

The Interplay of Friendship Networks and Social Networking Sites: Longitudinal Analysis of Selection and Influence Effects on Adolescent Smoking and Alcohol Use

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It is well established that adolescents' risk behaviors, such as smoking and alcohol use, are associated with their friends' behaviors.¹⁻⁶ Friendships have also been shown to be the most salient relationship through which these behavioral influences are transmitted, especially during adolescence,⁷ because of an increase in shared activities⁸ and opportunities for socialization.⁹ Furthermore, the desire for peer affirmation, social status, and group membership^{10,11} make adolescents particularly susceptible to normative influences.^{12,13} These influence processes play a significant role in the adoption of risk behaviors such as cigarette smoking and substance use.

PEER SELECTION AND INFLUENCE MECHANISMS

Although the association between adolescents' behaviors and their friends' behaviors has long been attributed to peer influence mechanisms between friends,³ an increasing body of research suggests that adolescents are also likely to form friendships around similarities in established risk behaviors. Social network methods have been used to distinguish between the effects of friendship selection and influence (socialization), but with mixed findings across smoking and alcohol use behaviors as well as across developmental stages.^{2,14,15} Among studies that show both mechanisms at work, many detect greater effects of selection,¹⁶⁻¹⁹ but others find that selection and influence both contribute to the association between friendships and risk behaviors²⁰⁻²³ (Appendix A, available as a supplement to this article at <http://www.ajph.org>).

Two social network principles provide the framework for selection and influence. Homophily is the tendency for similar people to be drawn to each other.²⁴ Adolescents who engage in risk behaviors are likely to be attracted to

Objectives. We examined the coevolution of adolescent friendships and peer influences with respect to their risk behaviors and social networking site use.

Methods. Investigators of the Social Network Study collected longitudinal data during fall 2010 and spring 2011 from 10th-grade students in 5 Southern California high schools (n = 1434). We used meta-analyses of stochastic actor-based models to estimate changes in friendship ties and risk behaviors and the effects of Facebook and MySpace use.

Results. Significant shifts in adolescent smoking and drinking occurred despite little change in overall prevalence rates. Students with higher levels of alcohol use were more likely to send and receive friendship nominations and become friends with other drinkers. They were also more likely to increase alcohol use if their friends drank more. Adolescents selected friends with similar Facebook and MySpace use habits. Exposure to friends' risky online pictures increased smoking behaviors but had no significant effects on alcohol use.

Conclusions. Our findings support a greater focus on friendship selection mechanisms in school-based alcohol use interventions. Social media platforms may help identify at-risk adolescent groups and foster positive norms about risk behaviors. (*Am J Public Health.* 2014;104:e51-e59. doi:10.2105/AJPH.2014.302038)

each other, and these risk behaviors are consequently reinforced as a result of shared time and activities. Adolescents' self-concept may hinge on the social groups to which they belong, so they alter their behaviors to conform to appropriate group- and self-defined norms.²⁵ Socialization is the process by which information or ideas are diffused through a network by contact or communication.²⁶ The spread of behavior may be driven by a centrally positioned individual or by the prevalence of risk behaviors and associated norms defined by peer environments.²⁷ Influence processes may also be triggered by direct peer pressures or internal cognitive perceptions about the norms and risks associated with the behaviors.

ADOLESCENT ONLINE SOCIAL NETWORKING

Online social networking sites (SNSs) have increased the potential channels through which peer selection and influences take place. In the United

States, SNSs are used by approximately 80% of adolescents (aged 12-17 years) and have gradually become the preferred means of communication across all racial and socioeconomic groups.^{28,29}

Adolescents frequent popular SNSs to form and build friendships, foster their sense of social connectedness,³⁰ and manage their self-presentations, according to their current interests.^{31,32} In accordance with social learning mechanisms through mass media channels, friendships that extend into the virtual context may foster similar but compounded mutual influences on behaviors through online chatting and the exchange of digital content. Online interactions may accelerate peer influence processes between friends because of their ubiquity and ability to cross boundaries of time and space. Broader influences may similarly originate from acquaintances or popular media figures who model behaviors that adolescents are likely to emulate.

