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# Social Networks and the Diffusion of Adolescent Problem Behavior: Reliable Estimates of Selection and Influence from 6th through 9th Grade

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## Abstract

Seeking to reduce problematic peer influence is a prominent theme of programs to prevent adolescent problem behavior. To support the refinement of this aspect of prevention programming, we examined peer influence and selection processes for three problem behaviors (delinquency, alcohol use, and smoking). We assessed not only the overall strengths of these peer processes, but also their consistency versus variability across settings. We used dynamic stochastic actor-based models to analyze five waves of friendship network data across sixth through ninth grades for a large sample of U.S. adolescents. Our sample included two successive grade cohorts of youth in 26 school districts participating in the PROSPER study, yielding 51 longitudinal social networks based on respondents' friendship nominations. For all three self-reported antisocial behaviors, we found evidence of both peer influence and selection processes tied to antisocial behavior. There was little reliable variance in these processes across the networks, suggesting that the statistical imprecision of the peer influence and selection estimates in previous studies likely accounts for inconsistencies in results. Adolescent friendship networks play a strong role in shaping problem behavior, but problem behaviors also inform friendship choices. In addition to preferring friends with similar levels of problem behavior, adolescents tend to choose friends who engage in problem behaviors, thus creating broader diffusion.

### Keywords

social networks; substance use; problem behavior

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## INTRODUCTION

For decades, scholars have recognized the strong associations between individuals' problem behaviors (e.g, substance use, delinquency) and those of their friends; consequently, prevention program developers have placed considerable emphasis on addressing potential negative influences of peers (Botvin and Griffin, 2004; Ellickson et al., 2000; Hansen and Dusenbury, 2004). Much theorizing and empirical work has attempted to understand how similarity between friends comes about. The two main explanations are straightforward: Either friends *influence* each other's behaviors, or people *select* friends who already have similar behaviors. Of course, these two processes are not mutually exclusive (Thornberry et al., 1994). The relative strength of these processes would implicate different prevention strategies, as discussed below. Recent methodological advances have resulted in a new wave of research addressing this long-standing debate about influence versus selection (Friedkin, 1998; Steglich et al., 2010; Valente, 2010). In particular, stochastic actor-based (SAB) modeling of longitudinal change in both individual behavior and social ties has provided new means for studying the processes linking individual and peer behaviors (Snijders, 2001, 2005; Steglich et al., 2010). Such research may yield better understanding of peer influences on adolescent problem behaviors and thus more effective prevention strategies to enhance public health.

In this paper, we apply SAB modeling to a large-scale study of U.S. adolescents in two grade cohorts from 26 school districts in order to obtain empirical estimates of selection and influence for three problem behaviors: delinquency, alcohol use, and smoking. An earlier paper presented data from this sample on selection and influence processes for alcohol use (Osgood, Ragan, Wallace, Gest, Feinberg, & Moody, 2013) but was primarily concerned with issues not included here, namely the reasons adolescents select alcohol users as friends and the impact of having many friends on alcohol use. In the current study, we expand on the prior results for alcohol by extending our analyses to additional types of problem behavior, testing the variability of selection and influence processes across networks, and considering the implications of our results for diffusion processes. We include results for alcohol use that overlap with the previous paper in order to provide comparison across three problem behaviors that are core targets of prevention efforts during adolescence. In the rest of this introduction, we discuss the complexities of selection and influence, the possibility that variability in these processes across communities has led to inconsistent findings in prior literature, and the advances embedded within SAB modeling that may help to further our understanding of these processes.

### Selection and Influence

The longstanding evidence that antisocial individuals associate with one another has been understood as reflecting *selection*, in which antisocial individuals seek out similar others (Glueck and Glueck, 1950), and/or *influence*, in which the antisocial behavior of one promotes change in the behavior of the other (Akers, 1985; Bandura, 1977). Research has generally estimated the magnitude of influence processes by controlling for respondents' prior behavior as a means of accounting for selection (Aseltine, 1995; Haynie & Osgood, 2005; Popp et al., 2005).

The relative strength of selection and influence processes has direct implications for the focus of prevention efforts (Gest et al., 2011). For example, where influence processes are strong, prevention strategies may attempt to coach youth that, because friends are the source of influence, choices about friends should be made carefully. Where selection processes are strong but influence processes are not, prevention strategies may rather focus on encouraging youth to adopt healthy behaviors directly with less regard to helping youth buffer the influence of peers.

Prior research has portrayed selection and influence processes as competing explanations for understanding the tendency for adolescent friends to display similar levels of risky behaviors. However, determining how influence and selection operate *together* is crucial for an integrated understanding of how social processes are linked to adolescents' adoption of problem behaviors (Thornberry et al., 1994). An integrated view is particularly important when moving from a focus on individual adolescents to the diffusion of behaviors. From a network perspective, the diffusion of behavior depends upon both influence and selection processes because the influence comes from people chosen as friends (Osgood, Ragan, et. al., 2013). Selection, in this view, is the source of influence, not simply a nuisance factor to be controlled.

