

# Peer Smoking, Other Peer Attributes, and Adolescent Cigarette Smoking: A Social Network Analysis

Susan T. Ennett · Robert Faris · John Hipp ·  
Vangie A. Foshee · Karl E. Bauman ·  
Andrea Hussong · Li Cai

Published online: 11 April 2008  
© Society for Prevention Research 2008

**Abstract** Peer attributes other than smoking have received little attention in the research on adolescent smoking, even though the developmental literature suggests the importance of multiple dimensions of adolescent friendships and peer relations. Social network analysis was used to measure the structure of peer relations (i.e., indicators of having friends, friendship quality, and status among peers) and peer smoking (i.e., friend and school smoking). We used three-level hierarchical growth models to examine the contribution of each time-varying peer variable to individual trajectories of smoking from age 11 to 17 while controlling for the other variables, and we tested interactions between the peer structure and peer smoking variables. Data were collected over five waves of assessment from a longitudinal sample of 6,579 students in three school districts. Findings suggest a greater complexity in the peer context of smoking than previously recognized.

**Keywords** Adolescent smoking · Peers · Social networks

Affiliation with peers who smoke long has been identified as a principal risk factor for adolescent cigarette smoking.

---

S. T. Ennett (✉) · R. Faris · V. A. Foshee · K. E. Bauman  
Department of Health Behavior and Health Education,  
The University of North Carolina at Chapel Hill,  
Campus Box 7440, Chapel Hill, NC 27599, USA  
e-mail: sennett@email.unc.edu

J. Hipp  
University of California,  
Irvine, CA 92697, USA

A. Hussong · L. Cai  
Department of Psychology,  
The University of North Carolina at Chapel Hill,  
Campus Box 3270, Chapel Hill, NC 27599, USA

The most recent comprehensive review of the literature on peers and adolescent smoking identified the number of friends who smoke as the single most commonly cited peer risk factor (Hoffman et al. 2006). Aspects of peer relations other than peer smoking have less often been a research focus, even though the need for a more inclusive perspective on the role of peers in smoking etiology has been noted (Ennett et al. 2006; Kobus 2003; Valente et al. 2004). Both smoking and non-smoking aspects of peer relations need consideration. Examples of the latter include peer interaction, social status, and attributes of the larger peer networks in which friendships are embedded, all of which have been identified as having developmental significance for adolescents (e.g., Crosnoe 2000; Giordano 2003; Hartup 1996; Savin-Williams and Berndt 1990).

The purposes of this paper are to characterize adolescent peer relations along multiple dimensions suggested in the adolescent development literature on friendships and peer relations and to examine the unique and interactive effects of these factors on youth smoking. Our primary interests are in whether structural attributes, such as extent of involvement with peers, contribute to smoking net of friend smoking and/or condition the effect of affiliation with smoking friends. Peer structural characteristics could be uniquely associated with higher or lower risk of smoking. As well, structural characteristics in interaction with friend smoking could have enhancing or buffering effects.

We use social network analysis to identify adolescents' friends, define structural attributes of peer relations, and measure peer smoking. Social network analysis is well suited for measuring structural properties of relationships. Because study adolescents identify their friends and friends are also in the study, friendship ties and characteristics can be directly measured from information provided by both adolescents and friends. Moreover, and also because data

from both the adolescent and friends can be linked, measurement of friend smoking can be based on the self-reports of friends rather than on adolescent reports.

We briefly review aspects of adolescent peer relations identified as having general developmental significance. We then review empirical studies from the adolescent smoking literature, with emphasis on studies that used social network methods.

### Dimensions of Adolescent Peer Relations

Although no single theory guides research on adolescent friendships, four prominent dimensions of adolescent peer relations described in the adolescent development literature are having friends, the quality of friendships, status among peers, and the identity, or behaviors, of friends (e.g., Crosnoe 2000; Giordano 2003; Hartup 1996; Savin-Williams and Berndt 1990). Research on the socializing functions of peers finds evidence for both adaptive and maladaptive socialization. More attention has been focused on adaptation associated with having friends and friendships of high quality and on maladaptation associated with friends' behavior; in particular, friends who exhibit problem behaviors. Yet, there is some evidence for both adaptation and maladaptation associated with most peer dimensions.

Among the adaptive functions cited of making and keeping friends and having high-quality friendships are the development of social competencies, emotional adjustment, norms of mutuality or reciprocity, and models for intimate relationships (Crosnoe 2000; Giordano 2003; Hartup 1996; Savin-Williams and Berndt 1990). Similarly, not having friends has been associated with poorer social competencies and adjustment (Hartup 1996) and even suicide ideation in girls (Bearman and Moody 2004). Some research, however, reports that having friends and high-quality friendships also characterize adolescents who engage in problem behaviors such as drug use and delinquency (Dishion et al. 1995; Giordano 2003).