There is growing concern that SNSs may also serve as conduits of risk behaviors in instances

when risky content is discussed or showcased by friends online.^{33,34} Adolescents may exhibit fewer inhibitions in their display of risky behaviors such as smoking or alcohol use in an online context because the repercussions that come with face-to-face contact are minimized. Exposures to unfavorable media sources³⁵ or risky online encounters^{34,36,37} may also distort perceptions of risk.³⁸

Emerging evidence points to an association between adolescent social media use and risk behaviors,³³ but the mechanisms of influence are unclear. SNSs are also characterized by distinct user traits,³³ which provide a space for adolescents to commune with others who are similar to themselves. Studies that have used SNSs for health interventions have found modest results but increasingly suggest that social media platforms can be effective in facilitating new norms that encourage or discourage risk taking.³⁹

We examined, in the context of face-to-face friendships in a school setting, whether selection—by similarity in smoking and alcohol use—had greater impact on behavior than did peer influence. Secondly, we investigated possible mechanisms leading to an association between adolescents' online activity and their risk behaviors: (1) Did similarity in SNS use or exposure affect friendship formation and maintenance among students in the same grade (selection)? (2) Did exposure to friends' risk behaviors online increase the likelihood of adolescent risk behaviors (influence)? Findings will shed light on how social media may alter selection and influence mechanisms and inform the design of social media interventions.

METHODS

Data were from the first 2 waves of the Social Network Study,⁴⁰ a longitudinal network study of 5 Southern California high schools. We administered paper-and-pencil surveys during class on a regular school day in October 2010 and in May 2011. Of the total 2290 enrolled 10th-grade students, 2016 returned valid parental consent forms (88.0%), with 1823 allowing participation in the study; 28 of these students did not assent. The eligible pool was 1795 students, of whom 1719 completed surveys at time 1 and 1620 at time 2.

We collected sociometric (saturated) network data at the grade level and egocentric

(personal) network data at the community level. For grade-level networks, we asked students to nominate up to 19 best friends, identified by ID numbers on a photo roster of all students in their grade.⁴⁰ We constructed egocentric networks by asking students to “name seven best friends regardless of where they live or go to school.” Of the total egocentric nominations that specified first and last names, we matched 54% to students in respondents' grade.

Measures

To model selection effects, we specified the network as the dependent variable. We conducted analyses on the 5 friendship networks across the 5 schools. Of the 1795 eligible participants in the analytic sample, 1434 (79.9%) 10th graders provided friendship nominations at both time points.

To model peer influence effects, we specified students' self-reported tobacco and alcohol use as the dependent behavioral variables. We derived a composite smoking score (1 = not susceptible, 2 = susceptible, 3 = ever smoker, 4 = past-month smoker, 5 = daily smoker) from responses to 5 questions on smoking frequency and intention. We deemed the composite ordinal items appropriate for Siena modeling.⁴¹ We coded a response of “definitely not” to the first question, “At any time in the next year do you think you will smoke a cigarette?” as not susceptible and all others as susceptible. We defined ever smokers as all students who gave any response other than never having smoked to the questions “How old were you when you first smoked a whole cigarette?” and “Have you ever tried cigarette smoking, even one or two puffs?” For the last 2 questions, “During the past 30 days, on how many days did you smoke?” and “Have you ever smoked cigarettes daily?” we coded responses other than zero days or never smoked as past-month and daily smokers, respectively.

Similarly, we coded alcohol use as a composite score (1 = not susceptible, 2 = susceptible, 3 = ever drinker, 4 = past-month drinker, 5 = past-month binge drinker) derived from these items: 12-month drinking intention, age at first drink of alcohol except for religious purposes, number of days having at least 1 drink of alcohol during the past 30 days, and

number of days having 5 or more drinks of alcohol in a row during the past 30 days.

We tested 4 social media use variables as covariates in the model. Two items captured the frequency of visits to the SNSs Facebook and MySpace in the past month (1 = never, 2 = rarely [once a month or less], 3 = occasionally [once a week or less], 4 = frequently [once every 2–3 days], and 5 = very frequently [once a day or more]). Two items derived from the students' egocentric networks captured online risk exposures across SNS sites. These items asked respondents to indicate whether their nominated friends ever (1) posted pictures of themselves partying or drinking alcohol online and (2) talked about partying online. We separately tallied the total number of friends for both items as an indicator for online risk exposure (range = 0–7). Demographic covariates were students' age, gender, ethnicity (1 = Latino or Hispanic ethnic origin, 2 = other), academic performance, parental smoking, and parental alcohol use.

Analyses

We estimated stochastic actor-oriented models (SAOMs) with RSiena (Simulation Investigation for Empirical Network Analysis) version 4.0,⁴¹ a software package for estimating longitudinal coevolution models of social networks,⁴² offered through the open-source statistical system R.⁴³

The primary advantage of using SAOMs over previous methods for longitudinal network analysis is the ability to simultaneously estimate network and behavioral dynamics while accounting for endogenous network tendencies. These may include the tendencies for friends to nominate each other as friends (reciprocity), the tendency for friends of friends to become friends (transitivity), or the tendency for actors with similar attributes to become friends (homophily).^{42,44} Individuals within a bounded network are actors, who may change their ties in response to behaviors and attributes of others around them (i.e., selection) or change their behavior because of their current network ties (i.e., influence).