Consider that friendship selection strongly based on *similarity* will lead to pairs of friends having similar behavioral profiles before influence can occur, which will diminish the potential for diffusion to occur even given strong influence. In contrast, selection that consistently favors higher levels of peer's problem *behavior* will mean that many youth who do not engage in the problem behavior will form friendships with the youth who do (Moffitt, 1993). Those choices will bring about more exposure of, for instance, non-smokers to smokers, promoting diffusion. Thus, the selection and influence parameters of a particular network lead to a particular pattern and rate of diffusion. A fruitful direction for prevention efforts would be to promote the value of prosocial versus antisocial friendship choices. This insight leads to an interest in the variability of influence and selection parameters across networks, as varying estimates will result in a range of patterns and diffusion rates. Our previous work indicates that the prevention trial in which our research is embedded enhanced the network centrality of prosocial versus antisocial youth (Osgood, Feinberg, et al., 2013), which should promote the diffusion of the program's benefits.

## Inconsistent Findings and the Possibility of Inter-Network Variability

Whether there is substantial peer influence on problem behaviors has direct implications for parents, schools, and prevention planners. Unfortunately, results have been inconsistent across studies of adolescent problem behavior. Two recent Nordic studies, for example found significant levels of both selection and influence on alcohol use (Kiuru et al., 2010; Popp et al., 2008), while a large SAB study in the Netherlands did not find clear evidence of influence on alcohol use (Knecht et al., 2011). Similar differences across studies have been found for other problem behaviors, such as smoking (Hall and Valente, 2007; Mercken et al., 2009).

The inconsistency in previous findings across studies could arise from two very different sources: genuine differences in social processes across various settings or statistical noise.

The scope of our data allows us to address this question. Determining whether there is variability across networks in peer processes related to problem behavior is important: If networks do not vary in selection and influence regarding risky behaviors, a single prevention strategy may be utilized across settings. However, if prior inconsistent findings reflect genuine differences across settings, different prevention strategies may be more effective in one setting than another.

The potential variability in influence and selection factors across communities deserves serious consideration, as any number of substantive factors might produce such variability (Osgood, Ragan, et al., 2013). For example, overall levels of substance use in a community may lead to different conceptions of what is normative behavior, which may alter selection and influence processes. As another example, schools may implement various degrees of academic tracking, affecting the prevalence of friendships between students who differ in levels of risk.

Regarding statistical noise, a relevant constraint for generating reliable estimates is not only the sample size in terms of individuals, but also the number of networks assessed. For SAB analyses, precision of influence estimates is limited in the typical samples of one or a few school grade cohorts, and it is not possible to know if differences in findings are due to substantive differences across networks, methodological differences (e.g., measurement, sample, analytic procedures), or statistical noise. For example, Schaefer and colleagues (2012) analyzed two waves of data from the social network of 500 students attending a single school, leaving questions of generalizability. The large number of students and networks we examine (51 school district grade cohorts) affords a unique opportunity to obtain reliable estimates.

## Methodological Issues and Advances of SAB Modeling

The study of peer influence presents special conceptual and methodological problems that require adopting a network perspective. Peer influence is a dyadic process, flowing from one person to another through relationships such as friendships. Dyadic relationships do not occur in isolation, but rather they occur as part of a larger pattern within an interacting population, thereby constituting a social network (Friedkin, 1998; Valente, 2010). This realization has brought a major shift in standards for research on peer influence, away from relying on respondents' perceptions about their friends' behavior to using social network data to ascertain the friends' reports of their own behavior (Bauman and Ennett, 1996; Haynie and Osgood, 2005).

The network perspective on peer influence has dramatic implications regarding modeling the complexities of influence and selection processes that conventional regression models are not sufficient to address (Friedkin, 1998; Valente, 2010). Because peer dyads are embedded in networks, influence and selection processes entail complex patterns of feedback. The process of influence by which one friend influences another also implies the second friend influences the first and both receive indirect influence from each other's friends (Payne and Cornwell, 2007). Friendship choices are subject to endogenous processes, as well, such as the tendency to reciprocate friendships (McPherson et al., 2001; Steglich et al., 2010).

Because all of these processes feed into each other through the evolving connections of the social network, an adequate analytic approach must address this pervasive endogeneity by modeling friendship choices and behaviors jointly. The RSiena SAB approach has been designed for this purpose (Snijders, 2001, 2005; Steglich et al., 2010). Using multiple waves of data for a social network, it jointly estimates a complex set of influence and selection processes. The SAB approach uses simulation to allow for endogeneity, with the changes produced by all processes serving as input to the system's further evolution. Like all analyses of passive observational data, the method does not yield definitive causal estimates. Even so, the results are estimates of "effects" in that they derive from a model of processes with a clear causal direction.

### Current Study

The present study extends previous SAB research by estimating peer influence and selection processes for delinquency, alcohol use, and smoking and by studying variation across two successive grade cohorts in 26 school districts. Applying the same methods to studying these processes for different problem behaviors in the same sample enables us to compare peer processes for a set of problem behaviors addressed by many prevention efforts. We assess multiple relevant selection processes and analyze five waves of data for a large U.S. sample.

Our data come from the PROSPER study (Spoth et al., 2007; 2011), a randomized trial of substance use prevention diffusion. PROSPER employed university Cooperative Extension educators to lead prevention teams, which were charged with selecting evidence-based prevention programs from a menu and implementing those programs with fidelity. Prior reports have demonstrated the efficacy and sustainability of the PROSPER model for proximal outcomes as well as substance use and conduct problems (Spoth et al., 2007, 2011). We have tested the PROSPER intervention's effects on friendship network structure and identified beneficial effects that would reduce potential influence toward antisocial behavior (Osgood, Feinberg, et al., 2013). The current analyses conclude with a brief preliminary examination of whether program effects on the processes assessed here would account for those effects.