Status among peers has received less empirical attention than the presence and quality of friendships, but is well established as characterizing peer relationships (Eder 1985; Savin-Williams and Berndt 1990). Interest in status calls attention to the fact that adolescent friendships are embedded in a larger peer context, typically the entire network of peers in school. Relationships in the peer network may be particularly relevant for adolescents in gauging their social worth (Giordano 2003). Status among peers, often measured by popularity, has been identified as a marker of adaptation (Allen et al. 2005). Conversely, holding higher status may cause pressure for adolescents and invoke disliking or resentment by other youth (Eder 1985). In addition, status concerns may make adolescents more vulnerable to being socialized into deviant behavior (Allen et al. 2005).

Research on the behavior of friends is the aspect of friendships where maladaptive socialization has been most explicitly considered and consistently suggested. Similarity among friends in drug use, drinking, sexual activity, delinquency, and antisocial behavior is well documented (e.g., Berndt 1982; Hartup 1996). Adolescent-peer similarity in behavior is often attributed to peer socialization or influence but the similarity also is due to selection whereby adolescents choose friends like themselves. Studies with longitudinal data needed for separating socialization and selection effects find evidence for both processes, and suggest that the deviance socialization attributed to peers has been overestimated, though influence nonetheless occurs (Bauman and Ennett 1996; Steglich et al. 2004).

### Dimensions of Adolescent Peer Relations and Cigarette Smoking

*Having Friends* Having friends per se has not been a focus of social network studies of adolescent cigarette smoking. Friendship nominations have been used, however, to measure indicators of isolation versus embeddedness in friendships. Social position, typically defined as group member, liaison or bridge, or isolate, has been examined in several studies (Abel et al. 2002; Ennett and Bauman 1993; Ennett et al. 2006; Fang et al. 2003; Pearson and Michell 2000; Pearson and West 2003). Both group members and liaisons are characterized by having friends, but group members have most friendships with others in their group whereas bridges have friendships spanning different groups. Isolates, depending on the definition, have zero or one friend. With few exceptions, social position has been shown to be significantly related to smoking, such that adolescents isolated from their peers were more likely to smoke than those having friendships. Whereas isolation appears to have consequences for substance use, research has typically not found strong or consistent differences between group members and liaisons. While these findings are consistent with the adaptive functions associated with having friends reported in the developmental literature, they contrast with the common characterization of the maladaptive influence of peers on smoking.

Other indicators of embeddedness in friendships have been less often examined in studies using social network methods. In one study, however, adolescents with a higher density friendship group, meaning that a higher proportion of the friends were friends with each other, had lower odds of smoking (Ennett et al. 2006). Taken together, the studies suggest that having friends, and friends who are friends with each other, may be protective against smoking.

*Friendship Quality* Social network studies of adolescent cigarette smoking have rarely measured indicators of

friendship quality, perhaps because the studies are based on nominations of close friends. Indeed, a recent study concluded that information about friendship quality in social network studies might be redundant because it is already taken into account when adolescents nominate their friends (Bauman et al. 2007). In that study, several indicators of friendship quality (feelings of closeness to nominated friends, visits to friends' homes, interaction outside school, and parent involvement in the friendship) did not add to the prediction of adolescent smoking or other substance use. In contrast, a different analysis of the same dataset focused on best friend relationships, found that adolescents with a reciprocated compared with non-reciprocated best friendship were less likely to smoke (Ennett et al. 2006). Reciprocity may be an indicator of higher friendship quality.

The null and protective findings concerning friendship quality of these two social network studies stand in contrast to studies that did not use social network methods to measure friends' behavior. In those studies, smoking was associated with greater perceived supportiveness, attachment, or closeness to friends (Chassin et al. 1986; Krohn et al. 1983; Maggs and Hurrelmann 1998) and more frequent interaction with friends (Maggs and Hurrelmann 1998).

**Social Status** Social network analysis is well suited for measuring social status, but this dimension of adolescent friendship has received relatively little attention in studies of adolescent smoking. Two studies, however, examined indicators of social status: popularity and centrality (Alexander et al. 2001; Ennett et al. 2006). Both studies, using large samples, measured popularity by "indegree," or the number of friendship nominations received from other adolescents in the peer network, standardized for the size of the network, and neither study reported a relationship between popularity and cigarette smoking. The latter study also found no relationships between several indicators of centrality and smoking, where centrality measures indicated prominence in the network based on the patterns of friendship ties.

Two other studies augmented social network analysis methods with other methods for measuring social status and found some evidence for a positive relationship with smoking. Mitchell and Amos (1997) used qualitative data to characterize the social status of peer groups identified by social network analysis in a sample of Scottish youth. For girls, smoking was associated with belonging to either high or low, but not middle, status groups. The authors concluded that popular girls used smoking to maintain their image while less popular girls used smoking in hopes of gaining popularity. Abel and colleagues (2002) identified group members with social network analysis and then used cluster analysis of friendship nominations of the non group members to identify popular youth, among others. They also concluded that smoking may be a mechanism for gaining status among peers.

