about influence. This study applied statistical models for social networks to test the contribution of selection and influence to associations in marijuana use among friends in two large high schools (N = 1,612; M age = 16.4). There was evidence for friend selection based on similar lifetime and current marijuana use at both schools, but friends were found to influence the initiation and frequency of adolescent marijuana use in just one of these schools. There was minimal evidence that peer effects were moderated by personal, school, or family risk factors.

Although adolescent marijuana use in the United States has been declining for years, this trend has recently started to reverse (Johnston, O'Malley, Bachman, & Schulenberg, 2012). Early initiation of marijuana use, and regular use in adolescence, are both robust predictors of drug use disorders in adulthood (Swift, Coffey, Carlin, Degenhardt, & Patton, 2008), and even experimental use during adolescence has been associated with poorer young adult outcomes (Tucker, Ellickson, Orlando, Martino, & Klein, 2005). Thus, adolescence is a critical developmental period for drug prevention and intervention. Although considerable progress has been made in identifying risk and protective factors associated with youth drug use, psychosocial prevention programs tend to have small to medium effects on behavior that are not enduring (Botvin & Griffin, 2007). Peer influence is often a focus of prevention programs as it plays a central role in theories of adolescent problem behavior, and is a key correlate of substance use (e.g., Botvin & Griffin, 2007; Cuijpers, 2002; Valente et al., 2007). However, limitations in this research preclude drawing strong conclusions about the extent to which peer relationships are a *contributing factor* to youth marijuana use, or in identifying youth who are most susceptible to peer influence.

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Peer and friend influence on youth drug use

Numerous studies have shown that peers' and friends' drug use predicts adolescent use (Coronges, Stacy, & Valente, 2011; Creemers et al., 2010; Duan, Chou, Andreeva, & Pentz, 2009; Kandel, 1978; Maxwell, 2002; Poulin, Kiesner, Pedersen, & Dishion, 2011; Wills & Cleary, 1999), with effects persisting for up to a decade (Perkonigg et al., 2008). Additionally, friend drug use is a stronger predictor of adolescent drug use than wider peer group norms (Duan et al., 2009), suggesting that close relationships may be especially trusted contexts for the use of illicit drugs and their socialization. Friends are valued social referents that play a key role in social learning by modeling, reinforcing, or punishing particular behaviors (Bandura, 1977); they are a source of behavioral norms (Festinger, 1954); and they may also provide opportunities for engaging in drug use (Oetting & Beauvais, 1986). Because the majority of young people *do not* use marijuana (Johnston et al., 2012), friends may also serve as a protective factor if their behaviors and norms endorse abstaining from marijuana use (Maxwell, 2002).

Drug use and friendships are embedded in broader bioecological systems

The growing integration of bioecological theory, systems science, and social network analysis in the fields of public health and child development has highlighted the interdependent and nested relationship between social settings and health. Applied to the study of substance use, this necessitates recognizing that youth are not only *influenced by their peers*, but that they also *influence their social settings* via the selection of friends (Brechwald & Prinstein, 2011; Poulin et al., 2011; Veenstra & Dijkstra, 2011). These selection and influence processes are likely interdependent because behaviors that are socially meaningful in peer contexts may be a basis for friendship choices and achieving peer acceptance. The friendship dyads and groups that form as a result are likely to further reinforce this behavior among group members.

Empirical research on alcohol and cigarette use provides convincing evidence that adolescents seek out friends who are similar to them in terms of substance use, and that these friends also influence their substance use (Bauman & Ennett, 1996; Go, Green, Kennedy, Pollard, & Tucker, 2010; Go, Tucker, Green, Pollard, & Kennedy, 2012; Mercken, Candel, Willems, & de Vries, 2009; Pearson, Steglich, & Snijders, 2006; Poulin et al., 2011; Wills & Cleary, 1999) . Whether these selection and influence processes also hold for marijuana is unclear, and may differ given that marijuana use is less socially accepted than alcohol and cigarettes. A handful of studies looking explicitly at selection and influence processes for marijuana use have reported mixed results: two studies found that youth select friends with similar marijuana use, and that friend use also predicted changes in adolescent use (Kandel, 1978; Poulin et al., 2011), whereas two studies found evidence of influence but not selection (Pearson et al., 2006; Wills & Cleary, 1999). Only the study by Pearson and colleagues (2006) applied longitudinal social network methods that capture self-reported information on relationships and behaviors. Additionally, they were the only study to apply stochastic actor-based models (SABMs) that are described throughout this special issue and elsewhere (Snijders, Steglich, & Schweinberger, 2007; Snijders, van de Bunt, & Steglich, 2010), which currently provide the most sophisticated approach to teasing apart these processes.

A key advantage of a methodological approach that utilizes information on complete social networks is that friendship and drug use measures are self-reported, rather than relying on youths' often biased perceptions of their peers' behavior (Bauman & Ennett, 1996). Additionally, complete network methods provide information on the relationships that are present *and absent* among a population of youth, allowing us to statistically model factors

that predict friendship choices among a set of potential friends. Finally, SABMs allow us to test for selection and influence processes simultaneously, controlling for each other.

The current study builds on the work by Pearson and colleagues (2006), who applied SABMs in their study of peer effects on marijuana use in a small sample ($N = 160$) of early adolescents in Scotland. This paper examines friendship selection and influence processes among a substantially larger sample of youth in middle to late adolescence in the U.S. We also consider the initiation of marijuana use, as well as changes in the frequency of use, and the role of friends in these transitions.

