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Social integration in friendship networks: The synergy of network structure and peer influence in relation to cigarette smoking among high risk adolescents

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Abstract

Using data from a study of high risk adolescents in Southern California, U.S.A. (N = 851), this study examined synergy between social network measures of social integration and peer influence in relation to past month cigarette smoking. Using Hierarchical Linear Modeling, results indicated that being central in networks was significantly and positively related to past month cigarette smoking, across all study models. In addition, there is modest evidence that the number of reciprocated friendship ties was positively related to past month cigarette smoking. There is also some modest evidence that the relationship between having reciprocated friendships and past month cigarette smoking was moderated by a network peer influence process, smoking with those in youths' best friend networks. Findings indicate that being integrated within a social network context of peer influences favoring drug use relates to more smoking among these high risk youth.

Keywords

Social networks; Adolescents; Adolescent smoking; Peer influence; Tobacco use; Risk behavior; Youth; USA

Introduction

Numerous studies spanning multiple decades suggest a protective effect of social network ties on health (e.g., Berkman & Syme, 1979; Durkheim, 1858/1917; House, Robbins, & Metzner, 1982; Seeman, Kaplan, Knudsen, Cohen, & Guralnik, 1987). Other studies, however, indicate that social ties can deleteriously affect health (e.g., Rook, 1992; Rook & Pietromonaco, 1987). Given this competing evidence, one critical step toward a better understanding of the relationship between social networks and health is to elucidate linkages through which social networks ties adversely affect health, which are currently not well understood.

The literature examining the relationship between social network ties and health generally focuses either on structural aspects of social network ties, such as network size, or on the commodities ties transmit (e.g., Lin, Woelfel, & Light, 1985), such as social support, in relation to health. Less research theorizes the interrelationship of network structure and the

commodities transmitted through ties as a linkage between social network ties and health behavior. Among studies of adolescents, past research suggests that not only does network structure influence health behavior, but that normative and other peer influences transmitted through network ties shape risk behavior (Krohn, 1986).

Grounded conceptually in social network theory, this study draws on theoretical intuition from Granovetter (1973) to focus on both individual and network level structures, including the relevance of weak ties, to examine how peer influence acts jointly with adolescent friendship networks in relation to cigarette smoking. This study examines potential synergy between characteristics of network ties and peer influences in relation to cigarette smoking among high risk adolescents in southern California continuation high schools. Youth who attend these schools have exited mainstream high schools due to reasons including truancy, drug use, and lack of academic credits (Sussman, Dent, Stacy, & Craig, 1998) and are at high risk for substance use relative to mainstream youth from adolescence into adulthood (e.g., Rohrbach, Sussman, Dent, & Sun, 2005; Sussman, Dent, & Leu, 2000; Sussman, Dent, & Stacy, 2002). In the present study, we focus on both structural and positional characteristics of youths' friendship networks. Structural characteristics describe linkages among individuals in a network, while positional characteristics describe the significance of occupying different network positions. This study attempts to elucidate linkages between social network ties and cigarette smoking among the adolescents under study. The network characteristics under study are salient from a theoretical standpoint to the peer influences under study and reflect the extent to which youth were socially integrated in their friendship networks. We define social integration as the extent and nature in which youth are embedded in networks. We also account for various dimensions of smoking related peer influence, including a normative process relevant to adolescent smoking. Few studies if any to date have taken this multidimensional theoretical approach in studying the relationship between adolescent friendship networks and smoking.

Social integration in networks and adolescent smoking

Past studies examining relationships between both structural and positional characteristics of adolescent networks and cigarette smoking (e.g., Abel, Plumridge, & Graham, 2002; Ennett & Bauman, 1993; Ennett et al., 2006; Fang, Li, Stanton, & Dong, 2003) generally find that adolescents occupying less socially integrated positions in networks are more likely to smoke. Other studies, however, show that popular (well connected) youth are likely to smoke (Alexander, Piazza, Mekos, & Valente, 2001; Valente, Unger, & Johnson, 2005) and that smoking largely takes place within the peer group context (Pearson & West, 2003). Interestingly, Valente et al. (2005) found that both popular and isolated youth were likely to smoke cigarettes. They assert that because popular youth are well connected in school, they may be disproportionately exposed to the pro-smoking peer influences that may be present in schools. Furthermore, they suggest that isolated youth likely associate with friends outside of school who smoke (Valente et al., 2005). Other work suggests that peer influence may mirror pervasive smoking trends in schools, as Alexander et al. (2001) found that popular youth were more likely to smoke in schools with a high smoking prevalence. Also indicating the importance of both friend smoking and network position to adolescent smoking, Ennett et al. (2008) found that the relationship between popularity and smoking involvement was negatively moderated by the smoking behavior of adolescents' friends. This finding suggests that being less well known in adolescent networks and having a higher proportion of friends who smoke relates to more smoking among adolescents. On a related note, Haynie (2001) found that personal network density and being central in networks (i.e., popular) positively moderated the delinquency-peer relationship among youth.

In sum, this mixed pattern of findings on the relationship between social integration in networks and smoking suggests the need for considering not only the structure of ties and position of adolescents in networks, but also their exposure to smoking relevant peer influences in their school and possibly other friendship network environments. In the remainder of this theoretical section, we describe peer influence processes relevant to adolescent smoking and conclude with a section on how network structure and position may act jointly with peer influence in relation to adolescent smoking.

Peer influence and adolescent smoking

Studies consistently and positively relate peer influence to adolescent smoking, both cross-sectionally and longitudinally (e.g., Flay et al., 1994; Hoffman, Monge, Chou, & Valente, 2007). Peer influence processes have been measured in relation to adolescent smoking in numerous ways. In order to capture different dimensions of the construct of smoking related peer influences arising from friends both inside and outside of adolescents' schools, we conceptualize this construct from three different perspectives, as the influence exerted by: 1) adolescents' best friends' (whose nominations were not restricted to school) smoking behavior; 2) adolescents' classroom friends' smoking behavior; and 3) adolescents' perceived normative beliefs of their friends about drug use.

A second rationale for examining various dimensions of peer influence was to tap into a normative dimension of peer influence, namely adolescents' perceived normative beliefs of friends about drug use. It has long been recognized that the norms of adolescents' peers play an important role in the transmission of substance use behaviors among adolescent youth (e.g., Dishion, 2000; Kandel, 1973; Krohn, 1986; Sutherland, 1947). Norms influence behavior through such mechanisms as comparison of attitudes with those of a similar reference group (Marsden & Friedkin, 1994), modeling (Bandura, 1977), creating expectations for behavior (Rimal & Real, 2003), and negative social feedback (Fischer & Misovich, 1990). The influence of norms may also extend to adolescents' perceptions of their peers' behavioral norms, as one study found that adolescents' perceptions of their peers' behavioral norms about cigarette smoking predicted their own smoking behavior (Ellickson, Bird, Orlando, Klein, & McCaffrey, 2003).

One possible explanation for why continuation high school youth display relatively high rates of cigarette smoking is because they may be disproportionately exposed to pro-drug use norms transmitted through relationships with their substance using friends. A number of theoretical perspectives support this notion: Differential Association theory (Sutherland, 1947), emphasized learned associations about deviance from close network contacts with deviant norms, and the work of Krohn (1986) emphasized the role of norms in shaping delinquent behavior among youth. In addition, other research finds that youth who maintain friendships with deviant peers adopt deviant behavior (Dishion, 2000). Lastly, one study highlighted the importance of friends' norms about smoking among continuation high school youth in southern California, as friends' norms regarding substance use predicted daily cigarette smoking among youth (Rohrbach et al., 2005).