Three main assumptions distinguish the SAOM from conventional methods for estimating individual-level changes within a network.⁴⁵ First, changes between measurement points are modeled according to a continuous-time

Markov process to simulate likely unobserved developmental trajectories between the measurement time points.⁴⁶ Second, each actor is assumed to independently make decisions about changes in friendship ties or behaviors, without conspiring with others about these decisions. Finally, actors take microsteps of change, 1 network tie or 1 level of behavior at a time, reducing the variation between assessments.

We tested the study aims in 2 stages. First we specified a risk behavior model to simultaneously estimate selection and influence of adolescent smoking and alcohol use. Because there is strong evidence for the co-occurrence of adolescent smoking and alcohol use,^{23,47} we included both as behavioral dependent variables to simultaneously control for the 2 behaviors. Our second social media model tested whether SNS use parameters added more explanatory power to the network and behavioral dynamics beyond those established in the first set of analyses.

Model Specification

Two main functions are used to govern network and behavior changes in both model estimations. The rate function represents the average number of opportunities for change in the network and behavior between discrete time points. The objective function provides parameters that guide the direction of these changes. We further specified 2 types of objective functions: the network objective function, to estimate the change in friendship ties based on adolescent attributes, and the behavior objective function, to estimate the change in behavior based on friendships and network structure.

We derived a set of a priori parameters (Table 1) from previous literature and theoretical justification, and further tested with a forward selection process that used Neyman–Rao score-type tests for interdependent effects of alternative models against a null model.⁴⁴ We separately estimated the 2 models for each school, then combined the results in a meta-analysis to test the means and variances of all parameter estimates across schools.⁴⁴ We used 2 types of tests⁴¹ to determine the significance of effects: (1) a likelihood method that used the *t* ratio (mean parameter estimate divided by its standard error) under iterative weighted least squares modification⁴⁸ and (2) a Fisher-type

TABLE 1—Tested Effects of Network and Behavior Coevolution Models of Peer Selection and Influence on Adolescent Smoking and Drinking: Social Network Study, 2010–2011

Effect	Description
Network dynamics (selection)	
Rate parameter—friendship	Average number of opportunities for tie changes over time
Endogenous structural effects	
Out-degree (density)	Tendency to form friendship with someone
Reciprocity	Tendency to form friendship with someone who previously selected participant as friend
Transitivity	Tendency to form friendship with a friend of a current friend
3 cycles	Tendency for network closure between 3 friends
Covariate effects (similarity)	
Female, grades, Hispanic	Tendency to form friendship with someone of the same gender, with similar academic grades, and with someone who is of Hispanic/Latino descent
Online risky pictures	Tendency to form friendship with someone who has similar exposures to friends' online posts of risky pictures
Online partying	Tendency to form friendship with someone who has similar exposures to friends' online discussions about partying
Facebook	Tendency to form friendship with someone who has similar Facebook use habits
MySpace	Tendency to form friendship with someone who has similar MySpace use habits
Behavioral effects ^a	
Behavior alter (popularity)	Effect of behavior on tendency to receive ties
Behavior ego (activity)	Effect of behavior on tendency to send ties out
Similarity in risk behavior	Effect of 2 people selecting each other as friends on the basis of similarity in behavior
Behavior dynamics (influence)	
Rate parameter—behavior ^a	Average number of opportunities for changes in behavior over time
Linear tendency	Linear distribution of behavior
Quadratic tendency	Quadratic distribution of behavior
Behavioral effects	
Behavior alter average	Effect of the average of friends' behaviors on participants' behavior
Female	Effect of being female on behavior
Grades	Effect of grades on behavior
Parental smoking/alcohol use	Effect of parental smoking or alcohol use on behavior
Hispanic/Latino	Effect of being Hispanic/Latino on behavior
Friends post risky pictures online	Effect of friends' online posts of risky pictures on behavior
Friends talk about partying online	Effect of friends' online discussions about partying on behavior
Facebook	Effect of Facebook use on behavior
MySpace	Effect of MySpace use on behavior
Current risk behavior	Effect of other risk behavior (smoking or alcohol use) on behavior

^aBehavior parameters refer to either smoking or alcohol use.

combination test of 1-sided *P* values.⁴⁹ We computed between-school differences with an approximate χ^2 test of parameter variances by the Snijders–Baerveldt method.⁴⁸

RESULTS

Network characteristics and risk behaviors of the 5 high schools are presented in Table 2.