Factors associated with susceptibility to peer effects on marijuana use

Friendship and marijuana use dynamics also operate in a larger context that includes personal, family, school, and neighborhood characteristics (Bronfenbrenner, 1977). A range of these factors exert independent influences on adolescent development and behavior, and may also interact in complex ways to moderate adolescents' susceptibility to peer influence, or their selection of friends based on drug-use behaviors. Empirical support for a multiplicative model of risk (Jessor, 1991; Prinstein, Boergers, & Spirito, 2001) suggests that distress arising from various personal and family risk factors can make some youth more susceptible to adopting the risk behaviors of their peers (Prinstein et al., 2001). Cross-sectional and longitudinal studies find that peer and adolescent risk behaviors are more strongly related for youth with risk factors such as depression, social anxiety, and internalized distress (Cohen & Prinstein, 2006; Prinstein et al., 2001); low academic achievement (Bryant, Schulenberg, O'Malley, Bachman, & Johnston, 2003); family dysfunction (Farrell & White, 1998; Prinstein, et al., 2001), parent substance use (Chaoyang, Pentz, & Chih-Ping, 2002; Clark & Lohéac, 2007), and permissive households (Tucker, Ellickson, & Klein, 2008).

Whereas many of the studies outlined above provide support for a multiplicative model of risk in relation to adolescents' susceptibility to peer influence on substance use, these risk factors may also heighten tendencies for risky peer selection. For example, youth with temperaments characterized as difficult, or high-intensity pleasure seeking, are more likely to associate with substance using peers (Creemers et al., 2010; Wills & Cleary, 1999). To date, no studies have applied SABMs to partition out selection effects for marijuana use, and test the moderating role of other risk factors on this process. Thus, research is needed to determine if a multiplicative model of risk applies to marijuana-based friendship choices and friend influence on marijuana use, when these processes are modeled simultaneously.

Research aims of the current study

This paper uses data from the National Longitudinal Study of Adolescent Health (Add Health) and applies SABMs to determine the extent to which friendship networks influence marijuana use (influence effects) and marijuana use influences friendship selection (selection effects). We hypothesize that friendships will be based on similar drug use behaviors, and that adolescents' drug use will be influenced by the behaviors of their friends. Additionally, we will test if these processes differ for lifetime initiation of marijuana use and for changes in the frequency of drug use. We anticipate that these peer effects will be similar given recent research showing that perceived peer substance use predicted both lifetime and regular marijuana use among Dutch youth (Creemers et al., 2010).

The second aim of the study is to assess if a multiplicative model of risk explains differences in marijuana-based selection and influence. In line with the correlational studies reported above, peer influences are expected to be stronger for individuals with poorer mental health and self-esteem; greater involvement in delinquency; weaker academic orientation and

school attachment; and individuals from households where there is greater exposure to drugs and lower parental involvement. We adopt an exploratory approach to testing moderator effects on marijuana-based friendship selection as there is limited literature from which to formulate specific hypotheses.

Method

Sample

Add Health is a study of adolescent health conducted in the U.S. (Bearman, Jones, & Udry, 1997), with participants recruited from a school-based probability sample of adolescents in Grades 7-12. Friendship nominations were collected at Wave I (1994-1995) and Wave II (1996) providing longitudinal information on the friendship networks of participants. The current study uses data from two large schools that were part of a "saturated school sample" developed by inviting *all* enrolled students in select schools to complete baseline in-home interviews. Although there were 16 'saturated schools' in total, we utilize data from two of these schools for the current analyses because most were too small in size, had too much missing data, or had very low rates of marijuana use. These two schools were notably different: one is ethnically heterogeneous and located in a major metropolitan area (school 1); the other is predominantly white and located in a mid-sized town (school 2). Information on adolescents' substance use and friendships in these saturated schools provide us with the rare opportunity to explore drug use in the context of *complete* grade-based friendship networks over time.

We limited our analysis to grade-level cohorts captured at Wave I and Wave II in both of these schools: thus any participant who was in grade 10 or 11 at Wave I, *or* who was in grade 11 or 12 at Wave II. This resulted in a total sample of 1,612, nested in two schools. In school 1 there were 1193 participants, 51.3% male and mean age = 16.34 (SD = 0.85). In school 2 there were 419 participants, 56.8% male and mean age = 16.47 (SD = 0.84). Retention rates at Wave II were 88.1% in school 1 and 87.4% in school 2. Enrollment was only undertaken at baseline and thus new students were not invited to participate at Wave II.

Measures

Data used in this study came from three surveys with participating adolescents, and one survey of their parents. Baseline questionnaires were administered to participants at school, followed by Wave I in-home surveys that assessed friendships and drug use behaviors. Wave II in-home surveys were conducted approximately one year later. A parent questionnaire was also included in the Wave I in-home assessment, and captured information on parent and household demographics. Measures are described below, and more detailed information on the source of these items can be found at: http://www.cpc.unc.edu/projects/addhealth/data/guides/refer.pdf .

Friendships—Respondents were asked to name up to five male and five female friends. School-based friends who were also participants in Add Health were coded with their respective identification numbers (out-of-school nominations were given specific codes). Only friendship nominations among participants in the current sample were included in subsequent analyses. Due to errors with a small number of computers used for data collection at Wave I, some participants were given the opportunity to name only one male and one female friend. This error occurred for approximately 5% of the current sample. To account for this issue, students with 'limited nominations' at Wave I were dummy-coded and this was included as a control in all models.