Peer influence, adolescent network structure and position

That peer influence plays an important role in adolescent smoking is well documented, however the question of how peer influence works in concert with structural and positional characteristics of adolescent networks in relation to smoking is less well understood. Network ties carry resources throughout a network, including peer influence. The structure and position of network ties may either amplify or attenuate peer influence in relation to adolescent smoking. Because both the local network (e.g., youth each adolescent is directly connected to, and the ties among them) and whole network structure may affect peer

influence, this study examines adolescents' socio-metric (whole) network characteristics at two levels: 1) the individual adolescent and 2) friendship networks of adolescents bounded by their school classrooms. At the individual level, we examine: 1) in-degree centrality, 2) reciprocity, 3) bridging, and 4) personal network density. At the network level, we examine clustering and path length. High scores on any of these constructs likely represent a moderate to high degree of social integration in a network at the level of the adolescent or the network. It is important to examine network characteristics at both levels as whole network structure may give rise to lower order structure in networks (Bearman, Moody, & Stovel, 2004). Below we describe the theoretical intuition and relevance of each network characteristic under study to peer influence and to adolescent smoking.

First, in-degree centrality reflects how directly connected an actor is to others in a network and indicates the number of people that report knowing an individual in a network. In general, centrality measures indicate prominence or popularity within the larger network (Wasserman & Faust, 1994). If an individual is directly connected to many others, then this actor can easily influence and be influenced by others. In-degree centrality has been positively related to adolescent smoking (Valente et al., 2005).

Second, the reciprocity or mutuality of ties is an important dimension of social cohesion (Wasserman & Faust, 1994) and likely taps into the symmetry, closeness, and strength of a relationship tie. Mutual relationships are characterized by close, frequent, trusting interactions, and therefore individuals in such relationships may have the potential to strongly influence one another. The reciprocity of network ties relates to smoking among adolescents, as one study found that adolescents with mutually reciprocated ties with a best friend were less likely to smoke at ages 11 and 13 than those without reciprocated best friend ties (Ennett et al., 2006).

Third, occupying a bridging position in a network may play a pivotal role in how peer influence works in relation to adolescent smoking. Bridge persons link otherwise separate groups, and can broker influence between densely connected and disparate network regions. As weak ties between these highly connected areas, bridge persons may facilitate or inhibit the flow of influence between the groups they connect (Valente & Fujimoto, 2010). Occupying a bridging position can provide access to resources outside an individual's local sub-network (Granovetter, 1973). Indeed, past studies demonstrate that bridge persons play an important role in substance use among adolescents. Ennett and Bauman (1993) found that bridge persons or liaisons were less likely to smoke than more socially isolated adolescents, while Ennett and Bauman (1994) found that liaisons who did not smoke but who were linked to a smoking clique were more likely to become smokers than non-smoking liaisons who were linked to a non-smoking clique. Thus, bridge persons are uniquely positioned to conform to or abstain from the norms and peer influences of the different groups they connect. Bridge persons may be less susceptible to the constraint imposed by being part of a densely knit group, which is able to strongly sanction conformity to group norms.

The density of an individual's personal network may affect both peer influence and adolescent smoking. Personal network density is a measure of the local connectivity of an individual's social network ties. Densely connected network ties strengthen network norms through promoting consensus around such norms (Bott, 1957) and through increased regulation of attitudes and behavior (Krohn, 1986; Laumann, 1973). Densely connected personal networks may strengthen adherence to network norms and influences for or against smoking in a network. One study found that adolescents with dense local ties had lower odds of recent smoking (Ennett et al., 2006).

Network level indicators reflect properties of a whole network and are less well studied in relation to cigarette smoking among youth. Such indicators provide insight into the overall structure of a network and its potential for conducting peer influence. Network level characteristics that may provide insight into how network structure acts in concert with peer influences in relation to smoking are: 1) clustering and 2) average path length. Clustering provides information about the degree of group based interactions among cliques, or highly connected groups of adolescents within the larger network. Clustering is of interest as individuals who comprise these groups may be homogenous on such key attributes as their substance use behavior, and exposure to norms and peer influence. The tightly-knit nature of such structures may promote adherence to group norms and peer influences. One study found that adolescent smokers tended to group with other smokers and non-smokers affiliated with other non-smokers, suggesting uniformity of smoking behavior within cliques (Ennett, Bauman, & Koch, 1994). Past research demonstrates that adolescents in cliques are less likely than those more socially isolated to smoke cigarettes (Ennett & Bauman, 1993).

Average path length, a measure of how far away network actors are from one another, may also act in concert with peer influence in relation to smoking. If on average actors are close to one another in a network (i.e., average path length is low), then people may more easily influence one another in the network. Path length is important for how peer influence flows throughout a network, as the probability of transmission of the content of network ties lessens over longer path lengths (Moody, 2002). Indeed, one study found that adolescents who were in close social proximity to a smoker had greater odds of smoking (Ennett et al., 2006).

The current study

With data from a study of continuation high school youth in three large and heterogeneous counties of Southern California, the present study examines individual and classroom level network measures of social integration with peer influences generated in these networks in relation to adolescent smoking. To gain a dimensional view of smoking related peer influences likely acting in adolescents' networks, we examine three peer influence processes: 1) whether youth smoked with those they nominate in their egocentric networks of best friends (i.e., such networks are defined from the vantage point of a single individual for some specific role relationship (e.g., friendship) and do not include all of an individual's social ties), unrestricted by the classroom or school; 2) the cigarette smoking behavior of those nominated in youths' classroom networks of best friends; and 3) youths' perceptions of friends' normative beliefs about drug use. We examine whether these peer influence processes moderate relationships between both individual and network classroom level indicators in relation to smoking (see Fig. 1).

Given that the study sample is at high risk for substance use, we expect that peer influences among this population will positively relate to cigarette smoking. Based on our understanding of how the network characteristics under study may act in concert with peer influence, we expect that individual-level network characteristics will be positively related to smoking, while network level characteristics will be negatively related to smoking. We hypothesize that the peer influence processes under study will moderate relationships between individual-level network characteristics and smoking and in a positive direction. We also expect that the peer influence processes will moderate relationships between classroom level network characteristics and smoking, although in a negative direction. Our expectations are premised upon the idea that being more socially integrated in friendship networks with friends holding pro-smoking norms and peer influences will result in more cigarette smoking among the adolescents under study.

Methods

Study overview

Data utilized in the present study are from the first wave of a longitudinal intervention study examining the effects of two social influence prevention programs targeting substance use prevention among continuation high school youth conducted by the University of Southern California Institute for Prevention Research. The study investigated the substance use behaviors, implicit cognitions, and social networks of continuation high school youth, ages 12–21, in 14 high schools, $N=894$ at baseline, in three large, populous, and highly diverse Southern California counties (i.e., Los Angeles, Orange, and Riverside).

Youth completed survey questions on their substance use behaviors, including frequency of past month cigarette smoking. All respondents answered identical questions about their substance use behaviors, implicit cognitions, attitudes toward drug use, friends' attitudes about drug use, and about psychological, familial, and demographic characteristics.

Data collection

Study recruitment began in fall of 2003. From February 2004 to December 2004, trained field staff administered three in-school structured interviews at approximately four to six month intervals lasting up to 50 min. A purposive sampling strategy was used to recruit schools into the study sample. Study personnel contacted 25 continuation high school districts in Southern California to solicit participation. Of these, 17 did not participate for various reasons: 10 refused citing administrative concerns; 7 were not used because the classroom populations were too small or some restriction on access was placed. Of the 8 districts used for the study, one served as a pilot location and the remaining 7 provided classrooms that could be randomly assigned to one of the three conditions. The three conditions were: control (prevention strategies as usual), Project Toward No Drug Use (TND), a prevention curriculum designed for adolescents, and a peer-led interactive version of TND, which provided a social network aspect to TND. Past studies examining the effectiveness of TND demonstrated a 27% decrease in the prevalence of 30-day cigarette use, a 22% decrease in prevalence of 30-day marijuana use, a 26% decrease in the prevalence of 30-day hard drug use, a 9% decrease in the prevalence of 30-day alcohol use among baseline drinkers, and a 25% decrease in the prevalence in one year weapons carrying among males (Sun, Skara, Sun, Dent, & Sussman, 2006) lasting from 1 to 5 years after the program was administered (Sussman et al., 2002).