TABLE 2—Descriptive Sample Statistics Among Adolescents in 5 Southern California Schools: Social Network Study, 2010–2011

Characteristic	Time 1, Fall 2010		Time 2, Spring 2011	
	Total Sample (n = 1434), Mean	Individual Schools Mean, low/high	Total Sample (n = 1434), Mean	Individual Schools, Mean, low/high
Network characteristics				
No.	287	215/371	...	...
Average degree ^a	5.17	4.21/5.87	5.23	4.17/6.27
Density ^b	0.018	0.015/0.023	0.018	0.013/0.025
Centralization ^c	0.034	0.031/0.044	0.031	0.023/0.037
Reciprocity ^d	0.260	0.233/0.284	0.254	0.229/0.299
Jaccard index ^e	...	...	0.302	0.28/0.34
Descriptive characteristics				
Tobacco use ^f	1.79	1.58/1.96	1.75	1.58/1.89
Not susceptible	61.09	54.8/71.2	63.06	57.5/71.6
Susceptible	8.79	6.9/12.1	7.50	5.9/11.3
Ever smoker	21.33	14.1/26.2	21.48	16.3/26.1
Past-month smoker	6.24	5.6/6.8	5.43	3.9/7.1
Daily smoker	2.56	0.9/4.7	2.52	2.0/3.5
Alcohol use ^f	2.62	2.18/2.95	2.55	2.18/2.87
Nonsusceptible	36.93	26.6/50.7	39.29	31.5/51.5
Susceptible	4.71	3.8/6.1	5.45	4.9/6.0
Ever drank	30.94	26.6/33.4	31.49	27.7/34.0
Past-month drinker	12.58	7.9/17.4	11.29	8.1/14.0
Daily drinker	14.81	9.9/18.4	12.49	7.8/14.9
Female ^g	0.51	0.48/0.54	...	...
Hispanic ^g	0.66	0.42/0.86	...	...
Grades ^h	6.21	5.81/6.50	...	...
Parental smoking ⁱ	1.37	1.34/1.40	...	...
Parental drinking ⁱ	1.63	1.53/1.69	...	...
Facebook use ^j	2.81	2.21/3.53	...	...
MySpace use ^j	2.70	2.11/3.09	...	...
Ego network friends			...	...
Friends who posted risky pictures online, ^k no.	0.36	0.25/0.53	...	...
Friends who posted talk about partying online, ^k no.	0.77	0.43/1.04	...	...

Note. Ellipses indicate not applicable.

^aNumber of nominations an actor received from others in the network.

^bRatio between total number of ties and total number of possible ties in network.

^cDegree to which network ties were directed to 1 or a few actors in the network.

^dProportion of ties that were reciprocated.

^eRatio between repeated ties over total ties across 2 time points.

^fRange = 1–5.

^gRange = 0–1.

^hRange = 1 (mostly As)–9 (mostly Fs).

ⁱRange = 1–3.

^jRange = 1–5.

^kRange = 0–7.

(School-level descriptive statistics in Appendix B, available as a supplement to this article at <http://www.ajph.org>.) Students were evenly distributed by gender, and their mean age was 15 years. Average self-reported academic

grades were “mostly C’s,” and about two thirds reported being Hispanic–Latino. Students nominated on average 5.17 school friends at time 1 and 5.23 at time 2. The average network densities remained similar but

fluctuated slightly within schools. Overall network centralization and reciprocity decreased slightly over time, suggesting that peers formed new friendships with more peripheral members in their grade. Jaccard indices, calculated

as the ratio of stable ties divided by the total number of ties across both times, ranged from 0.28 to 0.34. Indices above 0.2 indicated that the number of stable ties was sufficient to accurately estimate effects.⁴² Tobacco and alcohol use remained steady over time, suggesting that approximately equal numbers of students increased and decreased their risk behaviors. Students reported that most parents did not smoke (70%) and that about half (51%) drank alcohol at least once a week.

Coevolution of School-Based Friendships and Risk Behaviors

Two sets of meta-analysis outcomes are presented for both models (Tables 3 and 4); however, effects derived from the Fisher 1-sided test ($\alpha/2 = 0.025$) are described because the study sample represented the entire school district under study.⁴¹ We assessed parameter variances between schools with the χ^2 test and 4 degrees of freedom ($N-1$). With the exceptions of the endogenous structural parameters and similarity in Hispanic–Latino ethnicity, we observed few between-school differences. SAOM estimates derived with a dichotomous indicator of smoking and alcohol achieved nearly identical results (although 1 school did not converge).