## METHODS

### Sample and Data Collection

The current study employs data from 26 rural and semi-rural school districts in Iowa and Pennsylvania from the community-randomized trial of PROSPER (Spoth et al., 2007; 2011). One of the 28 school districts in the larger PROSPER study declined to participate in the social network aspect of the study, and a chaotic pattern of school transitions due to a school closing precluded SAB analysis for another. Districts had total enrollments of 1,300 to 5,200 students and at least 15% of youth eligible for free or reduced-cost school lunch. Most students in the participating districts were White (61% – 96%) and English-speaking. The 2002 and 2003 $6^{th}$ grade cohorts participated in the study; student survey data were collected in the fall of $6^{th}$ grade and every spring through the $9^{th}$ grade, resulting in five waves of data. With IRB approval, passive consent procedures allowed students or parents to opt out of student participation at any time. Open enrollment allowed new students to join the sample

at each wave, and participation rates ranged from 86% to 90% of eligible students across the five waves. Students who participated in the first wave contributed data for an average of 4.18 waves. Analyses use data from over 8,000 students at each wave and more than 13,000 students overall.

Questionnaire items asked students to name their best and closest friends in their grade (up to seven). Two coders, assisted by a computer program that suggested plausible matches based on phonetic and spelling similarity, matched the handwritten names to those on school rosters. The two coders agreed at a 98% rate, and matched 83.0% of names. Of the remaining 17%; 1.9% had multiple plausible matches, .4% were inappropriate nominations (e.g., celebrities), and 14.7% did not appear on the class roster.

## Measures

The measure of delinquency derives from adolescents' reports of how many times in the past year they engaged in each of 12 delinquent acts (original response scale 1 = never to 5 = 5 times or more). Scores are based on the number of different acts an adolescent committed at least once, which criminologists refer to as variety scoring (Sweeten, 2012). To obtain sufficient frequencies for RSiena analysis, which requires ordered categorical measures of behavioral outcomes, we recoded the measure to four categories corresponding to counts of 0, 1, 2–3, and 4–12. Measures of alcohol and tobacco use come from answers to the questions, "During the past month, how many times have you had beer, wine, wine coolers, or hard liquor?" and "During the past month, how many times have you smoked any cigarettes?" We recoded the original response categories for both to "0" (none), "1" (once), and "2" (two times or more) because initial rates of use were too low to support finer distinctions.

Our analyses also include control variables that earlier analyses demonstrate are relevant both to selection processes and to our behavioral outcomes (Osgood, Ragan, et al., 2013). Including them ensures that their contributions are not mistakenly attributed to the influence and selection processes of primary interest. The controls for both selection and influence are dummy variables for sex ("1" = male) and race ("1" = White). The influence portion of the analysis also includes control variables that have been linked to adolescent substance use in prior research (Ragan, 2014): whether the respondent resided with both biological parents ("1" = both parents), school adjustment and bonding (eight items, $\alpha = 0.81$), family relations (four subscales, $\alpha = 0.75$), and sensation seeking (three items, $\alpha = 0.75$).

## Statistical Model

We analyze these data through the RSiena SAB statistical model and software (Snijders, 2001, 2005; Steglich et al., 2010). Using longitudinal panel data for a network, the method jointly estimates two models of change, one for friendship choices (or other relationship ties) and the other for a behavioral outcome. The method produces estimates of the strength of various processes that could affect friendship ties or behavior, such as a preference for friends of one's own gender or a tendency to behave like one's friends. We provide an overview of this approach; for more thorough explanations see Snijders (2001, 2005) or Steglich et al. (2010).

The statistical model focuses on discrete choices assumed to accumulate to produce the observed evolution of both the network of relationships and the actors' behavior. The focus of the network model is a single actor making a single friendship choice, either adding or dropping one friendship, or making no change. This network model addresses processes contributing to the attractiveness of one person to another as a potential friend. The behavior model treats the behavior as an ordered categorical variable, with the actor choosing between increasing one level, decreasing one level, and making no change. The statistical models take the form of logistic regression equations for the relative probabilities of these alternatives.

The model treats actors as forward looking because the processes concern the new state of the network produced by the potential choices. For instance, a preference for friends of the same gender corresponds to a parameter that raises the probability for choosing any same-gender friend, which alters the network so that this person has more same-gender friendships. For the behavior model, an example would be peer influence toward balance (McGloin, 2009), captured by a term that raises the probability for changing one's behavior to be closer to the mean of one's friends, which creates a more balanced network.

The RSiena SAB method estimates the strength of the processes of interest through iterative simulations of their implications for network and behavior change. Simulation starts with the observed data at the first wave and consist of sequences of friendship and behavior choices by the actors. The order of the choices is random, and the probabilities for the simulated choices depend on both the tentative parameter estimates and the evolving state of the network. The software revises the estimates in light of discrepancies between the completed simulations and the data, stopping when estimates agree with the data. The basic model assumes processes are constant across waves, but this assumption can be relaxed, if desired (Lospinoso et al., 2011). Similar to a lagged regression model, this SAB approach uses an earlier wave of data to predict outcomes at the next wave. The approach is quite different, however, in capturing the interdependence of the actors and the endogenous feedback among network processes through a process model and using simulation to reveal its implications.