Each student was invited to participate in the study and to provide active parental consent and student assent. All procedures were reviewed and approved by the Institutional Review Board at the University of Southern California. Of the 1493 invited to participate, 980 provided valid consent and assent forms (65.5%). From the 980 students with completed parental consent and assent forms at baseline, 113 did not provide information on their smoking behavior and were excluded from the study sample. Of the remaining 867, 16 were dropped from the sample as we restricted the study sample to individuals in school classes greater than or equal to 5 people, to allow for some variation in the structure and sizes of networks in classes ($N=851$).

Measures

Measures included indicators of cigarette smoking, social integration in networks, peer influence processes, demographic characteristics, and class size. The dependent variable, past month cigarette smoking, was measured using the item, "About how many times have you smoked cigarettes in the last month (30 days)" (1=0 times; 2 = 1–10 times; 3 = 11–20 times; 4 = 21–30 times; 5 = 31–40 times; 6 = 41–50 times; 7 = 51–60 times; 8 = 61–70

times; 9 = 71–80 times; 10 = 81–90 times; 11=91+ times). Due to the range of values present in each response category, we recoded each response category to the mean of that range and then natural log transformed this variable to reduce skewness and the possibility of outliers.

We constructed all of the social network measures from baseline survey items asking youth to name up to five best friends in the class in which the survey was administered from a class roster with random numbers assigned to each student's name. These measures are sociometric as they are based on friendship ties among all youth in the classroom. The four individual-level indicators are measured at the level of the adolescent. For each equation, i denotes the respondent and j is each person a respondent nominated as a friend, n is the number of people in respondents personal (local) network, and N is the number of adolescents in a classroom. In-degree centrality (IDC_i) for each respondent i is measured as the number of times a respondent was named as a friend:

$$IDC_i = \sum d_i / N - 1 \quad (1)$$

where d_i is the number of people who nominated each respondent. Reciprocity of ties (R_i) is measured as the number of reciprocated friendship ties, see Eq. (2):

$$R_i = \sum r_{ij} \quad (2)$$

where r_{ij} are reciprocated ties. Bridging is measured by systematically deleting links and then calculating the resultant change in inverse average path length (Valente & Fujimoto, 2010). Innovations of this measure relative to existing brokerage measures include utilizing complete network information, a purely structural emphasis, consideration of network size, and the provision of an individual-level measure of the function of a node's links. We utilized the average normalized version of this measure, which controls for network size. For a more complete discussion of how this new bridging measure compares to other measures of brokerage see Valente and Fujimoto (2010). The expression for average normalized bridging (B_i) for each actor i is:

$$B_i = 1 / [2(N - 1)] \sum_j^{N-1} \Delta C_{ij} / D_i \quad (3)$$

where C is the inverse average path length, ΔC_{ij} is the difference in cohesion when the link from i to j is removed, D_i is the degree of the actor, B_i is the average of the differences (ΔC_{ij}) for a node's links. Personal network density (ND_i) is measured as the percent of links among a person's friends:

$$ND_i = \sum_{i=1}^N L / n(n - 1) \quad (4)$$

where L is a count of all ties between those respondents nominated (alters).

Classroom network level characteristics reflect information about friendship ties among students in youths' classrooms. We calculated average path length (APL_k) by using the distance in steps between all network nodes and then computed the average for each school k :

$$APL_k = 1/N \sum_{i=1}^N \sum_{j=1}^N (d_{ij}) \quad (5)$$

where d_{ij} is the minimum path length between i and j . The clustering coefficient (CC_k) is calculated as the average personal network density, as shown in Eq. (6):

$$CC_k = 1/N \sum_{i=1}^N L/n(n-1) \quad (6)$$

We constructed three indicators of peer influence, measured at the individual level. The first peer influence indicator, *best friend network smoking*, is constructed from the set of baseline survey items asking youth to name their five best friends; their choices were not limited to nominating from a class roster. We used this information to construct youths' egocentric friendship networks, which could contain any friend, inside or outside of their classroom and school. To create the measure of *best friend network smoking (BFNS_i)*, we created a proportion of the people in respondents' egocentric friendship networks with whom respondents reported having smoked a cigarette:

$$BFNS_i = 1/n \sum_{j=1}^n s_{ij} \quad (7)$$

where s_{ij} is 1 when person i smokes with person j and 0 otherwise.

We constructed the second peer influence measure, *classroom best friend network smoking (CBFNS_i)*, using the set of baseline survey items asking youth to nominate up to five best friends in their class in which the survey was administered from a class roster. To construct the measure, we averaged the friends' self-reports of their cigarette smoking behavior:

$$CBFNS_i = 1/N \sum_{i=1}^N 1/n \sum_{j=1}^n e_j \quad (8)$$

where e is the smoking behavior of person j .

We constructed the third peer influence measure, *perceived normative beliefs of friends about drug use*, using the item "When thinking of your five best friends, how many of them think it's OK for someone to use drugs?" with four response categories (1 = none, 2 = 1 or 2 friends; 3 = 3 or 4 friends; 4 = all 5 friends).

Demographic control variables are age, gender, ethnicity, and mother's education. Past studies demonstrate the relevance of these demographic variables in relation to the network characteristics (e.g., Ennett & Bauman, 1993; Hoffman, Suh, & Pach, 1997), peer influence processes (e.g., Dornelas et al., 2005; Evans, Powers, Hersey, & Renaud, 2006; Flay et al., 1994) and to the cigarette smoking behavior (e.g., Dornelas et al., 2005). Age was measured continuously under study. Gender is coded so the reference group was male. Ethnicity is coded as three dummy variables, Ethnicity 1 (Asian/Asian American, Black/ African American = 1, Other Ethnicity = 0); Ethnicity 2 (Hispanic or Latino = 1, Other Ethnicity = 0); and Ethnicity 3 (White/ Caucasian = 3, Other Ethnicity = 0). Ethnicity 2 is the reference group and was therefore dropped from all analyses. Mother's education was coded as (1 = Did not complete 8th grade, 2 = Did not complete high school, 3 = Completed high school, 4 = Some college or job training, 5 = Completed college, 6 = Completed graduate school).

Class size is coded continuously as the number of people in each class. We restricted these analyses to class sizes of five or more to allow for emergence of and variation in network structure and variation in the number of ties and network actors.

Before data analysis, we imputed missing values on independent variables. The number of missing values on study independent variables were as follows: 10 from “age,” 35 on each ethnicity dummy variable, 49 from “mother’s education,” one from “in-degree centrality,” 169 from “exposure to classroom friendship network smoking,” 60 from “exposure to egocentric friendship network smoking,” and 69 from “perceived normative beliefs about drug use.” To account for missing data, we used a multiple imputation approach. Since there was a modest amount of missing data, following the common strategy of imputing five datasets provided a satisfactory degree of information for the study sample, for a more complete discussion of multiple imputation strategy, see Schafer (1997). Multiple imputation allows use of information from all cases, and is therefore subject to the less stringent assumption of missing at random rather than listwise deletion’s assumption of missing completely at random [i.e., for a complete discussion of the distinction between types of missing data, see Rubin, 1976, 1987]. We also estimated the study analysis models using listwise deletion and found similar results.

Analytic strategy

The focus of data analysis was first to examine whether the network characteristics related to past month cigarette smoking controlling for the three peer influence measures, demographics, and class size. This main effects model was conducted as a comparison model to assess study relationships prior to inclusion of the peer influence measures as potential moderators. The second focus of our analysis strategy was to test three separate models examining whether each peer influence process moderated relationships between both individual and classroom level network characteristics and past month cigarette smoking, controlling for each peer influence measure, demographics, and class size. To test interactions between network indicators and peer influence indicators in relation to past month cigarette smoking, we created interaction terms using peer influence indicators and network indicators.