Covariate effects. In the risk behavior model (Table 3), parameter estimates of the 4 endogenous structural effects were statistically significant ($P < .001$), indicating that best friends were likely to reciprocate friendships (reciprocity), become friends with someone who was a friend of an existing friend (transitivity), and form network closure with triadic friendship ties (3 cycles). Because we limited the number of nominations to 19 in the survey, the network density was significantly less than 50% (negative out-degree). Of the actor covariates, students who were the same gender, both Hispanic–Latino, and similar in academic achievement were likely to form new friendships and maintain their existing ones over time ($P < .001$).

Among the covariates used to predict drinking and smoking, being female was marginally protective against the increase in smoking risk, but academic achievement and being of Hispanic origin did not have effects on either risk behavior. Parental smoking and drinking significantly predicted higher levels of these risk

TABLE 3—Meta-Analysis Results of Risk Behavior Model of Peer Selection and Influences on Adolescent Smoking and Drinking: Social Network Study, 2010–2011

Variable	Snijders-Baerveldt Method		Fisher's Combination 1-Sided Test ($df = 10$)			
	B (SE)	Between-School Difference ^a	χ^2 (Left Side)	P	χ^2 (Right Side)	P
Network dynamics						
Rate friendship	13.17*** (1.039)	2.32***	0	> .999	3051.50	< .001
Out-degree (density)	-2.66*** (0.048)	0.11***	3469.06	< .001	0	> .999
Reciprocity	1.85*** (0.083)	0.19***	0	> .999	2704.18	< .001
Transitive triplets	0.49*** (0.036)	0.08***	0	> .999	1628.16	< .001
3 cycles	-0.35*** (0.014)	0.03	230.68	< .001	0	> .999
Female similarity	0.42*** (0.023)	0.05	0	> .999	375.72	< .001
Grades similarity	0.44*** (0.053)	0.12	0	> .999	92.81	< .001
Hispanic similarity	0.19 (0.078)	0.17***	2.21	.994	129.28	< .001
Smoking alter	0.03 (0.015)	0.03	3.74	.958	16.17	.095
Smoking ego	-0.02 (0.021)	0.05	14.51	.151	7.27	.7
Smoking similarity	0.08 (0.143)	0.32*	9.74	.464	16.98	.075
Drinking alter	0.04* (0.013)	0.03	0.98	> .999	31.88	< .001
Drinking ego	0.03 (0.014)	0.03	2.84	.985	23.58	.009
Drinking similarity	0.39** (0.081)	0.18	1.28	.999	53.80	< .001
Smoking behavior dynamics						
Rate smoking	1.43*** (0.073)	0.16	0	> .999	218.93	< .001
Linear shape	-1.08*** (0.082)	0.18	227.33	< .001	0	> .999
Quadratic shape	0.16** (0.024)	0.05	0.75	> .999	37.92	< .001
Average alter smoking	0.03 (0.164)	0.37	6.81	.743	11.76	.301
Female	-0.25* (0.076)	0.17	19.57	.034	2.55	.99
Grades	-0.06 (0.022)	0.05	16.50	.086	3.30	.973
Parental smoking	0.22 (0.091)	0.20	2.97	.982	22.76	.012
Hispanic	-0.07 (0.160)	0.36	10.06	.436	9.17	.516
Current drinking	0.18* (0.053)	0.12	1.97	.997	32.04	< .001
Drinking behavior dynamics						
Rate drinking	2.24*** (0.125)	0.28	0	> .999	272.88	< .001
Linear shape	-0.32** (0.054)	0.12	107.97	< .001	0.02	> .999
Quadratic shape	0.09* (0.028)	0.06	3.73	.959	31.53	< .001
Average alter drinking	0.19 (0.084)	0.18	2.76	.987	18.37	.049
Female	0.09 (0.105)	0.24	7.34	.693	17.99	.055
Grades	< -0.01 (0.016)	0.04	8.24	.606	8.70	.561
Parental drinking	0.13 (0.060)	0.13	2.87	.984	23.78	.008
Hispanic	< -0.01 (0.071)	0.16	7.74	.654	9.17	.516
Current smoking	0.17* (0.054)	0.12	1.22	> .999	42.27	< .001

^aSignificance derived from approximate χ^2 test ($df = 4$). * $P < .05$; ** $P < .01$; *** $P < .001$.

behaviors at time 2 ($P = .012$ and $P = .008$, respectively). Furthermore, an adolescent's engagement in either smoking or alcohol use at time 1 significantly predicted higher levels of the other risk behavior at time 2 (both $P < .001$), suggesting a significant degree of co-occurrence between the 2 risk behaviors.