Marijuana use—Items assessed the number of times respondents had used marijuana a) in their lifetime (Wave I only), b) in the past year (Wave II only), and c) in the past 30 days (Wave I and Wave II). This information was used to create a dichotomous measure of lifetime use at each wave (where 1 = had ever used marijuana, with changes from 0 to 1 in lifetime use between waves capturing initiation), and a continuous measure of frequency of past month use. To deal with outliers and create a more normally distributed dependent variable, frequency of past month use was rescaled by taking the log of "number of times marijuana was used in the past 30 days", adding a constant of 1, and rounding to the nearest whole number. This recoded scale represents the following categories of past month use: 0 = none, 1 = 1 to 3 times, 2 = 4 to 11 times, 3 = 12 to 32 times, 4 = 33 times or more. Outliers whose frequency of use exceeded 90 times in the previous month (scores of 5 and 6 on this scale) were recoded and given a value of 4.

Respondent-level moderators

Personal risk factors: Depression was measured using the CES-D (Radloff, 1977), and calculated as the mean of 19 items assessing the frequency of experiencing different symptoms of depression (e.g., loss of appetite, feeling depressed) during the last week (1 = *never or rarely* to 4 = *most of the time or all of the time*; α =.86). Self-esteem was measured by averaging respondents' agreement (l = *strongly agree*, 5 = *strongly disagree*) with six statements (e.g. "you have a lot of good qualities"), some of which were reverse coded so that lower scores indicate low self-esteem (α = .84). Delinquency was measured with 15 items asking the number of times during the past year that specific delinquent behaviors were performed (e.g., property damage, theft, selling drugs) with responses ranging from 0 = *never* to 3 = *5 or more times*. Due to skewness, responses greater than 1 were set equal to 1 for each item, and a summary variable was created by calculating the proportion of delinquent acts endorsed (α = 0.80).

School risk factors: Academic orientation was based on respondent reports of their past year grades in English or language arts, mathematics, history or social studies, and science (1=A, 2=B, 3=C, 4=D or lower). These grades were used to compute a GPA scale, and responses were reverse-scored so that a lower value reflected low GPA (α = 0.75). School attachment was assessed by a 3-item scale (α = .72), measuring agreement (1 = *strongly agree* to 5 = *strongly disagree*) towards feeling close to people at school, part of their school, and happy at school over the last year. Trouble at school was assessed with four items asking how often in the past year the respondent had trouble paying attention, getting along with teachers, getting along with other students, and getting homework done (0 = *never* to 4 = *every day*; α = 0.69).

Family risk factors: Family bonding was measured using three subscales: closeness with mother (5 items); closeness with father (5 items), and overall family closeness (3 items). Responses were recorded on one of two 5-point scales (1 = *not at all* to 5 = *very much*; 1 = *strongly agree* to 5 = *strongly disagree*) and items were combined so that lower scores reflected less family bonding (α = 0.75 for the overall scale and > 0.70 for each subscale). Respondents were also asked whether illegal drugs were easily available in their home (1 = *yes*).

Control attributes—Analyses controlled for Wave I measures of gender, race or ethnicity, and grade (1 = older grade cohort). Family socioeconomic status was also controlled, based on the highest level of education attained by either parent (parent report; 1 = *<high school*, 2 = *high school or trade school*, 3 = *some college*, 4 = *college graduate*). We also included a measure for the number of outside-of-school friends the adolescent had,

derived from the number of non-school based friends they had listed during the friend nomination task.

Analytic method

To test for effects of marijuana use on the friendship network, and the role of friendships on adolescent marijuana use, we applied SABMs (Snijders et al., 2007; Snijders et al., 2010; Veenstra, Dijkstra, Steglich, & Van Zalk, 2013) implemented in the RSiena program (Ripley, Snijders, & Preciado, 2012). Each school cohort was defined as a separate social network, and models were fit for each school group with missing data imputed by the program (Ripley et al., 2012). Because of the limited number of friend nominations in the questionnaire, the maximum outdegree for the simulated networks was set at 10. Model parameters were estimated using a Methods of Moments procedure and were tested for significance based on a *t*-ratio (estimate divided by the standard error).

Two models were estimated to examine associations of adolescent friendships with a) marijuana initiation, and b) frequency of past month marijuana use. Each model includes effects predicting the evolution of the friendship network (friend selection effects), and effects predicting marijuana use (marijuana effects). For the model predicting marijuana initiation, which is a monotonic dependent variable, newly developed stochastic actor-based (SAB) diffusion models were applied (Greenan, 2012). This model is more appropriate than traditional SABMs because they estimate effects on the rate of *initiation of use*, not the direction of change (typically captured in the evaluation function) (see Ripley et al., 2012).

A forward selection approach to model specification (Snijders et al., 2010) was applied in developing these models, whereby control effects (covariates and network structure) on network and marijuana dynamics are score tested against a null model (Schweinberger, 2012). Covariates found to predict significantly network or behavior dynamics were retained in the final models.

Effects predicting friend selection—To test for effects of marijuana use on friendship selection, we estimated parameters that depict the marijuana use of the respondent (called *ego*) and of their peers (called *alters*). These include an effect of adolescents' marijuana use on their tendency to nominate friends (marijuana use ego); an effect of peers' marijuana use on actor's preference to nominate them as a friend (marijuana use alter); and an effect of same (dichotomous) or similar (continuous) marijuana use between actors and potential friends to determine if friendships were more likely to form among peers with similar drug use (same or similar marijuana use). All models controlled for effects of network structure and actor covariates (gender, race, grade, parent education) on friendship network dynamics.