Due to the nesting of students within school classrooms and schools, we employed a Hierarchical Linear Modeling (HLM) (Raudenbush & Bryk, 2002) approach using SAS Proc Mixed (Singer, 1998) to account for intraclass correlation. We examine associations between the individual and network level characteristics and cigarette smoking. Eq. (9) is the expression for the individual-level model for past month smoking:

$$Y_{ij} = \beta_{0j} + \beta_{1j}(X_{ij}) + r_{ij} \quad (9)$$

where Y_{ij} is the frequency of past month cigarette smoking for student i in class j , β_{0j} is the intercept at level one, the vector X_{ij} contains the individual-level measures which have β_{1j} effects on the outcome, and r_{ij} is a disturbance term. Eq. (10) is the level-two (classroom network level) expression:

$$\beta_{0j} = \gamma_{00} + \gamma_{10}(W_j) + u_{0j} \quad (10)$$

wherein β_{0j} represents the random intercept of the outcome measure for each classroom (past month cigarette smoking), γ_{00} is the intercept, W_j is a matrix of classroom level-predictors which have a γ_{10} effect on the classroom network level of the outcome, and u_{0j} is a disturbance term.

Analyses testing whether peer influence measures moderated relationships between classroom network level variables and past month smoking are cross level interactions, Eq. (11) describes these interactions:

$$\beta_{1j} = \gamma_{01} + \gamma_{11}(W_j) + u_{1j} \quad (11)$$

where β_{1j} is the random level one coefficient (for peer influence), γ_{01} is the intercept of this random coefficient, (W_j) is the classroom network level variable of interest which has an γ_{11} effect on this random coefficient, and u_{1j} is a disturbance with an assumed normal distribution.

We grand mean centered all explanatory, moderating, and control variables. All analyses included the control variables age, gender, ethnicity, mother's education, and class size. Because we are testing directional hypotheses, we also utilized one-tailed tests of significance.

Results

Study population

Of the cases eligible for the current study ($N = 851$), 61% were male, 97% were 12–18 years old, 69% were Hispanic or Latino, and 54% had mothers who had completed high school or less. The percentage of respondents who reported no past month smoking was 60% ($N = 510$); 19% smoked 1–10 times ($N = 162$); 4% smoked 11–20 times ($N = 34$); 3% smoked 21–30 times ($N = 26$); 3% smoked 31–40 times ($N = 26$); 2% smoked 41–50 times ($N = 17$); 1% smoked 51–60 times ($N = 8$); 1% smoked 61–70 times ($N = 9$); .92% smoked 71–80 times ($N = 7$); .08% smoked 81–90 times ($N = 1$); 6% smoked 91+ times ($N = 51$). Table 1 presents descriptive statistics for past month smoking, network characteristics, and peer influence processes.

Table 2 presents correlations among individual and classroom level network measures. In addition, although not shown, the correlations among the three peer influence measures and the network variables were low (at or below $r = .13$). The variance inflation factor (VIF) values of all network and peer influence measures and all their respective interaction terms were all below 3.10, indicating multicollinearity was not problematic among these variables. However, given the high correlation between *in-degree centrality* and *reciprocity*, we estimated six ancillary models (see Appendix 1), each one examining the relationship between one network variable and past month smoking, controlling for all peer influence, demographic, and class size variables. We compared these six models to a “baseline” main effects model, the latter included all network, peer influence, demographic and class size variables (see Appendix 1). Upon comparison, we observed that the coefficient on the network characteristic of *reciprocity* in the baseline model went from essentially zero to positive and significant in the ancillary model, which is consistent with multicollinearity. Consequently, we present two sets of main effects and interactions models: one set excluding *in-degree centrality* and its respective interactions with peer influence measures and the other set excluding *reciprocity* and its interactions with peer influence measures.

Main effects models

We tested whether the individual and classroom level network characteristics related to *past month cigarette smoking* in two models: the first excluded the network characteristic of *in-degree centrality* and the second excluded *reciprocity* (see Table 3). The first model showed that *reciprocity* was significantly related to past month cigarette smoking ($b = .228$, $p < .05$, one-tailed test), and that *best friend network smoking*, *classroom best friend network smoking* and *perceived normative beliefs about drug use*, were significantly related to past

month cigarette smoking ($b = 6.947, p < .01$; $b = .342, p < .05$; $b = .164, p < .05$, respectively). The second model indicated that *in-degree centrality* was significantly related to past month cigarette smoking ($b = .207, p < .01$). These analyses also showed that *best friend network smoking*, *classroom best friend network smoking* and *perceived normative beliefs about drug use*, were significantly related to *past month cigarette smoking* ($b = 6.931, p < .01$; $b = .325, p < .05$; $b = .154, p < .05$, respectively).

Interaction models

Two sets of three interaction models were estimated; each model examined the interactions between each of the three peer influence measures and the network variables in relation to past month cigarette smoking, controlling for peer influence measures, demographics, and class size. The first three models excluded *reciprocity* and its respective interactions with peer influence measures and the second three excluded *in-degree centrality* and its interactions with peer influence measures.

The first set of models indicated main effects of the following variables across models one through three, respectively: 1) *in-degree centrality* ($b = .187, p < .05$; $b = .203, p < .01$; $b = .219, p < .01$); 2) *best friend network smoking* ($b = 6.861, p < .01$; $b = 6.907, p < .01$; $b = 6.916, p < .01$), 3) *classroom best friend network smoking* ($b = .157, p < .05$; $b = .160, p < .05$; $b = .150, p < .05$), and 4) *perceived normative beliefs of friends about drug use* ($b = .340, p < .05$; $b = .326, p < .05$; $b = .324, p < .05$) (see Table 4). No interactions were indicated.

The second set of interaction models indicated main effects of the following variables across models four through six, respectively: 1) *reciprocity* ($b = .206, p < .05$, one-tailed test; $b = .226, p < .05$, one-tailed test; $b = .222, p < .05$, one-tailed test); 2) *best friend network smoking* ($b = 6.905, p < .01$; $b = 6.963, p < .01$; $b = 6.930, p < .01$), 3) *classroom best friend network smoking* ($b = .166, p < .05$; $b = .159, p < .05$; $b = .181, p < .01$), and 4) *perceived normative beliefs of friends about drug use* ($b = .370, p < .01$; $b = .341, p < .05$; $b = .324, p < .05$) (see Table 5). An interaction between reciprocity and *best friend network smoking* was also indicated ($b = .557, p < .05$, one-tailed test).

Fig. 2 shows a plot of the interaction between *reciprocity* and *best friend network smoking* in relation to *past month cigarette smoking*. In general, at low levels of *best friend network smoking*, the level of *reciprocity* makes little difference for *past month cigarette smoking* (as seen in the lower left hand side of the graph). At high levels of *best friend network smoking*, higher levels of *reciprocity* relate to higher levels of *past month cigarette smoking*. To assess the statistical significance of this difference, we use a technique pioneered by Bauer and Curran (2005). In one additional ancillary model, we centered the reciprocity variable at one standard deviation above its mean and created a new interaction with best friend network smoking. This allows us to test whether reciprocity has a significant effect on past month smoking among youth with high levels of best friend smoking. We found that for adolescents with high levels of best friend network smoking, reciprocity has a statistically significant positive effect ($b = .398; p < .01$). At high levels of best friend network smoking, an adolescent with high levels of reciprocity has 78% more past month smoking than one with average reciprocity (as seen in Fig. 2). This .78 difference represents a percentage change given that the outcome variable is log transformed.

Discussion

When key structural and positional characteristics of adolescents' network ties and dimensions of peer influence are both individually and jointly considered in relation to past month smoking, being socially integrated in networks relates to more past month cigarette smoking. Of the network characteristics under study, in-degree centrality consistently relates

to more past month cigarette smoking. We find some modest evidence that the number of reciprocated friendship ties was also important for past month smoking. We also find some modest evidence that the peer influence from youth's best friend (egocentric) networks moderated the relationship between the reciprocity of ties and past month cigarette smoking. The other peer influence processes under study, both classroom best friend network smoking and perceived normative beliefs of friends about drug use, did not moderate any relationships between network characteristics and past month smoking. However, each was consistently and positively related to past month cigarette smoking. Overall, our findings provide some support for examining the interrelationship of the structure and position of ties with peer influence in relation to smoking among the youth under study.