Methods for combining SAB results across multiple networks provide a means of addressing the variability of selection and influence processes across samples. Random effects meta-analysis (Raudenbush and Bryk, 2002) can take into account the varying precision of estimates (i.e., their standard errors) while combining the separate results across multiple networks. This method yields optimally weighted mean estimates with appropriate significance tests. In addition, it estimates the true variance of parameter across the networks, above and beyond the chance variation reflected in the network-specific standard errors.

**Processes included in the model—**The parameters estimated by the SIENA model approach fall into three categories: structural, selection, and behavior. Structural parameters reflect influences of the current pattern of friendships on the formation of future friendships, without regard to attributes of either party. None of our primary research questions concern structural processes, but controlling for these processes is valuable for ensuring that these

common patterns do not account for the focal results. The structural terms in the model include:

- *Outdegree density*, the overall rate of friendship choice.
- *Reciprocity*, the tendency to reciprocate friendships from others.
- *Transitive triplets*, the tendency to become friends with someone your current friend has chosen as a friend.
- *Balance*, the tendency to become friends with someone who has chosen your friend as a friend.
- *3-cycles*, the tendency to form friendships that would complete a cycle of *a* choosing *b*, *b* choosing *c*, and *c* choosing *a*. A negative coefficient would indicate a tendency toward hierarchy, with some actors chosen as friends by many but naming few friends.
- *Indegree – popularity, sqrt*, the tendency for continuity in actors' attractiveness as friends.

The second category of processes concerns the selection of friends based on the attributes of either party. There are three main types of these selection parameters.

- *Ego* terms indicate an attribute association with an actor naming more or fewer friends.
- *Alter* terms indicate whether a characteristic is associated with attractiveness, in the sense of a person more often being named as a friend.
- *Same/similarity* terms correspond to tendencies to add or keep friends similar to the actor for the attribute of interest.

Our models include all three terms for gender and race, as well as for the behavioral outcomes, which are our primary interest. The alter term indicates any general preference for or against friends who engage in antisocial behavior, which would affect exposure to antisocial influence. The similarity term indicates whether youth who engage in antisocial behavior tend to choose one another as friends, promoting segregation of the network in terms of that behavior.

The final category of processes in the SAB model is influences on the behavioral outcome. We capture peer influence through the *average similarity effect on behavior*, which corresponds to behavioral change toward greater similarity with one's friends' behavior, consistent with the notion of influence toward balance (McGloin, 2009). We also include the respondent attributes noted in the measures section as control variables.

**Reported analyses—**The PROSPER questionnaire asked respondents to name friends within their grade and school, thereby defining the potential friendship network as the school district grade cohort. The reported analyses include up to 51 of the potential 52 networks. One district-cohort network is omitted due to a missing wave of data. Results omit 10 networks for tobacco use and 2 networks for alcohol use that failed to converge, primarily due to low rates of use and little change in use in early grades. To examine

whether the loss of these networks for the tobacco use analysis was likely to affect results, we compared results for delinquency from the networks that did not converge when modeling tobacco and alcohol use with the delinquency results from the networks that did converge. We found no significant differences.

We combined results across networks through a three-level random effects meta-analysis using the HLM program (Raudenbush and Bryk, 2002) with squared SIENA standard errors as known variance at level 1, cohort as level 2, and community as level 3. As noted above, an earlier paper presented overlapping results for alcohol use (Osgood, Ragan, et al., 2013); we include those results to provide a more complete picture, not as novel findings.

## RESULTS

Table 1 presents descriptive statistics for all measures, including wave-specific means for the outcome measures of substance use and delinquency. Delinquency increased considerably over this age span, from a mean score of .58 in the fall of 6$^{th}$ grade to 1.06 in the spring of 9$^{th}$ grade. The growth of substance use was even more dramatic, from 8.16% reporting past-month alcohol use and 3.50% reporting past-month smoking at the beginning of the study, compared to 36.16% and 18.64%, respectively, in the final assessment in our analyses.

Osgood, Ragan, et al. (2013) reported detailed wave-specific descriptive statistics about the friendship networks of these school grade cohorts. The size of the networks ranged from 60 to 443 students, with (wave-specific) mean sizes of 158 to 192. The mean number of friendship choices per respondent varied from a low of 3.36 in fall of 6$^{th}$ grade to 4.07 in spring of 7$^{th}$ grade. Across waves, from 48.8% to 51.3% of friendship choices were reciprocated.

### The Role of Structural and Control Variables

Estimates for the structural terms, which reflect the influence of network structure on future friendship choices, are peripheral to the purposes of this article and are quite similar to previously published results (e.g., Osgood, Ragan, et al., 2013). Therefore, we mention them only briefly here, and we provide the full results in an appendix. Each structural influence on selection was statistically significant in models for all three outcomes. These results show strong tendencies to reciprocate friendships, to become friends with the people your current friends have named as friends, for currently popular students to continue to attract friendships, and to prefer friendship choices that maintain status hierarchies over those that would create greater equality. An important advantage of the RSiena SAB modeling approach is the ability to control for these processes when addressing our principle research questions, which concern the role of substance use and delinquency in influence and selection processes.