**Friend Smoking** The smoking behavior of friends is the most commonly measured peer attribute in social network studies. The measure differs, however, from non-network studies. Whereas social network studies measure friend smoking based on friend self-reports, traditional studies typically use adolescent perceptions of friend smoking. The latter measures result in inflated adolescent-peer smoking similarity due to the false consensus effect (e.g., Bauman and Ennett 1996).

While the associations between adolescent and peer smoking are weaker in the social network-based studies, significant associations are present across all studies. Moreover, relationships are present across all types of relationships measured, including friendship dyads, friendship groups, and sets of nominated friends (Alexander et al. 2001; Ennett and Bauman 1994; Ennett et al. 2006).

### Interactions Between Dimensions of Adolescent Peer Relations and Friend Smoking

Few social network and non-network studies of adolescent cigarette smoking have examined interactions between peer variables. One exception is a study by Urberg et al. (2003) where significant interactions between friends' smoking and positive friendship qualities were found in a sample of middle and high school youth, such that effects of friends' use were most pronounced in higher-quality friendships. Similarly, Haynie (2001) found that network density magnified the effects of friends' delinquent behavior. Another exception is the study by Alexander et al. (2001). While adolescent popularity was not associated with current smoking, the interaction of popularity with school smoking prevalence was associated with smoking. In schools with low smoking prevalence, popular students showed decreased odds of current smoking, whereas popular students in higher-smoking prevalence schools had increased odds of smoking. The Alexander findings suggest that attributes of the larger peer context, in addition to adolescents' more immediate friends, should be considered in examining interactions among peer variables.

In sum, peer attributes other than peer smoking may be consequential for adolescent smoking and need investigation. In the current investigation we test relationships between multiple peer attributes, interactions between attributes, and cigarette smoking from age 11 to 17 years using hierarchical linear growth modeling.

## Method

### Study Design and Sample

Data are from the Context of Adolescent Substance Use Study, a study designed to investigate peer networks and

other social contexts for adolescent substance use. To enable social network analysis, a saturated sample of all sixth, seventh, and eighth graders in three public school districts in North Carolina was enrolled and surveyed in school every 6 months, from spring 2002 through spring 2004, for a total of five assessments (waves 1–5). Data collection was timed to coincide with the beginning and end of the school year. At wave 1, all 13 schools in the three districts with middle grades were included (i.e., eight middle schools, two comprehensive K-8 schools, and three alternative schools with middle and high grades); beginning with wave 2 when eighth graders transitioned to high school, all six high schools were included.

At each data collection wave, all enrolled students at the targeted grade levels, except for students with limited English language reading skills and exceptional children (EC) in self-contained (but not regular) classrooms, were eligible for the study. Adolescents whose parents did not refuse their participation and who themselves provided written assent were surveyed. Due to new student enrollments, the sample included both continuing and new participants at each data collection wave. The samples ranged in size from 5,220 (wave 1) to 5,017 (wave 5) adolescents with 6,891 unique cases across all waves; response rates for waves 1–5 were 88.4%, 81.3%, 80.9%, 79.1% and 76.0%, respectively.

The analysis sample for the current investigation includes all adolescents who participated in at least one wave of data collection except for those missing birth date or outside the typical age range of 11 to 17 years for the grades studied ( $n=66$ , 1.0%) or whose home address could not be geocoded ( $n=246$ , 3.6%), as needed to account for the clustering of observations, yielding a sample size of 6,579 (95.5%). The mean age of adolescents was 14.17 years ( $SD=1.29$ ). About half were male (51%) and the race/ethnicity distribution was 51% white, 36% black, 5% Hispanic, and 8% other race/ethnicity. Approximately 87% of adolescents lived in a two-parent family and for 39% the highest education attained by either parent was high school or less.

### Social Network Analysis

Social network analysis was conducted on friendships reported by adolescents at each assessment. To identify friends, data collectors gave each student a student directory with an alphabetical listing of all enrolled students and a unique four-digit identification number for each student. Friends not in the directory were identified by “0000.” Adolescents identified up to their five closest friends, starting with the best friend. Because most adolescent friendships are with adolescents in the same school and grade, social networks and the directory listings were bounded by school and grade, with the following

exceptions. In high schools and alternative schools, networks were bounded by school because classes and activities are not grade segregated and therefore cross-grade friendships are likely. In the two K-8 schools, networks also were bounded by school because of their small enrollments. Social network analysis was conducted using network analytic SAS IML modules (Moody 2000) and UCINET (Borgatti et al. 2002), and is described in more detail elsewhere (Ennett et al. 2006).