Effects predicting marijuana use—These models simultaneously tested for effects predicting change in actors' marijuana use, including influence from friends. For the models of marijuana initiation, friend influence was tested with two effects: the effect of having friends who had ever used marijuana in their lifetime (a distal predictor), and the effect of having friends who had used marijuana in the past month (a proximal predictor). These two effects were tested independently to avoid issues of multicollinearity.

For models predicting frequency of marijuana use, friend influence was tested using a parameter that assesses the impact of friends' total marijuana use (i.e., total similarity effect) on changes to adolescent use (Ripley et al., 2012). The specification of this effect is based on the *sum* of similarity scores between actors and their friends; a greater difference in summed scores between actors and their friends is particularly influential. This effect was selected over other potential specifications of friend influence because it consistently converged across the models, and was statistically significant in score tests. Covariate

effects on changes to marijuana use were also controlled in all models (gender, race, grade, parent education, number of outside-of-school friends). In the models predicting marijuana frequency, linear and quadratic shape effects were included to model the overall distribution of the dependent behavior variable.

Models testing individual risk moderators—A separate model was estimated to test each of the following risk factors: depression, self-esteem, delinquency, GPA, school attachment, school trouble, family closeness, and access to drugs in the home. Models were specified that included the same effects included in the model for marijuana frequency described above: structural and covariate effects, effects for marijuana frequency on friendship dynamics, and a friend influence effect. Main effects for the risk factor on friendship dynamics (risk factor ego, alter) and on marijuana use dynamics were added to these models. The moderation effects were tested by including a term for the interaction between the actor's value of the risk factor (variable ego) and: a) the actor's selection of friends with similar marijuana use (similar marijuana use), and b) the effect of friends' frequency of marijuana use on the actor's frequency of marijuana use (friend influence).

Results

Descriptive results

Rates of marijuana use in each school are summarized in Table 1. From Wave I to Wave II, lifetime marijuana use went from 37.2% to 45.0% in school 1, and from 48.8% to 59.4% in school 2. Due to attrition, information on marijuana use is missing for approximately 20% of the sample at Wave II. Nonetheless, using the available information we identified 7.8% of participants in school 1 and 10.6% of students in school 2 who used marijuana for the first time over the year of the study. Rates of past month use were substantially lower than lifetime use, indicating that many respondents who had tried marijuana were not current users. In school 1, approximately 20% of participants had used marijuana in the past month at either wave; and in school 2 the corresponding percentage was 29.9% (Wave I) and 24.9% (Wave II). Respondent attributes included as controls in this study are also summarized in Table 1.

Characteristics of the school friendship networks are described in Table 2. On average, participants identified 2-3 friends at each wave, with the number of nominations ranging from 0-10 (the survey limit), and the number of nominations received ranging from 0-18. The proportion of friendship nominations that were reciprocated was approximately 30% in school 1, and 40% in school 2. The transitivity index captures the tendency for individuals who share a common friend to be friends, which was approximately 20% in the two schools. There was also substantial change in friendships between the two waves. As shown in Table 2, there was a high turnover of friends, with an average of 1 stable friendship observed at Wave I and Wave II. Of note, some of these "terminations" will be attributed to missing friendship data at Wave II (school 1 = 19.9%, school 2 = 12.6%).

Modeling the co-evolution of friendships and marijuana use

Lifetime marijuana use—SAB diffusion models were first estimated with initiation of marijuana use as the dependent behavior variable (Table 3). In both schools, lifetime marijuana use predicted actors' friendship choices. In both schools, adolescents who had used marijuana were significantly less likely than non-users to make a friend nomination (negative effect of MJ lifetime use ego), however lifetime marijuana use was not significantly associated with *receiving* friendship nominations (MJ lifetime use alter). In both schools, there was a highly significant effect for homophilic selection based on

marijuana use, meaning that adolescents tended to become or remain friends with peers whose lifetime use was the same as their own (same MJ lifetime use).

These models (Table 3) also controlled for covariate and structural effects on friendship network dynamics. In both schools, friendship choices were predicted by similarities in grade, and in school 1 they were also predicted by similarities in gender and race. Covariates also predicted the sending and receiving of friendship ties in school 1: students in the older grade cohort and students whose parents were more highly educated were less likely to nominate friends (grade ego, parents education ego), whereas students with these same attributes (older grade cohort, and parents with higher education) were *more likely* to receive friendship nominations (grade alter, parents education alter). Differences in the rate of friendship changes, and in the number of friend nominations made, for participants with limited nominations at Wave I were also controlled. Finally, structural effects were accounted for, including tendencies to reciprocate friend nominations, to befriend friends' of friends (transitive triplets and ties), and to avoid friendships with peers who nominated many friends (utdegree popularity square root). In school 1, there was also a tendency to form local hierarchies (negative effect of 3-cycles).

Controlling for factors predicting friendship networks dynamics, including the tendency for peers with similar lifetime marijuana use to become or remain friends, the second component of this model tested for effects predicting the 'diffusion' of marijuana initiation (Table 3, marijuana initiation dynamics). Having friends who had used marijuana in their lifetime (friends' lifetime MJ use) did not significantly predict adolescent initiation of marijuana use in either school. However in school 1 (but not school 2), having friends who had used marijuana in the past month predicted adolescent initiation of marijuana use. Most of the covariates did not significantly predict the initiation of marijuana use (including gender, grade, race, and parent education) although having more out-of-school friends positively and significantly predicted marijuana initiation in school 1 , but not school 2.