The model also includes selection processes associated with sex and race, and these results, which reveal the prominence of demographic factors in adolescent friendship selection, appear in the appendix as well. Adolescents are more likely to name new friends and retain old friends of the same sex and race, and non-White respondents attract more friendship

nominations relative to Whites. In addition, non-white respondents and males tend to name fewer friends relative to White and female respondents, respectively.

### Selection and Influence for Problem Behavior

Next we turn to the influence and selection processes that would promote the diffusion of problem behaviors, or potentially the diffusion of benefits of programs to prevent those behaviors. Table 2 first presents the mean levels of the RSiena estimates across all networks for delinquency, alcohol use, and smoking, which come from HLM meta-analyses of school-cohort-specific estimates. The significant and positive alter parameters for all three problem behaviors indicate that adolescents who engage in these behaviors are more likely to receive friendship nominations. The odds ratios indicate that this tendency is weakest for delinquency, where each unit raises the odds of being selected (or retained) as a friend by 2.9% per unit of this 0–3 index. This attractiveness as a friend was somewhat stronger for alcohol use and smoking, which correspond to 8.5% and 11.9% higher odds per unit of 0–2 indices.

The ego selection parameters reflect whether adolescents who engage problem behaviors were prone to select more or fewer friends than those who do not. Neither delinquency nor cigarette use was significantly associated with the rate of choosing friends in this fashion, but alcohol use was associated with choosing somewhat fewer friends, with the odds ratio indicating 3.9% lower odds of choosing any other student as a friend (with other factors held constant).

The consistently significant positive similarity terms for selection indicate a preference for friends of a similar level of each problem behavior to oneself. This odds ratio corresponds to the difference in odds of choosing someone identical to oneself on the behavior versus someone at the opposite end of the scale. Thus, a non-delinquent would have 24.6% greater odds of choosing another non-delinquent as a friend than for choosing a student who engaged in at least four of the delinquent acts (scoring the maximum of 3). The preference for similar friends was strongest for smoking (OR = 1.551), and intermediate for alcohol use (OR = 1.335).

Peer influence on problem behavior appears as the parameter for friends' behavior in the behavioral portion of the RSiena SAB results. Table 2 provides strong evidence that adolescents tend to change their behavior to become more similar to their friends. The odds ratios for the model correspond to the difference between odds for choosing to behave the same as the mean of one's friends (e.g., not smoking when none of them smoke), versus behavior at the opposite extreme of the measure (i.e., smoking frequently in the same situation). Because such extreme differences are uncommon, a useful alternative is the odds ratio for changing behavior to be one scale unit closer to one's friends' mean (from dividing the parameter estimate by the range and exponentiating). For delinquency the odds are 44.7% higher for moving one unit toward one's friends (versus not changing), and the corresponding figures are 89.5% for alcohol use and 175.0% for smoking.

The lower portion of table 2 reports findings for the relations of the control variables to change in the behaviors. Males, for example, are more likely to increase their delinquent

behavior, but increases in drinking and smoking are more likely for females. Non-White respondents reported more growth in delinquency than White respondents, but we observed no association between race/ethnicity and change in substance use. Students who lived with both of their biological parents were less likely to increase their delinquency and cigarette use. Increases in all three problem behaviors were associated with weaker school adjustment and bonding, poorer family relations, and high risk and sensation seeking.

### Variability across Networks

Our sizable sample of community-cohort networks enables us to examine whether peer influence and selection processes vary widely or are largely consistent across communities. The multilevel models that combine the SAB results provide estimates of the true variance for each parameter across networks, based on the degree to which observed variation exceeds that expected by chance, given the RSiena standard errors. Table 3 reports estimated standard deviations of the true values of each parameter across community/cohort networks (the square root of the sum of district-cohort [level 2] and district [level 3] variance estimates). For convenience, the table also includes the mean estimates reported in Table 2. Joint likelihood-ratio chi-square tests of level 2 and 3 variances reveal that, while significant variation exists among the ego parameters for all three outcomes, variation for other parameters is typically no greater than chance (with the exception of the delinquency similarity term).

Though the HLM variance estimates indicate that evidence of true variability is largely limited to the ego parameter, the columns of Table 3 showing the standard deviations and ranges for the observed SAB estimates create a different impression. This difference reflects the inherent imprecision from the limited statistical power of any given estimate. Consistent with the varying results of published SAB analyses for samples of this size (80 to 440 respondents per wave), the range of RSiena estimates for almost all terms includes both positive and negative values, despite their significant means and limited true variance. In contrast, the ranges and standard deviations for separate networks' raw parameter estimates create an erroneous impression of great variability. For instance, in the raw estimates the tendency to select more delinquent youth as friends (alter delinquency) ranged from −.031 to +.102 with a standard deviation of .030, but the estimated standard deviation for the true estimates is .007, indicating that the true estimates for 95% of the networks would range from .015 to .043.

Ego-selection parameters indicate the association of the problem behaviors with the tendency to pick more friends—perhaps reflecting a sense of integration in the school peer community. Table 3 provides evidence that these estimates vary widely across community-cohort combinations. In contrast to near zero mean parameters, the likely range across 95% of networks extends from moderately positive (i.e., deviant students selecting more friends) to moderately negative (conventional youth selecting more friends).