### Measures

*Adolescent Smoking Involvement* We measured smoking involvement, rather than initiation or experimentation, because of the greater public health significance of more problematic smoking. We constructed a scale measuring recent (past 3 months) smoking involvement using six items from the revised Fagerstrom Test for Nicotine Dependence (Heatherton et al. 1991). The items measured the number of cigarettes smoked daily and indicators of dependence (e.g., difficulty keeping from smoking in forbidden places); except for the number of cigarettes smoked daily, the response options were dichotomous. Because of the limited and skewed distributions of responses, as is typical in studies of smoking in general populations of adolescents, we used item response theory (IRT) to construct the scale (Thissen and Orlando 2001). After dichotomizing responses to the number of daily cigarettes, we ran two-parameter logistic IRT models in MULTILOG, simultaneously fitted to all five waves of data to compute expected a posteriori (EAP) scores (Thissen et al. 2003). The resulting scale more nearly approximated a continuous distribution, with reduced skewness and kurtosis, compared with a summed scale. The IRT scores can be interpreted as having a standard normal distribution.

*Peer Measures* Peer measures include six indicators of having friends, friendship quality, social status, and peer smoking. The limited set of variables avoided measurement redundancy; no correlation exceeded 0.41 and most were considerably smaller (results not shown). Because the peer variables were measured at each assessment, time varying measures were constructed.

*Having Friends* Our measure of having friends taps embeddedness in friendships as indicated by the adolescent’s membership in transitive triads, measured as the proportion of transitive triads the adolescent belongs to relative to membership in both transitive and intransitive triads. A transitive triad is a set of three peers linked through friendship nominations such that a friend’s friend is also a friend of the adolescent, whereas in intransitive triads a friend’s friend is not a friend of the adolescent. We chose this

measure instead of social position because it captures the important dimension of belonging to groups where friends are connected with each other while providing a continuous measure that is less subject to measurement error than social position (Moody 2001).

*Friendship Quality* Measures include reciprocated closeness and interaction with friends away from school, thus tapping the qualities of intimacy and involvement. Both measures relied on questions asked about each nominated friend. Reciprocated closeness captured two indicators of closeness (friendship reciprocity and closeness ratings) and measured the mean closeness (ranging from 4=very close to 1=not very close) reported by the friends who reciprocated the adolescent's nominations. If a nominated friend did not nominate the adolescent in turn, his/her closeness was set to 0.

Interaction with friends away from school was based on two questions asked about each nominated friend: whether the adolescent had ever been to the friend's home or had the friend over to his/her home, and whether they had done something together outside of school in the past week. Both measures were assigned a 1 if "yes" or 0 if "no," and a scale created by summing scores for the two measures across all friends (i.e., those nominated by the respondent and those who nominated the respondent). As with network measures that require symmetric graphs, when there was disagreement about the nature of the relation we used the maximum value.

*Social Status* Status among peers was measured by a single indicator of centrality: betweenness centrality (Wasserman and Faust 1994). Betweenness centrality measures the extent to which an adolescent indirectly links pairs of adolescents who are not directly linked as friends. It is calculated by determining the shortest path (geodesic) between each pair of adolescents in the network and then determining the number of geodesics that include the focal adolescent. A respondent's betweenness centrality is defined as the proportion of all the geodesics that include the respondent. Because path lengths are affected by network size, we further standardized the measure by dividing the respondent's betweenness centrality by the maximum observed betweenness centrality score in the network. The resulting measure ranged from 0 to 1. Conceptually, an adolescent with high betweenness centrality has high status because of being able to control flows of information or norms by serving as a gatekeeper between adolescents, as well as by connecting adolescents from different parts of the network who are not directly connected to each other (Ennett et al. 2006; Wasserman and Faust 1994).

*Peer Smoking* We constructed two measures of peer smoking: friend smoking and school smoking. Friend

smoking was measured for each adolescent's set of friends, where the set included the friends nominated by the target adolescent and all adolescents nominating the target adolescent. To capture absolute exposure to smokers, we used the number of friend smokers (any smoking in the past 3 months) rather than mean level of smoking involvement. For school smoking, we used the same indicator to measure the percent of smokers in the social network to which the adolescent belonged.

*Control Variables* Demographic variables included high school enrollment, gender, race/ethnicity, family structure, and parent education. All except gender and race/ethnicity were time varying; although race/ethnic identity may be evolving in adolescence, we found little variation in self-reported race/ethnicity across assessments. Enrollment in high school or middle school (reference group) was measured dichotomously at each wave. Sex was coded so the reference group is female. Race/ethnicity was dummy coded to four categories: white (reference group), black, Hispanic, and other race/ethnicity. Family structure was coded as two parents in the home (reference group) versus some other composition. Parent education, an indicator of family socioeconomic status, measured the highest education attained by either parent and was coded as high school graduate or less versus more than high school graduate (reference group).

Other control variables were the size of the set of friends (i.e., the set of nominated and nominating friends), the school size, and the number of friends nominated who did not belong to the school network. The first two measures of peer size were included to control confounding of other peer variables with relative exposure to peers. The last variable was included to adjust for peer relations not reflected in the social network-based measures.