Frequency of recent marijuana use—A second model was estimated for each school cohort testing selection and influence effects for the frequency of past month marijuana use (Table 4). In both schools, adolescents formed or maintained friendships with peers who had similar levels of marijuana use. Frequency of marijuana use was not significantly associated with the number of friendship nominations made (MJ use ego) or received (MJ use alter). Effects of the covariates and network structure on friendship dynamics were essentially the same as reported for the marijuana initiation model.

Change in the frequency of marijuana use (Table 4, marijuana use dynamics) was found to have a significant negative linear shape, coupled with a positive quadratic shape, in both schools. This indicates that there was an overall tendency for actors to adopt low levels of marijuana use, but that there was also a pull towards extreme values of this scale: actors tended to become or remain non-users *or* escalate to frequent use. Over and above these change tendencies, frequency of marijuana use was not significantly predicted by friends' frequency of marijuana use, although there was a positive trend for this effect in both schools. Covariates that increased significantly the risk for frequent marijuana use were lower parent education in school 1 and being in the older grade cohort in school 2. Adolescents' gender, race, or number of outside-of-school friends did not significantly predict frequency of marijuana use.

Risk factors that moderate friend selection and influence for marijuana use—The second stage of analysis tested if individual risk factors (described in Table 5) moderated adolescents' tendency to select friends based on similar marijuana use, or to emulate the drug use behaviors of their friends. A SABM for the co-evolution of friendships

and frequency of marijuana use was estimated to test each moderating variable. Models were specified that included the same structural, covariate, and marijuana-related effects that were included in the model for marijuana frequency (see Table 4), with the addition of effects to test an interaction between the actors' score on the risk factor (variable ego) and effects of "similar marijuana selection" and "friend influence on marijuana use". Because we estimated this complex model for each moderating variable, in each school, only the moderation effects are reported in Table 6.

In school 1, there was a negative interaction between similar selection and delinquency, meaning that adolescents with higher delinquency scores were *less* likely to select friends based on similar marijuana use. Among the moderators of friend influence tested in school 1, the only significant interaction was for school trouble: adolescents were likely to adopt the marijuana use behaviors of their friends if they had high scores on the measure of school trouble. In school 2, there was a negative interaction between similar selection and family support: adolescents with less family support were more likely to select friends based on similar marijuana use. We found no evidence that the risk factors significantly moderated the effect of friends' marijuana use in school 2.

Discussion

Substance use research and prevention may benefit from studies that provide a clearer understanding of the ways in which young peoples' friendships influence, and are influenced by, various stages of marijuana use. This study applied novel statistical models for social networks to test for marijuana-related selection and influences processes and tested a multiplicative model of risk to identify individual-level moderators of these effects.

Findings indicated that friendship choices at the two schools were based on similarities in marijuana use, controlling for the selection of friends based on other potentially confounding factors (including endogenous network effects and correlated attributes such as gender, grade, SES, and ethnicity). These results suggest that, over and above preferences to establish mutual friendships, or friends with peers having similar demographic backgrounds, respondents showed a preference for friends with similar marijuana use in both schools. However, evidence of friend influence on marijuana use, controlling for these selection effects, was only evident in school 1. In this school, having school friends who had used marijuana in the past month significantly predicted an increased likelihood that adolescents would try marijuana for the first time. Frequency of past month marijuana use was also predicted by school friends' frequency of use, although only among youth who got in trouble at school, with these 'risky' adolescents adopting similar drug-use as their friends over the year of the study. Additionally, in this school, students whose parents attained a higher level of education were less likely to become or remain frequent marijuana users, whereas students who nominated more friends from outside their school were more likely to become or remain frequent users. The latter effect emphasizes the need for future research to consider the role of these non-school based friends, which may be particularly salient to youths' drug use in larger metropolitan centers (as was the case for school 1) where there is likely to be greater exposure to neighborhood or community-based friends who do not attend the same school. Research has shown that even among pre-adolescents attending 'high-risk schools', marijuana is perceived to be less easily accessible from people they know at school than from those they know in the neighborhood, who are encountered at parties, or who are older (Komro et al., 1999).

The results presented here suggest that the role of marijuana as a salient attribute in the peer context differed across these two schools. School 1 (characterized as a large ethnically and socio-economically diverse school) had slightly lower rates of both lifetime use, initiation of

use, and current use compared to school 2. Interestingly, it appears that levels of marijuana use were particularly relevant to friendships in school 1, as it was only in this school that we found evidence that friends influenced adolescent marijuana use. The somewhat lower prevalence of marijuana use in school 1 may mean that this behavior is a unique and socially relevant aspect of peer group identity, and thus a factor in friendship choices and susceptibility to peer socialization. Future research examining network effects on youth substance use would benefit from sampling multiple peer networks to begin identifying broader school-level factors that moderate network-level selection and influence processes. Potentially relevant school-level factors that might impact the salience of marijuana use in peer relationships include overall prevalence of the behavior, status-based norms (i.e., the extent to which marijuana use is associated with popularity) (Dijkstra et al., 2010), or school-level policies or programs related to drug use.