The present study contributes to the literature examining adolescent social networks and smoking and the broader literature linking social networks and health. Past studies have examined relationships between network characteristics and adolescent smoking (e.g., Ennett et al., 2006; Valente et al., 2005). Our study builds on this work and the work of Ennett et al. (2008) to theoretically refine this question by examining how key network structural and positional characteristics might work in synergy with three dimensions of peer influence in relation to adolescent smoking. Understanding how peer influence works with both local and whole network structure and position may begin to offer insight into structures and processes linking high risk youth friendship networks and their smoking behavior. This approach is facilitated by our Hierarchical Linear Modeling strategy, which accounts for the nested nature of social networks. The present study brings the following new findings to the literature on adolescent friendship networks and smoking: 1) some modest evidence of a moderating role of best friend network smoking in the relationship between reciprocity of ties and smoking when simultaneously controlling for two other domains of peer influence; and 2) the importance of three dimensions of peer influence, tested simultaneously and in the presence of key network characteristics, in relation to smoking.

We first consider relationships between network characteristics and past month cigarette smoking. Of all of the network characteristics under study, in-degree centrality, an indicator of popularity, most consistently and positively relates to past month cigarette smoking. Central adolescents are embedded among many friendship ties and are highly visible to others in their school environment. Given the cross-sectional study design, our findings likely hold multiple interpretations, given the possibility of both influence and selection processes working simultaneously. One interpretation is that popular members of a group set norms for behavior in a social setting (Kelly et al., 1991; Latkin, 1998) which others will follow. Perhaps cigarette smoking is normative in our study population and that the popular adolescents reflect these behavioral norms. As such, it is possible that being popular in a social milieu of high risk youth carries the burden of more pressure to smoke cigarettes. Our findings are consistent with a past study indicating that popularity is positively associated with smoking (Valente et al., 2005).

An alternative interpretation of our finding that popularity was positively related to smoking is that the more youth smoked, the greater their popularity, as smoking may increase popularity. Because smoking is likely a normative behavior in this population, youth who smoke may appear popular and other youth will want to select them as friends, thus increasing their own popularity. Other work indicates that smoking behavior increased popularity among adolescents (Lakon, Hipp, & Timberlake, 2010).

Results also indicate that perceived normative beliefs of friends about drug use consistently and positively related to past month cigarette smoking. Taken together with our findings that popularity was positively related to smoking, these findings are consistent with past studies

indicating that being popular in a school with a high smoking prevalence positively relates to more smoking (Alexander et al., 2001; Valente et al., 2005). Our study findings are not surprising given the high risk nature of the study sample and the likelihood of pro-smoking norms operating in these adolescent networks.

Models conducted without in-degree centrality suggest modest evidence that the number of reciprocated friendship ties relates to greater past month cigarette smoking. Reciprocity is likely a key endogenous network process governing friendship tie formation. It is possible that having strong, mutual friendship ties reciprocated among high risk youth reinforces their smoking behavior via peer influence. This idea is consistent with prior work indicating that reciprocated relationships may be contexts in which influence processes lead to smoking among adolescents (Urberg, Luo, Pilgrim, & Degirmencioglu, 2003) and other work suggesting support for influence processes operating among reciprocated friendships for adolescent smoking (Mercken, Candel, Willems, & de Vries, 2007). An alternative explanation is that among reciprocated friendships, selection processes may be at work, as smoking more may lead youth to reciprocate friendship ties to other smokers. Past research has also indicated that selection processes play a role in the similarity in smoking behavior observed among adolescents who mutually reciprocate their friendship ties (e.g., Mercken et al., 2007). We note that our findings relating to the reciprocity of ties warrant cautious interpretation, given the less conservative requirements for significance at which these findings are interpreted. We allow this significance level because the study sample consists uniformly of youth at high risk for drug use, which likely increases homogeneity in the sample on key aspects such as smoking related norms and peer influences, and thus may limit the extent to which our theoretical model was tested. Secondly, this work is in its early stages from a theory development standpoint. As such, we see merit in interpreting these findings at a less conservative level of significance so that future work can build on these findings.

Next, we consider findings germane to the interactions between network measures and peer influence processes in relation to past month cigarette smoking. There is modest support for an interaction between the number of reciprocated ties and best friend network smoking, suggesting the importance of both reciprocity of ties and youths' best friend networks in their own smoking behavior. While this finding is interpreted at a less stringent level of significance than the norm, note that this interaction only tests differences in the slope of the line, while we however, observe key differences in reciprocity at high levels of best friend smoking. At low levels of best friend network smoking, the level of reciprocity makes little difference for past month cigarette smoking. However, at high levels of best friend network smoking, the lines diverge and reciprocity appears to matter quite a bit for levels of past month cigarette smoking. We found that for persons with high levels of best friend network smoking, reciprocity has a statistically significant effect. Perhaps these strong, mutual ties among youth who are at high risk for drug use may provide a favorable relationship context for peer influences to promote smoking. Conversely, it is possible that more smoking reinforces the mutuality of friendship bonds by influencing youths' decisions to reciprocate friendships nominations based on smoking status. Studies suggest that both influence and selection play an integral role in adolescent smoking among reciprocated friendships (Mercken et al., 2007; Urberg et al., 2003).

In general, study findings highlight the importance of the role of smoking with best friends in adolescents' egocentric networks. These best friends, whose nominations were not restricted to classrooms, are most strongly related to youths' smoking behavior. That best friends are important to adolescents' cigarette smoking behavior is consistent with past studies suggesting that adolescents' best friends are important in the initiation of cigarette smoking (Urberg, Degirmencioglu, & Pilgrim, 1997) and that close friends display similar

substance use behaviors (e.g., Kirke, 2004; Pearson & West, 2003). It is possible that youth look to their best friends to understand cues about normatively sanctioned smoking behaviors and these best friends may influence youths' cigarette smoking decisions and subsequent behavior. Alternatively, youth may select their friends based on friends' smoking behavior, although selection processes were not explored in the present study.

While two of the peer influence processes under study, best friend classroom network smoking and youths' perceived normative beliefs of friends about drug use, did not moderate any of the relationships between network characteristics and past month cigarette smoking, each stood alone in its importance to past month smoking among these youth. Perceptions of friends' normative beliefs about drug use and best friend classroom network smoking were positively related to past month smoking regardless of the network characteristics under study.

The present study has some limitations. The results should be considered in light of the specific nature of the continuation high school population comprising the sample, and that the schools were drawn into the sample using a purposive sampling strategy to maximize ethnic and racial heterogeneity. Therefore, the findings are not generalizable to mainstream high school youth populations. However, the findings are likely generalizable to the some 70,000 continuation high school youth in the 581 continuation high schools in California (as a note of comparison, there are 1839 mainstream high schools in the state) (California Department of Education, 2006), residing in ethnically, racially and socioeconomically diverse regions of this state. While the methodology for selecting the schools into the study sample and the uniformity of the study population both limit the generalizability of the findings, the counties from which schools in our study were drawn, Los Angeles, Orange, and Riverside, are highly diverse on race, ethnicity, income, and population density (Hipp, 2009; Local Government Commission Congress for the New Urbanism, 2002; Nagourney, 2010). The multiple dimensions of heterogeneity present in these counties may help counteract some of the limitations of the sample and sampling strategy. In addition, it is likely that bias may have been introduced into the sample when 980 of the 1493 invited to participate provided valid consent and assent forms (65.5%). We are unable to draw any conclusions regarding how the loss of the 513 students without valid consent forms may have affected study findings as we have no information about these youth. Secondly, the data we employed in this study are cross-sectional, and therefore do not account for the directionality of study relationships. Longitudinal studies are necessary to understand the causality and directionality of relationships under study. Third, findings relating to the reciprocity of ties are interpreted at a less stringent significance level than is conventional. Therefore, these findings warrant cautious interpretation and future study. Another study limitation is the cap on the number of friendship nominations of up to five friends for both types of friend networks – a common network elicitation strategy. It is unclear how network structure, social position, and peer influence would have differed if the number of nominations had not been capped at this level. In addition, we did not have full information from youth about those they nominated to be in their friends network who did not attend their schools. Potentially, this is an influential set of friends, as they may be some of youths' closest friends. Future work should more fully capture information about the role of these friends in continuation high school youths' friendship networks and cigarette smoking behavior.