## Analysis

*Multiple Imputation* Before the statistical analyses, we imputed missing values on variables with multiple imputation, specifying all variables in the current study in the missingness equation (Allison 2002). The primary reason for missing values was that adolescents could enter and leave the study any time over the five waves of data collection. Because we had only a modest amount of missing data, we imputed only five datasets. The relative efficiency of variables was between 0.88 and 0.99, indicating that stable estimates were achieved (Horton and Lipsitz 2001).

*Statistical Analysis* We used three-level hierarchical growth models (Curran and Hussong 2003) to account for our longitudinal data and the nesting of adolescents within schools and neighborhoods. The data were arranged in a

cohort sequential design with adolescent age used to measure the passage of time, thereby allowing accelerated trajectories of smoking involvement to be modeled from age 11 through age 17 (Duncan et al. 1996). Age was centered at 12 years and measured by actual birth date at wave 1 and by the birth date plus 6, 12, 18, and 24 months, respectively, at waves 2, 3, 4, and 5. Because of the larger number of neighborhoods than schools and because neighborhoods were largely nested within schools (in that adolescents from several neighborhoods attended the same school), we specified neighborhood residence at level 3 to account for the clustering of adolescents. Neighborhood was measured by the adolescent’s census block group (block group  $N=153$ ).

We first estimated and compared linear and curvilinear unconditional hierarchical growth models of smoking involvement to determine the best fitting model, using the Bayesian information criterion (BIC). We also determined the random components by specifying a random intercept and random slope at both level 3 (the neighborhood) and level 2 (the individual).

We then estimated three conditional growth models. The first conditional model included the demographic and other control variables. Because gender and race/ethnicity were time invariant, we included the interactions of these variables with age to determine their effects on the slope of smoking involvement. The remaining demographics were time varying; thus, a significant regression coefficient means that the relationship between the demographic variable and adolescent smoking involvement was significant on average over the ages examined. The next conditional model added the set of six time varying peer variables, with the same interpretation as for the demographics. The final conditional model added the two-way interactions between friend smoking and each of the peer structure variables: transitive triad membership, reciprocated closeness, interaction with friends, and betweenness centrality, and between school smoking and each of the peer structure variables. We also included the interaction between friend and school smoking. Significant interactions were probed by plotting the regression of smoking involvement on friend or school

smoking at values of the moderator variable set at the mean and one standard deviation above and below the mean (Curran et al. 2004).

Analyses were conducted using SAS version 9.1.3., using PROC MI for the multiple imputation of missing data and PROC MIXED and PROC MIANALYZE to estimate the mixed models (SAS 2002–2003).

**Results**

*Unconditional Growth Models of Smoking Involvement* The linear trajectory model for smoking involvement provided a better fit than the curvilinear model as indicated by a smaller BIC (50,213.2 compared with 50,218.2). In addition, the squared age term in the curvilinear model was not significant. For the linear model, the mean intercept of smoking involvement centered at age 12 was significantly different from zero and there was significant growth in smoking through age 17 (Table 1). All four random components were significant, indicating both individual and neighborhood variability about the mean intercept and slope.

*Conditional Model with Control Variables* Smoking involvement increased with high school enrollment ( $B=0.05$ ,  $p<0.01$ ), living in other than a two-parent family ( $B=0.19$ ,  $p<0.001$ ), and lower parental education ( $B=0.04$ ,  $p<0.001$ ). While initial smoking levels did not differ for black or Hispanic compared with white youth, their growth in smoking was less rapid than for white youth (black  $B=-0.07$ ,  $p<0.001$ ; Hispanic  $B=-0.04$ ,  $p<0.05$ ). In addition, the intercept was significantly higher for youth of “other” race/ethnicity than for white youth ( $B=0.11$ ,  $p<0.05$ ). There were no differences between girls and boys in either the intercept or slope. Among the network control variables, having more friends not in the school network ( $B=0.02$ ,  $p<0.001$ ) and larger school size ( $B=0.00$ ,  $p<0.001$ ) were significantly positively related to smoking involvement whereas the number of friends was not.