The next aim of this study was to test if individual-level risk factors impact adolescent's selection of friends based on marijuana use, or their susceptibility to adopt their friends' drug-using behaviors, as suggested by a multiplicative model of risk (Prinstein et al., 2001). We anticipated that negative personal attributes and contexts would heighten peer effects on drug use. However, of the numerous risk factors tested as moderators, few had significant effects. Moreover, factors that moderated selection and influence differed across the two schools. Only school trouble was found to positively moderate peer effects (school 1), indicating that students who got in more trouble at school were more likely to be influenced by the drug use behaviors of their friends. There were also few moderators of drug-based friend selection, and the two significant effects attenuated and accentuated tendencies to select friends based on similar drug use. In school 2, youth with higher levels of delinquency were significantly less likely to select friends based on similar marijuana use, whereas in school 2 youth with less family support were more likely to select friends based on similar marijuana use. Overall, the results provide little support for a multiplicative model of risk in predicting marijuana-based friend selection and influence. However, a limitation of the current analyses is that the moderating effects are partially explained by youth who do not use drugs forming friendships with peers who are also non-users. Thus, we are simultaneously testing if these risk factors moderate the selection of protective peer settings, or protective peer influence, which limits our ability to interpret directly these interactions.

Limitations

Although the Add Health data offer a valuable opportunity to explore a rich set of behaviors and characteristics in the context of complete peer networks, there are a number of limitations to consider. The restriction of 5 male and 5 female friend nominations may artificially restrict the distribution of outgoing friendship ties (i.e., outdegree). Although we consider both same-gender and cross-gender friendships in the current study, we do not test if these processes differ across these different friendship types. This would be a useful area for future research, as would be models for bipartite networks that focus on same-gender versus cross-gender nominations. Additionally, these data only allow us to examine the influence of friends in the same school. Studies of peer effects among youth would benefit from considering relationships outside of school settings, as well as including a broader range of peer relationships, in addition to friendships.

Additionally, complete network information is only available in a small number of schools that participated in Add Health, and longitudinal analyses of marijuana use were only possible in two of these schools. Thus, we were only able to compare qualitatively differences in peer effects across the two school friendship networks. To test for school or broader setting-level effects that moderate network and behavior dynamics, multiple networks need to be sampled. These data would allow us to draw stronger conclusions about if and why school factors give rise to drug-related selection and influence processes. The

power asymmetry due to the different sizes of the two schools included in the current analyses may have also limited our ability to detect effects on behavior dynamics (powered at the level of the individual) in school 2. However, our confidence in these findings is bolstered by the reasonable size of the standard errors for these effects. Finally, the SABM assumption that actors make decisions about relationship and behavior changes given the state of the entire network (Snijders et al., 2007) is not ideal for these data, particularly the school 1 network that comprised over 1000 students. In a school with this many students, it may be unrealistic to assume that individuals are aware of the friendships and drug use behaviors of all of their school peers. Currently SABMs for larger networks that restrict actor decisions to their local settings are under development (Preciado, Snijders, Burk, Stattin, & Kerr, 2012; Preciado, Snijders, & Lospinoso, 2011), and in the future these new applications will be more suited for the analyses of large networks such as these. To partially address this issue in our analyses, we included an actor attribute for grade to model the higher likelihood of relationships among grade-mates.

Conclusions

Youth drug interventions are likely to benefit from identifying schools in which substance use, and more specifically illicit drug use, is socially meaningful among peers. These school settings may be particularly amenable to peer and network-based drug interventions (Valente, 2010). In line with a multiplicative model of risk, peer-based interventions may benefit from focusing on adolescents who are in trouble at school, and may be particularly susceptible to pro-drug use peer influence. This and other recent research employing statistical models for longitudinal network and behavior dynamics also highlight the important role of youths' friendship choices, and the subsequent aggregation of adolescents into peer groups with similar drug use behaviors or similar underlying risk factors (e.g., prior experimentation). Schools and substance use interventions may have important roles to play in facilitating affiliations among peers that have the potential to influence positively adolescent behaviors, and in identifying naturally occurring peer clusters that are drug users or share risk factors for subsequent drug use.

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Table 1

Individual Descriptive Statistics

	School 1 (N = 1193)		School 2 (N = 419)	
Characteristic	**Wave I N = 1193**	**Wave II N = 1051**	**Wave I N = 419**	**Wave II N = 366**
Control attributes				
Race/ethnicity (%)				
Hispanic	39.7		1.0	
Non-Hispanic white	23.1		98.8	
Non-Hispanic black	24.7		0.0	
Asian	33.0		1.4	
Other	1.3		0.0	
Parent education (%)[a]				
Less than high school	24.6		3.9	
High school	20.2		32.5	
Some college or trade school	29.3		34.8	
Graduate of college/university	19.2		28.9	
Mean number of outside-of-school friends	1.9		1.3	
Limited nominations (%)[b]	5.3	0.0	4.8	0.0
Marijuana use				
Lifetime marijuana use (%)	37.2	45.0	48.8	59.4
Initiated marijuana use between WI and WII (%)		7.8		10.6
Past month marijuana use (%)[c]				
None	79.3	80.3	70.1	75.1
1 to 3 times	9.5	8.6	14.2	10.3
4 to 11 times	5.1	5.5	6.7	4.0
12 to 32 times	4.8	4.1	6.0	8.9
33 times or more	1.4	1.5	2.2	1.7

[a] Parent education had 307 missing cases in School 1, and 114 cases missing in School 2.

[b] Participants who were only able to nominate 1 male and 1 female friend.