Despite the noted limitations, our findings suggest merit in further exploring youths' egocentric best friends networks in relation to cigarette smoking. These networks should be examined with respect to whether these friends are inside or outside of youths' school, and the structure, position, and strength of these friendship ties.

Findings also indicate further study of relationships longitudinally, to understand how the relationships under study change over time. While not feasible with these data due to attrition and the time lag between waves, findings do warrant that future studies replicate the analysis strategy utilized in this paper with longitudinal data to examine the role of both peer influence and selection. Because the role of selection was not examined in the current study, it is possible that the parameter estimates may be overstated.

There were a number of null findings in this study. Perhaps a scope condition of our theoretical model is that it does not operate as theorized in our study population. It is possible that our model was not fully tested in the study sample because the study sample is uniformly comprised of youth at high risk for drug use, which may have resulted in homogeneity on key characteristics of the sample. Our theoretical and methodological approach warrants testing in more heterogeneous adolescent populations.

Our findings have some preliminary implications for social network and peer influence based smoking prevention programs targeting continuation high school youth. Notably, such programs should consider the resources inherent in youths' best friend networks and tap into naturally occurring friendship network structures, including friends inside and outside of school. Whether these friends influence one another to smoke or are those whom youth have selected to befriend based on similar smoking status, these youth are likely important referents whose beliefs and actions signal normative cigarette smoking behavior within friendship networks. Such networks may act as dissemination channels for anti-smoking information, in order to change smoking related beliefs and eventually behavioral norms and perceptions of them over time. Reciprocated relationships should also be considered as intervention targets, as youth in these mutual dyads may model each others' smoking behavior, be it through selection or influence or both processes.

Conclusion

Overall, study findings suggest that being integrated in networks with close friends in a social environment favoring drug use relates to more smoking among the high risk youth under study. Findings highlight the importance of youths' best friends and being popular. They also offer some modest evidence of the importance of having reciprocated friendships for smoking among the youth under study, as the reciprocity of ties was of note both alone and in synergy with smoking with best friends in relation to smoking. The present study suggests some value in the approach of considering both the individual and joint role of the structure and position of network ties with peer influence in examining the smoking behavior of the youth under study. Interpreting findings more broadly, this study gives some insight into the nuanced nature of social processes and structures linking high risk adolescent social networks and smoking, and that future research is necessary to refine these linkages.

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Appendix 1

Table A1

Baseline model: a Hierarchical Linear Model examining relationships between individual and classroom level network measures and past month cigarette smoking controlling for peer influence processes, demographics, and class size ($N = 851$).

	Estimate	SE
<i>Individual-level network indicators</i>		
In-degree centrality	.20 [†]	.11
Reciprocity	-.01	.17
Bridging	.17	.29
Personal network density	2.53	6.40
<i>Classroom level network indicators</i>		
Clustering	-2.12	3.34
Average path length	.02	.02
<i>Peer influence processes</i>		
Best friend network smoking	6.91 ^{**}	.45
Classroom best friend network smoking	.15 [*]	.07
Perceived normative beliefs of friends about drug use	.32 [*]	.14

Note: Standard errors in parentheses.

^{**}
 $p < .01$ for a two-tailed test,

^{*}
 $p < .05$ for a two-tailed test,

[†]
 $p < .05$ for a one-tailed test.

Note: this model includes the following control variables: class size, age, gender, ethnicity, and mother's education.

Table A2

Ancillary Models: Six Hierarchical Linear Models examining the relationship between each network characteristic and past month cigarette smoking controlling for peer influence processes, demographics, and class size ($N = 851$).

Individual-level network indicator	(1) Estimate (SE)	(2) Estimate (SE)	(3) Estimate (SE)	(4) Estimate (SE)	(5) Estimate (SE)	(6) Estimate (SE)
In-degree centrality	.160 [*] (.070)	—	—	—	—	—
Reciprocity	—	.190 [†] (.108)	—	—	—	—
Bridging	—	—	.092 (.280)	—	—	—
Personal network density	—	—	—	3.082 (6.183)	—	—
<i>Network level indicator</i>						
Clustering	—	—	—	—	-1.691 (2.635)	—
Average path length	—	—	—	—	—	—
<i>Peer influence processes</i>						
Best friend network smoking	6.955 [†] (.453)	6.972 ^{**} (.453)	6.965 ^{**} (.454)	6.944 ^{**} (.455)	6.941 ^{**} (.455)	6.941 ^{**} (.455)
Classroom best friend network smoking	.162 [*] (.068)	.169 [*] (.067)	.169 [*] (.068)	.170 [*] (.068)	.164 [*] (.068)	.164 [*] (.068)
Perceived normative beliefs of friends about drug use	.306 [*] (.138)	.324 [*] (.139)	.338 [*] (.139)	.341 [*] (.139)	.344 [*] (.139)	.344 [*] (.139)

Note: Standard errors in parentheses.

^{**}
 $p < .01$ for a two-tailed test,

^{*}
 $p < .05$ for a two-tailed test,

[†] $p < .05$ for a one-tailed test.

Note: All models include the following control variables: class size, age, gender, ethnicity, and mother's education.

References

- Abel G, Plumridge L, Graham P. Peers, networks or relationships: strategies for understanding social dynamics as determinants of smoking behavior. *Drugs, Education, Prevention and Policy*. 2002; 9(4):325–338.
- Alexander C, Piazza M, Mekos D, Valente TW. Peers, schools, and adolescent cigarette smoking. *Journal of Adolescent Health*. 2001; 29(1):22–30. [PubMed: 11429302]
- Bandura A. Self-efficacy: toward a unifying theory of behavior change. *Psychological Review*. 1977; 84:191–215. [PubMed: 847061]
- Bauer DJ, Curran PJ. Probing interactions in fixed and multilevel regression: inferential and graphical techniques. *Multivariate Behavioral Research*. 2005; 40:373–400.
- Bearman PS, Moody J, Stovel K. Chains of affection: the structure of adolescent romantic and sexual networks. *American Journal of Sociology*. 2004; 110(1):44–91.
- Berkman LE, Syme L. Social networks, host resistance, and mortality: a nine-year follow-up study of Alameda county residents. *American Journal of Epidemiology*. 1979; 109(2):86–204.
- Bott, E. Family and social network: Roles, norms, and external relationships in ordinary urban families. London: Tavistock; 1957.
- California Department of Education. Factbook 2006: Handbook of education information. 2006. Retrieved June 16, 2011, from <http://www.cde.ca.gov/re/ph/fb/>
- Dishion TJ. Cross-setting consistency in early adolescent psychopathology: deviant friendships and problem behavior sequelae. *Journal of Personality*. 2000; 68(6):1109–1126. [PubMed: 11130734]
- Dornelas E, Patten C, Fischer E, Decker PA, Offord K, Barbagallo J, et al. Ethnic variation in socioenvironmental factors that influence adolescent smoking. *Journal of Adolescent Health*. 2005; 36(3):170–177. [PubMed: 15737771]
- Durkheim, E. Suicide: A study in sociology. Spaulding, JA.; Simpson, G.; Trans, editors. Glencoe, ILL: Free Press; 1858/1917.
- Ellickson PL, Bird CE, Orlando M, Klein DJ, McCaffrey DF. Social context and adolescent health behavior: does school-level smoking prevalence affect students' subsequent smoking behavior? *Journal of Health and Social Behavior*. 2003; 44(4):525–535. [PubMed: 15038147]
- Ennett ST, Bauman KE. Peer group structure and adolescent cigarette smoking: a social network analysis. *Journal of Health and Social Behavior*. 1993; 34(3):226–236. [PubMed: 7989667]
- Ennett ST, Bauman KE. The contribution of influence and selection to adolescent peer group homogeneity: the case of adolescent cigarette smoking. *Journal of Personality and Social Psychology*. 1994; 67(4):653–663. [PubMed: 7965611]
- Ennett ST, Bauman KE, Hussong A, Faris R, Foshee VA, Cai L, et al. The peer context of adolescent substance use: findings from social network analysis. *Journal of Research on Adolescence*. 2006; 16(2):159–186.
- Ennett ST, Bauman KE, Koch GG. Variability in cigarette smoking within and between adolescent friendship cliques. *Addictive Behaviors*. 1994; 19(3):295–305. [PubMed: 7942247]
- Ennett ST, Faris R, Hipp JR, Foshee VA, Bauman KE, Hussong A, et al. Peer smoking, other peer attributes, and adolescent cigarette smoking: a social network analysis. *Prevention Science*. 2008; 9:88–98. [PubMed: 18404380]
- Evans WD, Powers A, Hersey J, Renaud J. The influence of social environment and social image on adolescent smoking. *Health Psychology*. 2006; 25(1):26–33. [PubMed: 16448295]
- Fang X, Li X, Stanton B, Dong Q. Social network positions and smoking: experimentation among Chinese adolescents. *American Journal of Health Behavior*. 2003; 27(3):257–267. [PubMed: 12751622]
- Fischer CS, Misovich SJ. Evolution of college students' AIDS-related behavioral responses, attitudes, knowledge, and fear. *AIDS Education and Prevention*. 1990; 2:322–337. [PubMed: 2288814]