Selection for similarity on delinquency also varied significantly, with the likely range extending from near zero to a relatively strong tendency to pick similar friends (b = .038 to .402). Though non-significant, the standard deviation for similarity selection on smoking reveals a sizable range in strong preference for similarity (b = .251 to .627), while the

standard deviation for the same parameter for alcohol use implies near uniformity (b = .267 to .311).

Table 3's results for variability provide additional perspective on the findings about general preference for students who engage in the problem behaviors (captured by the positive alter selection parameter). Variability across settings is not significant for the alter-selection estimates of any of the three behaviors, but the latent standard deviation estimate for smoking is large enough to suggest that preference for smokers could range from negligible in some school cohort settings to fairly consequential in others (95% range of b = .028 to . 196). In contrast, the estimated variability is near zero for delinquency and alcohol use.

The estimates of true variability are especially small for influence of friends on students' problem behavior, with estimated true standard deviations two orders of magnitude smaller than the mean estimates. Thus, the data give no hint of meaningful differences among communities and grade cohorts for the potency of peer influence. This result stands in stark contrast to the highly variable observed values, which are quite imprecise for any given school grade cohort.

### Program Effects of Peer Processes

We conclude our analyses with a preliminary examination of the possibility that PROSPER's preventive intervention altered peer influence and selection processes for problem behavior. To estimate that treatment effect, we added an indicator of school districts' treatment versus control status to our multi-level meta-analytic models for the RSiena parameters for peer influence, alter selection, and selection for similarity for the three problem behaviors. Of the nine significance tests, one reached $p < .05$ (similarity selection for smoking, b = .196, S.E. = .083) and another reached $p < .10$ (similarity selection for delinquency, b = .092, S.E. = .046), both reflecting stronger selection for similarity in treatment school districts. With the multiple significance tests, this result must be viewed as only suggestive. Notably, it would not account for Osgood, Feinberg, et al.'s (2013) findings for program effects on network structure.

## DISCUSSION

The results of this large study of problem behavior and peer network processes lead to several clear conclusions: Adolescents have a substantial friendship preference for peers similar to them in all three risky behaviors examined: smoking, alcohol use, and delinquent behavior. Table 2 indicates that the odds of adolescents choosing someone as a friend were 25%, 34%, and 55% higher if that person displayed the same level of problem behavior as themselves for delinquency, drinking, and smoking, rather than being maximally dissimilar. Yet adolescents also tended to choose as friends those peers who exhibit each of the problem behaviors. Furthermore, we found strong influence of friends on change in each of the three problem behaviors. Our general conclusion is that friends help shape problem behavior, while problem behavior also informs friendship choices. The preference for friends similar on problem behavior will combine with peer influence to create friendship clusters differentiated for that behavior. At the same time, the overall tendency to choose friends who engage in each problem behavior will expose ever-greater numbers of adolescents to

influence toward those behaviors, thereby creating broader diffusion across the entire network.

These results have a number of important implications, consistent with the view that a focus on friendship networks can be valuable for insights about directions for improving prevention programming (Gest et al., 2011). First, they support the hypothesis that youth are attracted to deviant peers, perhaps out of a desire to imitate a seemingly mature role model (Moffitt, 1993), although this tendency is not strong. Our analyses do not address the possibility that youth imitate such deviant peers from a distance without becoming friends, but they do indicate that youth who engage in these problem behaviors attract somewhat more friendship choices, which in turn will subject more people to their influence. This pattern is stronger for alcohol and tobacco than for delinquency. These results suggest that substance use prevention programs might enhance their effectiveness by addressing this selection dynamic through emphasizing the disadvantages of having friends who engage in these risky behaviors.

To help understand the different components of the selection process in one rubric, Table 4 shows the joint implications of the several components of the selection process for the relative odds of adding or retaining friends across all levels of problem behaviors for both the selector (ego) and the potential friend (alter). The odds of a friendship are always highest between people whose behavior matches, such as two frequent smokers or two non-smokers. Such friendships are likely to reinforce continuity in previous behavior, due to mutual influence or reinforcement.

In addition, the general preference for friends who engage in problem behavior dampens the preference for similarity among non-deviant adolescents (the “none” row for ego) and accentuates it among more deviant adolescents (the “more” row). For instance, adolescents who smoke more than once a month have 94% greater odds (1.298/.669) of choosing a friend who does so than choosing a nonsmoker, while the differential for non-smokers’ choices is only 24%. *This difference is the basis of diffusion because it implies that conventional youth are less inclined to avoid sources of influence toward antisocial behavior than antisocial youth are to avoid influence away from it.* Thus, there remains a role for parents and their school and community allies to help guide children’s friendship choices towards more positive influences.

In comparison to the selection effects, the influence processes detected in this sample are relatively strong. Given this study’s strengths in terms of number of school-cohorts assessed, number of waves over a key developmental period, and methodological rigor, this result is noteworthy. This finding provides support for ongoing efforts to “inoculate” youth from negative influence by giving them tools (e.g., refusal skills) to turn aside opportunities and pressure to engage in problem behavior within the context of close relationships.