[c] Log transformation (+1 constant) of the number of times marijuana was used in the past 30 days, rounded to the nearest whole number. Scores of 5 and 6 (which represent frequency of marijuana use in the past month of 90 times or more) have been recoded into the category of 33 times or more.

Table 2

Network Descriptive Statistics

	School 1 (N = 1193)		School 2 (N = 419)	
Characteristic	**Wave I1**	**Wave II**	**Wave I**	**Wave II**
% missing nominations	2.3	19.9	1.7	12.6
M friends nominated	2.0	1.8	3.4	3.2
Range of friend nominations made	0 - 10	0 – 10	0 – 10	0 – 10
Range of friend nominations received	0 – 15	0 – 8	0 – 18	0 - 13
Reciprocity index	.27	.34	.43	.42
Transitivity index	.21	.23	.24	.23
	Period 1		Period 1	
M stable friendship ties	0.59		1.26	
M new friendship ties	0.78		1.45	
M friendship ties dissolved	1.04		1.74	
Jaccard coefficient	.25		.28	

Note. The reciprocity index is the proportion of friendship nominations that were reciprocated. The transitivity index is the proportion of 2-paths (friendship ties between AB and BC) that were transitive (friendship ties between AB, BC, *and* AC). The Jaccard index measures the amount of network change between consecutive waves, and expresses quantitatively whether the data collection points are not too far apart. Values of 0.3 or greater are ideal, so that assumptions that the network change process is gradual are met (Snijders et al., 2010).

Table 3

Friendship Selection and Influence for Lifetime Marijuana Use (Initiation)

Model parameter	School 1			School 2		
	P.E.	S.E.	*p* value	P.E.	S.E.	*p* value
Friendship network dynamics						
Rate parameter	8.89	0.54	-	15.53	1.00	-
Effects of marijuana use						
MJ lifetime use ego	**−0.15**	0.08	.049	**−0.14**	0.07	.032
MJ lifetime use alter	−0.10	0.06	.099	0.11	0.07	.104
Same MJ lifetime use	**0.27**	0.07	.000	**0.43**	0.07	.000
Effects of covariates						
Male ego	0.11	0.06	.053	0.04	0.06	.440
Male alter	0.03	0.05	.567	0.03	0.05	.557
Same male	**0.32**	0.05	.000	0.09	0.05	.088
Same race/ethnicity	**1.15**	0.07	.000	-	-	-
Grade ego	**−0.14**	0.07	.048	−0.08	0.06	.224
Grade alter	**0.19**	0.06	.001	0.12	0.06	.055
Same grade	**0.41**	0.05	.000	**0.34**	0.06	.000
Parent education ego	−0.07	0.03	.014	n.s.		
Parent education alter	**0.08**	0.03	.002	n.s.		
Parent education sq. alter	0.01	0.03	.609	n.s.		
Similar parent education	0.21	0.12	.080	n.s.		
Rate limited nominations	**−0.77**	0.37	.037	−0.24	0.44	.587
Limited nominations ego	0.23	0.18	.213	**0.47**	0.18	.008
Effects of network structure						
Outdegree	**−4.87**	0.10	.000	**−3.32**	0.16	.000
Reciprocity	**3.07**	0.13	.000	**2.17**	0.13	.000
Transitive triplets	**0.71**	0.07	.000	**0.21**	0.10	.027
3-cycles	**−1.09**	0.12	.000	−0.12	0.16	.451
Transitive ties	**1.27**	0.13	.000	**1.22**	0.10	.000
Outdegree popularity (sqrt)	**−0.47**	0.08	.000	**−0.28**	0.09	.001
Marijuana initiation dynamics						
Rate	0.12	0.03	-	0.28	0.08	-
Effects of friends' behaviors						
Friends' total lifetime MJ use	n.s.			n.s.		
Friends' total past month MJ use	**1.31**	0.40	.001	0.61	0.39	.116
Effects of individual covariates						
Male	0.51	0.31	.094	n.s.		
Grade	n.s.			0.50	0.42	.237
Race/ethnicity	n.s.			n.s.		
Parent education	n.s.			n.s.		
Number of outside-of-school friends	**0.23**	0.07	.001	n.s.		

Note. MJ = marijuana. P.E. = parameter estimate. S.E. = standard error. n.s. = not statistically significant. All control effects were score tested during the forward model specification, and only effects found to be marginally or statistically significant ($p < .1$) were retained and estimated in the models. Effects listed as non-significant were found to be non-significant predictors in this forward selection process and so were not estimated in the final model.