- Flay BR, Hu FB, Siddiqui O, Day E, Hedeker D, Petraitis J, et al. Differential influence of parental smoking and friends' smoking on adolescent initiation and escalation and smoking. *Journal of Health and Social Behavior*. 1994; 35(3):248–265. [PubMed: 7983337]
- Granovetter MS. The strength of weak ties. *American Journal of Sociology*. 1973; 78(6):1360–1380.
- Haynie DL. Delinquent peers revisited: does network structure matter? *The American Journal of Sociology*. 2001; 106:1013–1057.
- Hipp, JR. The orange crush: The squeezing of orangecounty's middle class. 2009. Retrieved June 10, 2011, from http://www.cisj.ucicopc.org/PDF/Hipp_OC_Inequality_Study1.pdf
- Hoffman BR, Monge PR, Chou CP, Valente TW. Perceived peer influence and peer selection on adolescent smoking. *Addictive Behaviors*. 2007; 32:1546–1554. [PubMed: 17188818]
- Hoffman JP, Suh SS, Pach A. Changes in network characteristics and HIV risk behavior among injection drug users. *Drug and Alcohol Dependence*. 1997; 46:41–51. [PubMed: 9246552]
- House JS, Robbins C, Metzner HL. The association of social relationships and activities with mortality: prospective evidence from the Tecumseh community health study. *American Journal of Epidemiology*. 1982; 116(1):123–141. [PubMed: 7102648]
- Kandel D. Adolescent marihuana use: role of parents and peers. *Science*. 1973; 181(4104):1067–1070. [PubMed: 4726001]
- Kelly JA, Lawrence JS, Diaz YE, Stevenson YL, Hauth AC, Brasfield TL, et al. HIV risk behavior reduction following intervention with key opinion leaders of population: an experimental analysis. *American Journal of Public Health*. 1991; 81:68–71.
- Kirke DM. Chain reactions in adolescents' cigarette, alcohol and drug use: similarity through peer influence or the patterning of ties in peer networks? *Social Networks*. 2004; 26(1):3–28.
- Krohn MD. The web of conformity: a network approach to the explanation of delinquent behavior. *Social Problems*. 1986; 33:S81–S93.
- Lakon CM, Hipp JR, Timberlake DS. The social context of adolescent smoking: a systems perspective. *American Journal of Public Health*. 2010; 100(7):1218–1228. [PubMed: 20466966]
- Latkin CA. Outreach in natural setting: the use of peer leaders for HIV prevention among injecting drug users' networks. *Public Health Reports*. 1998; 113(S 1):151–159. [PubMed: 9722820]
- Laumann, EO. Bonds of pluralism: The form and substance of urban social networks. New York: John Wiley; 1973.
- Lin N, Woelfel MW, Light S. The buffering effect of social support subsequent to an important life event. *Journal of Health and Social Behavior*. 1985; 26(3):247–263. [PubMed: 4067240]
- Local Government Commission Congress for the New Urbanism. Older suburbs in the Los Angeles metropolitan area. 2002. Decline, Revitalization, and Lessons for other Communities Retrieved on July 1, 2011, from http://www.lgc.org/freepub/docs/community_design/reports/older_suburbs_in_LA.pdf
- Marsden PV, Friedkin NE. Network studies of social influence. *Sociological Methods & Research*. 1994; 22(1):127–151.
- Mercken L, Candel M, Willems P, de Vries H. Disentangling social selection and social influence effects on adolescent smoking: the importance of reciprocity in friendships. *Addiction*. 2007; 102(9):1483–1492. [PubMed: 17610538]
- Moody J. The importance of relationship timing for diffusion. *Social Forces*. 2002; 81(1):25–56.
- Nagourney, A. New York Times: 2010 Dec 12. Los Angeles confronts homelessness reputation. <http://www.nytimes.com/2010/12/13/us/13homeless.html> Retrieved 2010-12-14
- Pearson M, West P. Drifting smoke rings: social network analysis and Markov processes in a longitudinal study of friendship groups and risk-taking. *Connections*. 2003; 25(2):59–76.
- Raudenbush, SW.; Bryk, AS. Hierarchical linear models: Applications and data analysis methods. 2nd ed.. Newbury Park, CA: Sage; 2002.
- Rimal RN, Real K. Understanding the influence of perceived norms on behaviors. *Communication Theory*. 2003; 13(2):184–203.
- Rohrbach LA, Sussman S, Dent CW, Sun P. Tobacco, alcohol, and other drug use among high-risk young people: a five-year longitudinal study from adolescence to emerging adulthood. *Journal of Drug Issues*. 2005; 35:333–356.

- Rook, KS. Detrimental aspects of social relationships: taking stock of an emerging literature. In: Viel, HO.; Baumann, U., editors. *The meaning and measurement of social support*. New York: Hemisphere; 1992. p. 157-169.
- Rook, KS.; Pietromonoco, PR. Close relationships: ties that heal or ties that bind?. In: Jones, WH.; Perlman, D., editors. *Advances in personal relationships*. Vol. 1. Greenwich, CT: JAI Press; 1987. p. 1-35.
- Rubin DB. Inference and missing data. *Biometrika*. 1976; 63:581–592.
- Rubin, DB. *Multiple imputation for nonresponse in surveys*. New York: Wiley; 1987.
- Schafer, JL. *Analysis of incomplete multivariate data*. New York: Chapman and Hall; 1997.
- Seeman TE, Kaplan GA, Knudsen L, Cohen R, Guralnik JM. Social network ties and mortality among the elderly in the Alameda county study. *American Journal of Epidemiology*. 1987; 126(4):714–724. [PubMed: 3631060]
- Singer JD. Using SAS PROC MIXED to fit multilevel models, hierarchical models and individual growth models. *Journal of Educational and Behavioral Statistics*. 1998; 23:323–355.
- Sun W, Skara S, Sun P, Dent CW, Sussman SY. Project towards no drug abuse: long-term substance use outcomes evaluation. *Preventive Medicine*. 2006; 42:188–192. [PubMed: 16413605]
- Sussman S, Dent CW, Leu L. The one-year prospective prediction of substance abuse and dependence among high risk adolescents. *Journal of Substance Abuse*. 2000; 12:373–386. [PubMed: 11452840]
- Sussman S, Dent CW, Stacy AW. Project towards no drug abuse: a review of findings and future directions. *American Journal of Health Behavior*. 2002; 26(5):354–365. [PubMed: 12206445]
- Sussman S, Dent CW, Stacy AW, Craig S. One-year outcomes of project towards no drug abuse. *Preventive Medicine: An International Journal Devoted to Practice & Theory*. 1998; 27:632–642.
- Sutherland, EH. *Principles of criminology*. 4th ed.. Philadelphia: J.B. Lippincott; 1947.
- Urberg KA, Degirmencioglu SM, Pilgrim C. Close friend and group influence on adolescent cigarette smoking and alcohol use. *Developmental Psychology*. 1997; 33(5):834–844. [PubMed: 9300216]
- Urberg K, Luo Q, Pilgrim C, Degirmencioglu. A two stage model of peer influence in adolescent substance use: individual and relationship specific differences in susceptibility to influence. *Addictive Behaviors*. 2003; 28:1243–1256. [PubMed: 12915166]
- Valente TW, Fujimoto K. Bridging: locating critical connectors in a network. *Social Networks*. 2010; 32:212–220. [PubMed: 20582157]
- Valente TW, Unger JB, Johnson CA. Do popular students smoke? The association between popularity and smoking among middle school students. *Journal of Adolescent Health*. 2005; 37:323–329. [PubMed: 16182143]
- Wasserman, S.; Faust, K. *Social network analysis: Methods and applications*. Cambridge, MA: Cambridge University Press; 1994.