Our results also address the issue of variability in the strength of these processes across networks and school districts. The raw network-specific estimates might suggest considerable variability in selection and influence processes across networks. However, after taking expected chance into account, this variability rarely remains statistically significant,

showing that these peer processes are largely consistent across this range of settings. Yet our tests of variability are not so powerful as to rule out the possibility of interesting and informative differences in these processes, even if they must fall within a limited range. Future research examining community or network level correlates of these processes might yield a deeper understanding.

Among the limitations of this study is that, despite the advance represented by SAB modeling over prior methods of analyzing peer influence, this remains a passive longitudinal study. There may be other factors than those we controlled for that influence network processes. Further, the sampling frame of the parent study also sets restrictions on possible network effects. Most importantly, youth were asked to name friends within their grade, precluding examination of network processes involving younger and older friends and siblings (Feinberg, Solmeyer, & McHale, 2012). Further, the present sample of non-urban districts should be complemented by studies that encompass a wider range of communities. Finally, although SAB modeling represents an advance over prior network strategies, our analyses assumed that processes were stable across the four years we studied. Future research should examine potential variation in selection and influence processes across this age span.

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# Appendix: Structural Parameters and Selection Parameters for Sex and Race

| | Delinquency | | Alcohol Use | | Smoking | |
|---|---|---|---|---|---|---|
| | ***b*** | ***SE*** | ***b*** | ***SE*** | ***b*** | ***SE*** |
| **Structural parameters** | | | | | | |
| Outdegree (density) | −3.186 *** | 0.054 | −3.186 *** | 0.053 | −3.172*** | 0.059 |
| Reciprocity | 1.950 *** | 0.042 | 1.953 *** | 0.042 | 1.934*** | 0.047 |
| Transitive triplets | 0.335 *** | 0.014 | 0.335 *** | 0.014 | 0.330*** | 0.015 |
| 3-cycles | −0.413 *** | 0.017 | −0.409 *** | 0.016 | −0.408*** | 0.018 |
| Balance | 0.100 | — | 0.100 | — | 0.100 | — |
| Indegree - popularity (square root) | 0.177 *** | 0.009 | 0.179 *** | 0.009 | 0.181*** | 0.010 |
| Merger ego | −0.715 *** | 0.110 | −0.735 *** | 0.105 | −0.705*** | 0.115 |
| Transition ego | −0.234 *** | 0.041 | −0.227 *** | 0.043 | −0.218*** | 0.043 |
| **Selection parameters** | | | | | | |
| **Alter effects** | | | | | | |
| Sex | 0.015 † | 0.008 | 0.016 * | 0.007 | 0.008 | 0.008 |
| Race | −0.074 *** | 0.012 | −0.075 *** | 0.012 | −0.073*** | 0.010 |
| **Ego effects** | | | | | | |
| Sex | −0.132 *** | 0.016 | −0.141 *** | 0.016 | −0.144*** | 0.018 |
| Race | −0.051 ** | 0.015 | −0.050 ** | 0.015 | −0.052** | 0.015 |
| **Similarity effects** | | | | | | |
| Sex | 0.723 *** | 0.024 | 0.726 *** | 0.025 | 0.720*** | 0.024 |
| Race | 0.173 *** | 0.022 | 0.176 *** | 0.022 | 0.173*** | 0.024 |

*** $p < .001$.
** $p < .01$.
* $p < .05$.
† $p < .10$.

**Table 1**

Descriptive Statistics[a]

| Variable | *Mean* | *Std. Dev.* | *Min.* | *Max.* |
|---|---|---|---|---|
| Delinquency | 0.830 | 1.091 | 0 | 3 |
| Alcohol Use[b] | 0.307 | 0.644 | 0 | 2 |
| Smoking[c] | 0.173 | 0.533 | 0 | 2 |
| Sex | 0.486 | — | 0 | 1 |
| Race | 0.813 | — | 0 | 1 |
| Lives with Both Biological Parents | 0.609 | — | 0 | 1 |
| School Adjustment & Bonding | 3.788 | 0.766 | 1 | 5 |
| Family Relations | −0.009 | 0.502 | −2.997 | 1.188 |
| Risk & Sensation Seeking | 2.138 | 1.002 | 1 | 5 |

| | Wave 1 | Wave 2 | Wave 3 | Wave 4 | Wave 5 |
|---|---|---|---|---|---|
| Delinquency | | | | | |
| Mean | 0.583 | 0.658 | 0.813 | 0.985 | 1.056 |
| Std. Dev. | (0.916) | (0.987) | (1.077) | (1.156) | (1.188) |
| Alcohol Use | | | | | |
| Mean | 0.108 | 0.155 | 0.251 | 0.398 | 0.574 |
| Std. Dev. | (0.385) | (0.459) | (0.582) | (0.710) | (0.818) |
| Smoking | | | | | |
| Mean | 0.051 | 0.078 | 0.150 | 0.226 | 0.329 |
| Std. Dev. | (0.281) | (0.358) | (0.495) | (0.602) | (0.712) |