Table 4

Friendship Selection and Influence for Frequency of Past Month Marijuana Use

Model parameter	School 1			School 2		
	P.E.	S.E.	*p* value	P.E.	S.E.	*p* value
Friendship network dynamics						
Rate parameter	8.51	0.46	-	15.39	1.21	-
Effects of marijuana use						
MJ use ego	−0.02	0.08	.822	0.10	0.05	.069
MJ use alter	−0.25	0.42	.558	0.39	0.33	.238
MJ use sq. alter	0.16	0.14	.268	−0.09	0.13	.459
Similar MJ use	**1.49**	0.28	.000	**1.02**	0.29	.000
Effects of covariates						
Male ego	0.11	0.06	.079	0.04	0.05	.441
Male alter	0.03	0.05	.584	0.03	0.06	.576
Same male	**0.33**	0.05	.000	0.09	0.05	.096
Same race/ethnicity	**1.17**	0.06	.000	-.	-	-
Grade ego	**−0.14**	0.07	.031	−0.08	0.06	.200
Grade alter	**0.19**	0.06	.001	**0.12**	0.06	.048
Same grade	**0.42**	0.05	.000	**0.36**	0.06	.000
Parent education ego	**−0.07**	0.03	.016	n.s.		
Parent education alter	**0.08**	0.03	.005	n.s.		
Parent education sq. alter	0.01	0.02	.627	n.s.		
Similar parent education	0.20	0.13	.118	n.s.		
Rate limited nominations	**−0.76**	0.29	.009	−0.24	0.45	.591
Limited nominations ego	0.25	0.19	.190	**0.51**	0.18	.005
Effects of network structure						
Outdegree	**−4.91**	0.16	.000	**−3.00**	0.17	.000
Reciprocity	**3.12**	0.12	.000	**2.18**	0.12	.000
Transitive triplets	**0.70**	0.08	.000	**0.21**	0.08	.013
3-cycles	**−1.10**	0.15	.000	−0.12	0.15	.406
Transitive ties	**1.30**	0.13	.000	**1.24**	0.10	.000
Outdegree popularity (sqrt)	**−0.49**	0.07	.000	**−0.29**	0.07	.000
Marijuana use dynamics						
Rate	4.38	0.59	-	4.09	0.85	
Effects of friends' behaviors						
Friends' total MJ frequency	0.63	0.41	.126	0.51	0.33	.125
Effects of individual covariates						
Male	n.s.	n.s.	n.s.	n.s.		
Grade	n.s.	n.s.	n.s.	**0.33**	0.15	.032
Race/ethnicity	n.s.	n.s.	n.s.	n.s.		
Parent education	**−0.14**	0.06	.013	n.s.		
Number of outside-of-school friends	0.05	0.03	.060	n.s.		

Model parameter	School 1			School 2		
	P.E.	S.E.	*p* value	P.E.	S.E.	*p* value
Shape effects						
Linear shape	**−1.63**	0.12	.000	**−1.33**	0.16	.000
Quadratic shape	**0.37**	0.03	.000	**0.39**	0.05	.000

Note. MJ = marijuana. P.E. = parameter estimate. S.E. = standard error. n.s. = not statistically significant. All control effects were score tested during the forward model specification, and only effects found to be marginally or statistically significant ($p < .1$) were retained and estimated in the models. Effects listed as non-significant were found to be non-significant predictors in this forward selection process and so were not estimated in the final model.

Table 5

Descriptive Statistics of Actor-Level Moderators of Marijuana-Based Friendship Selection and Influence

Risk factors	School 1		School 2	
	Mean (SD)	Range	Mean (SD)	Range
Depression	0.73 (0.39)	0.00 - 2.84	0.62 (0.42)	0.00 - 2.53
Self esteem	3.92 (0.64)	0.00 – 5.00	3.96 (0.61)	1.14 – 5.00
Delinquency	0.23 (0.21)	0.00 – 1.00	0.22 (0.20)	0.00 – 1.00
GPA	2.45 (0.79)	1.00 – 4.00	2.53 (0.74)	1.00 – 4.00
School attachment	2.69 (0.81)	0.00 – 4.00	2.57 (0.91)	0.00 – 4.00
School trouble	0.97 (0.73)	0.00 – 4.00	1.22 (0.74)	0.00 – 4.00
Closeness to family	3.99 (0.64)	1.45 – 5.00	3.85 (0.65)	1.38 – 5.00
Access to drugs at home	0.04	0, 1	0.06	0, 1

Note. Because SABMs use only whole numbers, depression was rescaled by multiplying by two, and delinquency was rescaled by multiplying by 5, for all analyses.

Table 6

Actor-Level Moderators of Friendship Selection and Influence for Frequency of Marijuana Use

	School 1						School 2					
	Similar selection			Friend influence			Similar selection			Friend influence		
Risk factors	**P.E.**	**S.E.**	***p value***	**P.E.**	**S.E.**	***p value***	**P.E.**	**S.E.**	***p value***	**P.E.**	**S.E.**	***p value***
Depression	−0.37	0.47	.437	−0.04	0.78	.959	0.14	0.30	.643	0.01	0.51	.982
Self esteem	0.58	0.38	.131	0.04	0.66	.953	−0.31	0.34	.372	0.59	0.81	.468
Delinquency	**−0.61**	0.23	.008	−0.22	0.50	.666	0.14	0.26	.593	0.03	0.44	.945
GPA	−0.14	0.34	.674	0.23	0.74	.753	0.15	0.37	.681	0.11	0.65	.869
School attachment	0.56	0.37	.126	0.08	0.57	.894	0.22	0.18	.223	−0.41	0.50	.413
School trouble	0.13	0.43	.759	**1.38**	0.63	.027	0.09	0.21	.663	0.45	0.55	.416
Drugs in the home	−1.27	0.92	.170	−0.53	4.11	.896	−0.92	0.54	.087	0.46	5.89	.938
Family support	0.13	0.37	.478	0.61	0.85	.478	**−0.77**	0.37	.037	0.96	0.76	.210

Note. Parameters included in this table test interactions between actor attributes and a) actor selection of friends based on similar frequency of current marijuana use, and b) the effect of friends' frequency of marijuana use on actor frequency of marijuana use. All models control for the same effects on network dynamics and marijuana frequency dynamics included in the preliminary model for marijuana frequency (Table 4).