Fig. 1. Relationships between individual and classroom network indicators, peer influence processes, and past month cigarette smoking.

Fig. 2. Interaction of reciprocity and best friend network smoking in relation to past month cigarette smoking controlling for peer influence processes, demographics, and class size.

Table 1

Descriptive statistics: past month cigarette smoking, network characteristics, and peer influence processes ($N = 851$).

	Mean	SD
<i>Outcome variable</i>		
Past month smoking (natural log)	-3.07	4.79
<i>Individual-level network indicators</i>		
In-degree centrality	2.25	2.01
Reciprocity	1.26	1.30
Bridging	.49	.59
Personal network density	.01	.02
<i>Classroom level network indicators</i>		
Clustering	.18	.05
Average path length	18.18	9.76
<i>Peer influence processes</i>		
Best friend network smoking	.34	.37
Classroom best friend network smoking	2.61	2.26
Perceived normative beliefs of friends about drug use	2.24	1.10

Table 2

Correlations among individual and classroom level network characteristics (n = 851).

	In-degree centrality	Reciprocity	Bridging	Personal network density	Clustering	Average path length
In-degree centrality	—	.77***	-.14***	.15***	.34***	-.31***
Reciprocity	.77***	—	-.08***	.27***	.28***	-.28***
Bridging	-.14***	-.08***	—	-.09***	-.09***	-.08***
Personal network density	.15***	.27***	-.09***	—	.11***	-.07***
Clustering	.34***	.28***	-.09***	.11***	—	-.56***
Average path length	-.31***	-.28***	-.08***	-.07***	-.56***	—

*** Note: $p < .01$ for a two-tailed test,* $p < .05$ for a two-tailed test,* $p < .05$ for a one-tailed test.

Table 3

Two Hierarchical Linear Models examining relationships between network characteristics and past month cigarette smoking controlling for peer influence processes, demographics, and class size ($N = 851$).

	(1)	(2)
<i>Individual-level network indicators</i>		
In-degree centrality	—	.207 ^{**} (.076)
Reciprocity	.228 [†] (.116)	—
Bridging	.109 (.282)	.174 (.284)
Personal network density	1.097 (6.352)	2.450 (6.237)
<i>Classroom level network indicators</i>		
Clustering	−1.477 (3.304)	−2.109 (3.325)
Average path length	.012 (.019)	.016 (.019)
<i>Peer influence processes</i>		
Best friend network smoking	6.947 ^{**} (.452)	6.913 ^{**} (.451)
Perceived normative beliefs of friends about drug use	.164 [*] (.068)	.154 [*] (.068)
Classroom best friend network smoking	.342 [*] (.140)	.325 [*] (.139)

Note: Standard errors in parentheses.

^{**}
 $p < .01$ for a two-tailed test,

^{*}
 $p < .05$ for a two-tailed test,

[†]
 $p < .05$ for a one-tailed test.

Note: All models include the following control variables: class size, age, gender, ethnicity, and mother's education.

Table 4

Three Hierarchical Linear Models examining interactions between network characteristics and three peer influence measures in relation to past month cigarette smoking, controlling for peer influence processes, demographics, and class size ($N = 851$), excluding reciprocity and its interactions.

	(1)	(2)	(3)
	Model of interactions with best friend network smoking	Model of interactions with classroom best friend network smoking	Model of interactions with perceived normative beliefs of friends about drug use
<i>Individual-level network indicators</i>			
In-degree centrality	.187* (.077)	.203* (.076)	.219** (.079)
In-degree centrality $\times$ peer influence measure	.166 (.186)	.027 (.033)	-.032 (.063)
Bridging	.168 (.282)	.164 (.283)	.156 (.290)
Bridging $\times$ peer influence measure	.043 (.796)	.121 (.123)	-.165 (.316)
Personal network density	2.229 (6.323)	1.556 (6.255)	1.875 (6.464)
Personal network density $\times$ peer influence measure	-2.210 (15.799)	-2.466 (2.626)	.360 (6.338)
<i>Classroom level network indicators</i>			
Clustering	-1.660 (3.370)	-1.440 (3.289)	-2.665 (3.409)
Clustering $\times$ peer influence measure	9.177 (8.949)	2.165 (2.175)	-2.969 (2.997)
Average path length	.018 (.019)	.018 (.020)	.013 (.020)
Average path length $\times$ peer influence measure	-.010 (.052)	.006 (.008)	-.021 (.017)
<i>Peer influence processes</i>			
Best friend network smoking	6.861** (.451)	6.907** (.458)	6.916** (.453)
Perceived normative beliefs of friends about drug use	.340* (.140)	.326* (.139)	.324* (.140)
Classroom best friend network smoking	.157* (.068)	.160* (.069)	.150* (.070)

Note: Standard errors in parentheses.

** $p < .01$ for a two-tailed test,

* $p < .05$ for a two-tailed test,

† $p < .05$ for a one-tailed test.

Note: All models include the following control variables: class size, age, gender, ethnicity, and mother's education.

Table 5

Three Hierarchical Linear Models examining interactions between network characteristics and three peer influence measures in relation to past month cigarette smoking, controlling for peer influence processes, demographics, and class size ($N = 851$), excluding in-degree and its interactions.

	(4)	(5)	(6)
	Model of interactions with best friend network smoking	Model of interactions with classroom best friend network smoking	Model of interactions with perceived normative beliefs of friends about drug use
<i>Individual-level network indicators</i>			
Reciprocity	.206 [†] (.117)	.226 [†] (.117)	.222 [†] (.117)
Reciprocity × peer influence measure	.557 [†] (.323)	.012 (.104)	.056 (.052)
Bridging	.102 (.277)	.088 (.288)	.111 (.282)
Bridging × peer influence measure	-.008 (.792)	-.153 (.320)	.126 (.124)
Personal network density	1.239(6.441)	.580 (6.566)	.460 (6.372)
Personal network density × peer influence measure	-7.561 (16.007)	-.224 (6.477)	-2.628 (2.666)
<i>Classroom level network indicators</i>			
Clustering	-1.042 (3.348)	-1.973 (3.376)	-.722 (3.287)
Clustering × peer influence measure	10.275 (8.825)	-2.781 (2.975)	2.319(2.171)
Average path length	.015 (.019)	.009 (.020)	.015 (.020)
Average path length × peer influence measure	.000 (.054)	-.019 (.017)	.007 (.008)
<i>Peer influence processes</i>			
Best friend network smoking	6.905 ^{**} (.446)	6.963 ^{**} (.454)	6.930 ^{**} (.459)
Perceived normative beliefs of friends about drug use	.370 ^{**} (.140)	.341 [*] (.141)	.344 [*] (.140)
Classroom Best friend network smoking	.166 [*] (.068)	.159 [*] (.069)	.181 ^{**} (.070)

Note: Standard errors in parentheses.

^{**}
 $p < .01$ for a two-tailed test,

^{*}
 $p < .05$ for a two-tailed test,

[†]
 $p < .05$ for a one-tailed test.

Note: All models include the following control variables: class size, age, gender, ethnicity, and mother's education.