Predictors of school-based friendship networks. Students who had higher rates of smoking showed a marginal trend toward receiving more nominations ($\chi^2 = 16.17$; $P = .095$) but did not send out more ties. Students who were similar in smoking status had a tendency to form and maintain friendships ($\chi^2 = 16.98$;

$P=.075$). Friendship selection and maintenance effects were stronger for alcohol use: students who reported more drinking had higher tendencies to both receive ($\chi^2 = 31.88$; $P < .001$) and send ($\chi^2 = 23.58$; $P = .009$) more nominations than those who reported low rates of drinking. Students who were similar in drinking status were also significantly more likely to form and maintain their friendships ($\chi^2 = 53.80$; $P < .001$).

Predictors of school-based smoking and alcohol risk. Regarding behavior dynamics, we found no influence effects attributable to smoking friends, but adolescents with drinking friends had marginally higher tendencies to maintain or increase their drinking behaviors over the past 6 months ($\chi^2 = 18.37$; $P = .049$). Students were more likely to change their drinking status than their smoking status (2.24 vs 1.43 times). The negative linear shape effects indicated that the majority of students reported no use or low levels of tobacco and alcohol use. The significant positive quadratic shape effects indicated that risks for both smoking and drinking were self-reinforcing, suggesting that those who exhibited higher risk at time 1 were likely to continue the risk behavior at time 2 and that those who were abstinent were likely to remain abstinent. The associations between adolescent and friend risk behaviors were better explained by selection than by influence mechanisms.

Effects of Social Media Use

In the social media model (Table 4), we added the effects of SNS use and online exposures to risk behaviors. Effects estimated in the first model remained stable. Students who were similar in Facebook and MySpace use were likely to form or maintain ties ($\chi^2 = 40.53$ and $\chi^2 = 52.82$, respectively; both, $P < .001$). Friends who were similarly exposed to risky online postings by personal network friends also had a tendency to maintain or form new friendship ties ($\chi^2 = 20.54$; $P = .033$).

Regarding behavioral influence, frequency of Facebook and MySpace use did not significantly predict higher smoking and alcohol risk. Effects of exposure to risky pictures posted online by personal network friends was significantly predictive of adolescents' likelihood of increasing or maintaining their smoking levels ($\chi^2 = 26.03$; $P = .004$); however, exposure to

TABLE 4—Meta-analysis Results of Social Media Model of Peer Selection and Influences on Adolescent Smoking and Drinking: Social Network Study, 2010–2011