**Table 1** Unconditional model of smoking involvement from age 11 through age 17 ( $N=6,579$ )

Unconditional model of smoking involvement			
Fixed effect	<i>B</i>	(SE)	<i>t</i>
Mean intercept	-0.10	(0.009)	-10.77***
Mean slope	0.19	(0.004)	41.9***
Random effect	LR	<i>df</i>	<i>p</i> value
Individual intercept	992.99	1	***
Individual slope	1,126.05	1	***
Neighborhood intercept	8.30	1	**
Neighborhood slope	13.75	1	***

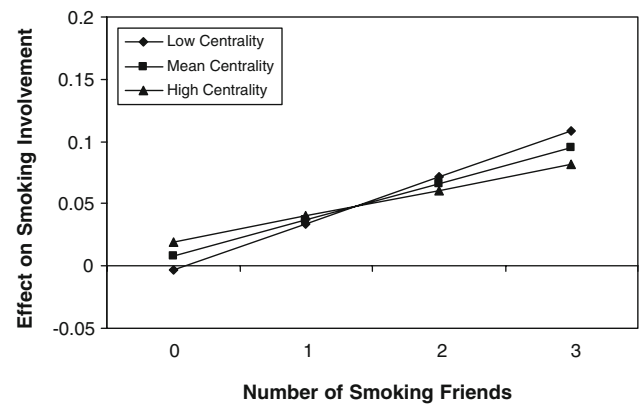
\*\* $p<0.01$ , \*\*\* $p<0.001$

**Conditional Model with Peer Variables Added** Adolescents belonging to higher percentages of transitive triads had lower smoking involvement, while those who interacted more with friends away from school, had more smoking friends, and went to schools with higher percentages of smokers had higher smoking involvement (Table 2, model 1). Neither reciprocated closeness nor betweenness centrality was related to smoking involvement. Except for high school status and the interaction between “other” race/ethnicity and age, which were reduced to non-significance, relationships with the demographic and social network control variables were unchanged, so we do not show those coefficients.

**Conditional Model with Interactions Between Peer Variables Added** The interaction between friend smoking and betweenness centrality was significant (Table 2, model 2). For adolescents with more friends who smoked, the relationship between friend smoking and smoking involvement decreased with increasing centrality (Fig. 1). In contrast, for adolescents with few or no smoking friends, higher centrality was associated with increased smoking involvement.

The interaction between friend smoking and involvement with friends away from school was marginally significant ( $p < 0.10$ ). The positive relationship between the number of friends who smoked and smoking involvement increased the more that adolescents interacted with these friends away from school.

None of the interactions between school smoking and the peer structural measures was significant. However, the interaction between school smoking and friend smoking



**Fig. 1** Effect on smoking involvement of the number of smoking friends by betweenness centrality ( $N=6,579$ )

was significant; the positive relationship between adolescent-friend smoking strengthened as the prevalence of school smoking increased.

With the addition of these two-way interactions the main effects of transitive triad membership, away from school interactions with friends, and school smoking remained significant. The main effect of friend smoking, however, was reduced to non-significance.

## Discussion

As forecast by the developmental literature on adolescent friendships, multiple peer dimensions were relevant to adolescent smoking involvement in this accelerated cohort of youth between the ages of 11 and 17. Friend smoking,

**Table 2** Peer attributes associated with smoking involvement from age 11 through age 17 ( $N=6,579$ )

Peer attribute	Model 1			Model 2		
	<i>B</i>	(SE)	<i>p</i> value	<i>B</i>	(SE)	<i>p</i> value
Transitive triad membership	-0.13	(0.02)	****	-0.15	(0.06)	***
Reciprocated closeness	0.001	(0.00)		0.001	(0.01)	
Friend interaction	0.01	(0.00)	****	0.01	(0.00)	***
Betweenness centrality	-0.03	(0.02)		0.07	(0.05)	
Friend smoking	0.05	(0.00)	****	0.02	(0.03)	
School smoking	0.78	(0.07)	****	0.78	(0.27)	**
Transitive triad × friend smoking	–			0.01	(0.02)	
Reciprocated closeness × friend smoking	–			0.00	(0.00)	
Friend interaction × friend smoking	–			0.002	(0.001)	*
Centrality × friend smoking	–			-0.04	(0.02)	**
Transitive triad × school smoking	–			0.07	(0.24)	
Reciprocated closeness × school smoking	–			0.00	(0.04)	
Friend interaction × school smoking	–			-0.02	(0.01)	
Centrality × school smoking	–			-0.27	(0.23)	
Friend smoking × school smoking	–			0.09	(0.04)	**

Models 1 and 2 adjust for all demographic and network control variables.

\* $p < 0.10$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ , \*\*\*\* $p < 0.001$

the peer variable most often examined in research on adolescent smoking, was confirmed as a risk factor for smoking involvement, as was smoking by schoolmates. The primary contribution of the current analysis, however, was to demonstrate the contribution of other peer variables net of the smoking behavior of peers. Indicators of embeddedness in friendships, friendship quality, and peer social status, as identified through social network analysis, were associated with adolescent smoking involvement across the ages examined either as unique effects or in interaction with friend smoking. The only peer variable not related to adolescent smoking was reciprocated closeness.