[a] Based on 51 networks unless noted; average n = 9,135

[b] Based on 49 networks; average n = 8,733

[c] Based on 41 networks; average n = 7,693

**Table 2**

Selection and Influence Processes for Adolescent Problem Behaviors[a]

| | Delinquency | | | Alcohol Use | | | Smoking | | |
|---|---|---|---|---|---|---|---|---|---|
| | ***OR*** | ***b*** | ***SE*** | ***OR*** | ***b*** | ***SE*** | ***OR*** | ***b*** | ***SE*** |
| **Selection parameters** | | | | | | | | | |
| Behavior alter | 1.029 | 0.029 *** | 0.004 | 1.085 | 0.082 *** | 0.009 | 1.119 | 0.112 *** | 0.017 |
| Behavior ego | 0.985 | −0.015 | 0.010 | 0.961 | −0.039 * | 0.019 | 0.993 | −0.007 | 0.034 |
| Behavior similarity | 1.246 | 0.220 *** | 0.026 | 1.335 | 0.289 *** | 0.022 | 1.551 | 0.439 *** | 0.044 |
| **Behavioral parameters** | | | | | | | | | |
| **Friends' attributes** | | | | | | | | | |
| Friends' Behavior | 3.029 | 1.108 *** | 0.084 | 3.590 | 1.278 *** | 0.079 | 7.564 | 2.023 *** | 0.165 |
| **Control variables (individual level)** | | | | | | | | | |
| Sex | 1.041 | 0.040 *** | 0.009 | 0.867 | −0.142 *** | 0.013 | 0.818 | −0.201 *** | 0.025 |
| Race | 0.923 | −0.080 ** | 0.022 | 0.993 | −0.007 | 0.026 | 0.986 | −0.014 | 0.020 |
| Lives with Both Biological Parents | 0.883 | −0.125 *** | 0.015 | 0.968 | −0.032 | 0.019 | 0.809 | −0.211 *** | 0.037 |
| School Adjustment & Bonding | 0.871 | −0.138 *** | 0.012 | 0.831 | −0.185 *** | 0.012 | 0.789 | −0.237 *** | 0.012 |
| Family Relations | 0.815 | −0.204 *** | 0.020 | 0.868 | −0.142 *** | 0.020 | 0.848 | −0.165 *** | 0.025 |
| Risk & Sensation Seeking | 1.104 | 0.099 *** | 0.006 | 1.158 | 0.147 *** | 0.010 | 1.150 | 0.140 *** | 0.014 |

*** $p < .001$.

** $p < .01$.

* $p < .05$.

† $p < .10$.

[a] Models also include rate and shape, structural, and selection parameters for sex and race

**Table 3**

Variability of Selection and Influence Processes, RSiena Estimates

| | HLM | Latent | | | Observed | | |
|---|---|---|---|---|---|---|---|
| | | | 95% Range | | | | |
| | Mean | Std. Dev. | Lower | Upper | Std. Dev. | Min | Max |
| **Alter selection parameters** | | | | | | | |
| Delinquency | 0.029 | 0.007 | 0.015 | 0.043 | 0.030 | −0.031 | 0.102 |
| Alcohol Use | 0.082 | 0.014 | 0.055 | 0.109 | 0.125 | −0.364 | 0.340 |
| Smoking | 0.112 | 0.043 | 0.028 | 0.196 | 0.143 | −0.274 | 0.385 |
| **Ego selection parameters** | | | | | | | |
| Delinquency | −0.015 | 0.049*** | −0.111 | 0.081 | 0.070 | −0.180 | 0.160 |
| Alcohol Use | −0.039 | 0.077*** | −0.190 | 0.112 | 0.147 | −0.373 | 0.251 |
| Smoking | −0.007 | 0.131*** | −0.264 | 0.250 | 0.247 | −0.440 | 0.892 |
| **Similarity selection parameters** | | | | | | | |
| Delinquency | 0.220 | 0.093** | 0.038 | 0.402 | 0.152 | −0.085 | 0.535 |
| Alcohol Use | 0.289 | 0.011 | 0.267 | 0.311 | 0.361 | −1.048 | 1.074 |
| Smoking | 0.439 | 0.096 | 0.251 | 0.627 | 0.365 | −0.292 | 1.296 |
| **Friends' behavioral influence parameters** | | | | | | | |
| Delinquency | 1.108 | 0.018 | 1.073 | 1.143 | 0.714 | −0.899 | 3.117 |
| Alcohol Use | 1.278 | 0.017 | 1.245 | 1.311 | 0.936 | −1.328 | 4.086 |
| Smoking | 2.023 | 0.030 | 1.964 | 2.082 | 2.480 | 0.359 | 15.866 |

*** $p < .001$.

** $p < .01$.

* $p < .05$.

† $p < .10$.

**Table 4**

The Relationship of Ego and Alter Problem Behaviors to the Odds Ratios of Selecting Someone as a Friend

| Past-Year Delinquency | | | | | Past-Month Alcohol Use | | | | Past-Month Smoking | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Alter | | | | | Alter | | | | Alter | | |
| Ego | None | Once | Two/Three | More | Ego | None | Once | More | Ego | None | Once | More |
| None | 1.072 | 1.026 | 0.981 | 0.939 | None | 1.062 | 0.998 | 0.937 | None | 1.052 | 0.945 | 0.849 |
| Once | 0.981 | 1.087 | 1.040 | 0.995 | Once | 0.884 | 1.109 | 1.042 | Once | 0.839 | 1.169 | 1.050 |
| Two/Three | 0.898 | 0.995 | 1.103 | 1.055 | More | 0.736 | 0.923 | 1.157 | More | 0.669 | 0.932 | 1.298 |
| More | 0.822 | 0.911 | 1.009 | 1.118 | | | | | | | | |