Variable	Snijders-Baerveldt Method		Fisher's Combination 1-Sided Test (df = 10)			
	B (SE)	Between-School Difference ^a	χ^2 (Left Side)	P	χ^2 (Right Side)	P
Network dynamics						
Rate friendship	13.19*** (1.048)	2.34***	0	> .999	2676.61	< .001
Out-degree (density)	-2.67*** (0.050)	0.11***	31786.19	< .001	0	> .999
Reciprocity	1.84*** (0.083)	0.19***	0	> .999	2669.08	< .001
Transitive triplets	0.48*** (0.037)	0.08***	0	> .999	1433.43	< .001
3 cycles	-0.35*** (0.013)	0.03	210.64	.001	0	> .999
Female similarity	0.42*** (0.022)	0.05	0	> .999	393.15	< .001
Grades similarity	0.42** (0.056)	0.12	0.01	> .999	83.53	< .001
Hispanic similarity	0.17 (0.076)	0.17***	2.33	.993	109.47	< .001
Online risk picture similarity	0.06*** (0.007)	0.01	1.60	.999	20.54	.033
Online party similarity	0.01 (0.026)	0.06	9.10	.523	12.38	.261
Facebook similarity	0.13** (0.019)	0.04	0.41	> .999	40.53	< .001
MySpace similarity	0.20** (0.034)	0.08	0.18	> .999	52.82	< .001
Smoking alter	0.02 (0.015)	0.03	3.96	.949	15.58	.112
Smoking ego	-0.02 (0.019)	0.04	15.22	.124	6.00	.815
Smoking similarity	0.06 (0.132)	0.29	9.15	.518	14.35	.158
Drinking alter	0.05* (0.014)	0.03	0.89	> .999	36.75	< .001
Drinking ego	0.04* (0.014)	0.03	2.17	.995	27.45	.004
Drinking similarity	0.35* (0.100)	0.22	1.87	.997	48.54	< .001
Smoking behavior dynamics						
Rate smoking	1.39*** (0.059)	0.13	0	> .999	272.48	< .001
Linear shape	-1.11*** (0.079)	0.18	217.36	.001	0	> .999
Quadratic shape	0.13** (0.022)	0.05	1.17	> .999	26.62	.003
Average alter smoking	0.04 (0.204)	0.46	6.83	.741	11.16	.345
Female	-0.33* (0.120)	0.27	24.85	.006	2.33	.993
Grades	-0.07* (0.019)	0.04	16.91	.076	2.71	.987
Parental smoking	0.24 (0.104)	0.23	3.41	.97	23.99	.008
Hispanic	0.04 (0.216)	0.48	8.54	.576	11.61	.312
Online risky pictures	0.43 (0.210)	0.47	3.53	.966	26.03	.004
Online party	-0.01 (0.213)	0.48*	12.04	.283	13.50	.197
Facebook	0.02 (0.044)	0.10	7.47	.68	12.68	.242
MySpace	-0.02 (0.073)	0.16	13.53	.196	10.36	.41
Current drinking	0.16* (0.056)	0.13	2.69	.988	23.34	.01
Drinking behavior dynamics						
Rate drinking	2.19*** (0.126)	0.28	0	> .999	283.82	< .001
Linear shape	-0.34*** (0.055)	0.12	104.52	.001	0.02	> .999
Quadratic shape	0.08 (0.034)	0.08	4.26	.935	31.37	< .001
Average alter drinking	0.18 (0.086)	0.19	3.12	.978	18.00	.055
Female	0.06 (0.102)	0.23	7.73	.655	15.41	.118
Grades	< 0.01 (0.010)	0.02	6.92	.733	8.03	.626
Parental drinking	0.13 (0.065)	0.15	3.04	.981	25.53	.004
Hispanic	0.02 (0.072)	0.16	6.37	.783	10.44	.403
Online risky pictures	-0.05 (0.072)	0.16	10.68	.383	6.09	.807
Online party	0.11 (0.068)	0.15	4.95	.895	14.41	.155

Continued

friends talking about partying online had no effect.

DISCUSSION

Consistent with some previous studies, selection effects, particularly for alcohol use, were stronger than influence effects among adolescents in our sample.^{17–20,23,50–52} Adolescent drinkers had stronger tendencies to send and receive friendship nominations from other 10th graders, which indicated that students who used alcohol were more outgoing and popular than those who did not. Students who had similar alcohol use habits were also more likely to select each other as friends. We observed peer influence effects only for alcohol use, suggesting that norms favoring alcohol use may have been more widespread among the adolescents in our sample and regarded as more social than smoking.⁵⁰ The weaker selection effects associated with smoking may have resulted from the simultaneous modeling of both behaviors, diluting effects that have been found in previous single-behavior models. Statistically significant smoking selection effects confirmed this when we conducted SAOM meta-analyses independently from alcohol use (results not shown).

When we jointly considered structural and behavioral effects, a more detailed view of how these evolve in a secondary school emerged. Although the overall prevalence of smoking and drinking did not increase over 6 months, we saw significant shifts in behavior and friendships. In essence, behaviors coalesced: friends increased their reciprocity and became friends of existing friends. Likewise, friendship evolved: behaviors created attractors for network dynamics, partitioning friendship groups into those who embraced the behavior and those who did not.

We also shed light on potential selection and influence mechanisms related to adolescents' use of SNSs. Friendships were more likely to exist between students who had similar Facebook and MySpace use habits and between students similarly exposed to their friends' online displays of drinking and partying. If exposures indicate higher acceptance of risk behavior norms, the results may suggest an affinity between students with similar normative perceptions of these risk behaviors.

TABLE 4—Continued

Facebook	0.02 (0.023)	0.05	4.98	.892	14.96	.134
MySpace	0.02 (0.039)	0.09	8.88	.544	14.67	.145
Current smoking	0.16* (0.057)	0.13	1.36	.999	38.09	< .001

^aSignificance derived from approximate χ^2 test ($df = 4$).
* $P < .05$; ** $P < .01$; *** $P < .001$.

Adolescents are drawn toward specific SNSs because of their demographic or other behavioral characteristics,³³ so the selection and maintenance of friends might also be conceptualized as the result of similarity in these domains.