By including measures of both peer smoking and structural attributes of peer relations, the peer context for adolescent smoking was revealed to be more complex than suggested by studies with the peer focus limited to friend smoking. That complexity is exhibited in the evidence for conditional effects, the pro-smoking nature of some relationships, and the anti-smoking nature of other relationships. The possibility that peers may have a prosocial role in adolescent smoking rarely has been investigated or acknowledged in prior research. Yet it was demonstrated by our finding that lower smoking involvement was reported by adolescents with transitive friendships. This finding may add to the other adaptive functions of friendship reported in the developmental literature: Among the competencies associated with having friends may be less susceptibility to engaging in smoking. As well, it is consistent with prior social network studies suggesting the risk for smoking from isolation (e.g., Ennett and Bauman 1993; Fang et al. 2003) and conversely the benefits of embeddedness in peer relations (Ennett et al. 2006).

But the smoking of friends does matter. Across the age span examined, adolescents reported higher smoking involvement when exposed to more smokers among both friends and in the larger network of peers at school. These findings are consistent with the maladaptive functions often linked to friends' antisocial behavior and the extensive literature linking adolescent and peer smoking. Yet, at least for friend smoking, other aspects of peer relations conditioned the association with adolescent smoking, with evidence for both buffering and exacerbating effects.

The interaction between friend smoking and betweenness centrality was particularly complex. Adolescents with higher rather than lower betweenness centrality and more rather than fewer friends who smoke, reported lower smoking involvement. Perhaps adolescents with higher social status, which could reflect greater social competency and liking by peers, have more resources for withstanding negative effects of exposure to friends who smoke. On the other hand, adolescents with higher centrality and few or no smoking friends had higher risk of smoking involvement. The consistency in this seemingly contradictory crossover

is that adolescents with higher centrality exhibited different smoking behavior than friends. Differentiating oneself from friends may be a marker of social status.

These social status findings contrast with another study of a different behavior showing that the influence of best friend's alcohol use on adolescent behavior was stronger for more rather than less centrally located adolescents (Crosnoe and Needham 2004). Other studies found positive relationships between social status and smoking (Abel et al. 2002; Michell and Amos 1997) and alcohol and marijuana use (Ennett et al. 2006) but did not test interactions with peer variables. Further research on how social status might condition adolescent-peer behavioral similarity is indicated for different problem behaviors.

In contrast to the apparent buffering effect of social status on having friends who smoke, interaction with friends away from school, an indicator of friendship quality, was positively related to adolescent smoking and exacerbated the adolescent-friend smoking relationship, although we note that the interaction was only marginally significant. The more adolescents were involved with smoker friends away from school, the higher their risk of smoking involvement. Away from school activities with smoking friends may provide unsupervised opportunities that promote smoking. Alternatively, adolescents may more readily choose to be with smoker friends outside of school. It also is noteworthy that the control variable of the number of friends not in school (i.e., friends not listed in the school directory) was positively associated with smoking involvement. These friends who would only interact with adolescents away from school and who might be older also may have provided opportunity and reinforcement for smoking or been selected as friends because of smoking.

While the relationship between adolescent-friend smoking was always conditional on other peer variables, the relationship between adolescent-school smoking was not. Our findings contrast with the study of Alexander et al. (2001) that reported an interaction between the prevalence of smoking in the school and adolescent social status as indicated by popularity. We found both a positive main effect of the percentage of smokers in the school on adolescent smoking involvement and a magnifying effect of exposure to smoking among both friends and school peers. The findings suggest that adolescents are sensitive both to friends and to the general smoking climate in their larger network of peers. That smoking among more distal peers is a unique risk factor for adolescent smoking involvement adds to recent studies indicating the contribution of school-level effects to adolescent smoking (Sellstrom and Bremberg 2006).

Collectively, our findings suggest that aspects of peer relations tapping social competencies—having close circles of friends and having social status among peers when one's



friends are smokers—are protective against smoking involvement while aspects tapping exposure to smokers and opportunity for interactions with them confer risk for smoking. These findings are consistent with the fuller consideration of the role of friendships, both positive and negative, in adolescent behavior suggested by the developmental literature compared with the relatively more narrow public health perspective that emphasizes the behavior of peers. As well, the findings are consistent with the social network paradigm that emphasizes relational patterns and properties in explaining behavior (Knoke and Kuklinski 1982; Scott 2000; Wasserman and Faust 1994). Development of a theory of the structure and function of adolescent friendships relevant to engagement in risk behaviors that draws on the developmental, public health, and social network literatures is needed. Such theory should include consideration of how friendship properties interrelate with other peer attributes linked to adolescent smoking, such as adolescent perceptions of peer substance use and peer approval of use (i.e., descriptive and injunctive norms).

Because all adolescents' peer relations and school environments can be described along the multiple dimensions investigated in this study, the peer context for smoking for any single adolescent may provide more or less support for smoking. When research is limited to the smoking behavior of friends, it risks overestimation of the importance of this peer attribute and underestimation of the importance of the overall peer context, both positively and negatively, to adolescent smoking. Moreover, when applied to guide prevention, it risks missing opportunities for strengthening protective friendship qualities and limiting risky friendship situations. Smoking prevention interventions that include emphasis on development of friendships and social competencies are likely to be more effective than those that focus more narrowly on negative peer influences.