Although use of Facebook and MySpace did not affect the tendencies for adolescents to smoke or use alcohol, adolescents who were exposed to their friends' risky online displays reported an increase in smoking at time 2. This supports previous findings that SNS use alone does not pose risks, but rather it is the content exchanged through SNSs that triggers behavioral influences.³³ Pictures posted on SNSs, which are readily transmitted, may compound biased normative beliefs among friends connected through online social networks. This is especially pertinent for close friends who also interact daily in school. Through vicarious learning mechanisms,⁵³ online social media content may exert greater influences than traditional media channels as media figures are replaced by actual friends.

SNS influences from friends outside of the 10th grade who had higher perceived rates of smoking and drinking (not presented) and who represented almost half of the egocentric nominations, might also have been a source of peer influence. To test this possibility, we added to the SAOM models an indicator derived from the ratio of nominations of egocentric friends who were not grade-level friends to total egocentric friends and found it to be a significant predictor of network change for both risk behavior and SNS models ($\chi^2 = 21.13$ and $\chi^2 = 22.16$, respectively; both $P = .01$), while behavior was not affected.

We observed a stronger association of online risk exposures with smoking than with alcohol use. Online mechanisms may be a more comfortable environment for adolescents to exhibit smoking behaviors, which are less

prevalent and less normative than alcohol use. In the wake of increasing prevalence and expanded utility of SNSs among adolescents, these findings provide timely evidence that peer influence effects may be transmitted through online displays of risk behavior.

Limitations

We drew our study sample from 1 Southern California high school district; findings may not be generalizable to the wider US adolescent population. Results from other districts may vary by prevalence of alcohol and tobacco consumption as well as the cultural mores of social media use. Although egocentric friend influences extended beyond the influences assessed within participants' grade, for which we modeled selection and influence mechanisms, the use of self-reported attributes of egocentric friends might not have fully captured these adolescents' online exposures. Nevertheless, the self-reported data of friends' displays from our respondents can be considered a proximal source of influence, by contrast with exposures through general Web browsing activity. Future studies might consider including direct measures of online risk activity to more accurately estimate selection and influence effects attributable to network exposures.

We restricted sociometric friendship nominations to students in the same grade, which therefore might not have accounted for all possible sources of selection and influence effects on the 2 risk behaviors under study. However, participants could nominate up to 19 grade-level friends, so our results provide a reliable representation of grade-level peer influences.

We collectively modeled the change and maintenance of friendship ties, and thus our analyses did not distinguish between newly created, dissolved, and maintained ties over time. Recent studies that have found these

differential selection effects in relation to smoking and alcohol use^{54,55} suggest that further investigation of these mechanisms and their associations with both risk behaviors and SNS experiences is warranted.

Implications

Despite the limitations, our study provides further evidence of risk-related selection mechanisms in school-based peer networks, and these deserve more attention in the design and implementation of school-based smoking and alcohol use prevention interventions. Interventions that incorporate SNSs or similar platforms may enhance peer selection and influence processes through higher levels of engagement, extended contact, and accelerated diffusion of positive social norms. SAOMs can be an effective way to examine the use patterns of existing SNSs such as Facebook and MySpace and to determine whether SNS activity might be indicative of risk-related social norms.

Future studies might incorporate more precise measurements of online risk exposure to better inform the mechanisms of online social influences. Use of SNSs or other online health applications could be modeled as a behavioral dependent variable to assess direct effects of online participation on risk behaviors.⁵⁰ SAOMs can furthermore inform the efficacy of SNS-based interventions by examining whether users of specific social media applications are perceived as popular, whether users are effectively reaching out to others through the applications, and whether direct associations exist between intervention use and health outcomes.

Continued application of the SAOM is necessary to test potential social and environmental factors that may contribute to selection and influence processes. It could be useful to investigate the effects of SNS use and friendship reciprocity⁵² on degree of mutual influence as well as the differential effects of smoking and alcohol use on the creation, dissolution, and maintenance of friendships over time. Future studies might also focus on cross-behavior influences of selection and influence effects to uncover mechanisms that drive the simultaneous progression of alcohol and smoking³⁵ among high-risk groups. Just as a calm sea masks the dramatic activities that occur below it, static rates of given behaviors can disguise the considerable dynamic influence and

selection activities that adolescents engage in over time. ■

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Contributors

G. C. Huang led the conceptualization, instrument development, data analysis, interpretation of findings, and writing of the article. D. Soto coordinated all aspects of data collection and data cleaning and helped review the article. K. Fujimoto oversaw data analysis and interpretation of findings and helped review the article. T. W. Valente oversaw the conceptualization, instrument design, data collection, data analysis, and interpretation of findings and helped write and review the article.

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Human Participant Projection

All study protocols were approved by the institutional review board of the University of Southern California.

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