While our social network approach is intended to measure multiple dimensions of adolescent friendships potentially relevant to cigarette smoking, even social network analysis is limited in fully capturing the dynamic interplay that characterizes adolescent friendships. Our analysis is based on five moment-in-time reports of adolescent friendships that may not do justice to the day-to-day dynamics of friendships, with the resulting variables being limited proxies for these dynamic interactions. Nevertheless, because social network analysis depends on linking data from multiple actors to measure relational properties, it is a substantial improvement over traditional methods of measuring friendships that assume independence of observations (e.g., adolescent perceptions of friendship qualities or patterns). Thus it holds substantial promise for uncovering interactional patterns, as well as mechanisms and conditions of social influence (Berkman et al. 2000).

A further limitation of our study is that our statistical models, while based on longitudinal data, do not allow us to assess temporality of relationships and therefore causal inferences are tempered. Thus we cannot determine whether the similarity in smoking between adolescents and friends is due to socialization or selection. Our models assessed the contemporaneous relationships between the time-varying friend smoking measure and smoking involvement at each time point assessed (modeled as age). The models did not assess whether friend smoking at earlier ages predicted adolescent smoking involvement at later ages after controlling for prior smoking by the adolescent. For the school smoking variable, however, we can fairly confidently conclude that the relationship with adolescent smoking is one of peer influence because adolescents do not (typically) select their school environment. Nevertheless, the relationship could be spurious although we controlled for several sociodemographic variables that could confound the relationship. Other statistical models (e.g., autoregressive latent trajectory models) are needed to conduct analyses of socialization and selection among close friends (Curran and Hussong 2003) and are a consideration for future research.

Despite these limitations, our statistical models are a strong point of the study in the modeling of individual trajectories of smoking involvement from age 11 through 17 and in using measures of peer relations assessed repeatedly over the same time span. As well, our analysis demonstrates the usefulness of social network analysis for operationalizing an inclusive set of peer variables and the importance of simultaneously examining multiple peer variables. A social network perspective, with its focus on the structure and content of relationships, provides a strong methodological match to developmental perspectives on the nature and meaning of adolescent friendships and other peer relations. We conclude that advancement in understanding of the contribution of peers to adolescent smoking etiology would benefit from more frequent application of social network methods. In addition, research is needed that comprehensively examines interrelations between peer variables and other social contextual variables (e.g., family, school), as well as intrapersonal characteristics (e.g., motivation to smoke, perceptions of peer smoking), linked to adolescent smoking.

**Acknowledgment** This research was supported by a grant from the National Institute on Drug Abuse (R01 DA13459). An earlier version of this paper was presented at the Applications of Social Network Analysis to the Prevention of Substance Use and Delinquency Conference held November 11, 2005 at Pennsylvania State University.

## References

- Abel, G., Plumridge, L., & Graham, P. (2002). Peers, networks or relationships: Strategies for understanding social dynamics as determinants of smoking behaviour. *Drugs: Education, Prevention and Policy*, 9, 325–338.
- Alexander, C., Piazza, M., Mekos, D., & Valente, T. (2001). Peers, school, and adolescent cigarette smoking. *Journal of Adolescent Health*, 29, 22–30.
- Allen, J. P., Porter, M. R., McFarland, F. C., March, P., & McElhaney, K. B. (2005). The two faces of adolescents' success with peers: Adolescent popularity, social adaptation, and deviant behavior. *Child Development*, 76, 747–760.
- Allison, P. D. (2002). *Missing data*. Thousand Oaks, CA: Sage.
- Bauman, K. E., & Ennett, S. T. (1996). On the importance of peer influence for adolescent drug use: Commonly neglected considerations. *Addiction*, 91, 185–198.
- Bauman, K. E., Faris, R., Ennett, S. T., Hussong, A., & Foshee, V. A. (2007). Adding valued data to basic social network measures: Does it add to prediction of adolescent substance use? *Social Networks*, 29, 1–10.
- Bearman, P. S., & Moody, J. (2004). Suicide and friendships among American adolescents. *American Journal of Public Health*, 94, 89–95.
- Berkman, L. F., Glass, T., Brissette, I., & Seeman, T. E. (2000). From social integration to health: Durkheim in the new millennium. *Social Science & Medicine*, 51, 843–857.
- Berndt, T. J. (1982). The features and effects of friendship in early adolescence. *Child Development*, 53, 1447–1460.
- Borgatti, S. P., Everett, M. G., & Freeman, L. C. (2002). *Ucinet for windows: Software for social network analysis (Version 6)*. Harvard, MA: Analytic Technologies.
- Chassin, L., Presson, C. C., Sherman, S. J., Montello, S. J., & McGrew, J. (1986). Changes in peer and parent influence during adolescence: Longitudinal versus cross-sectional perspectives on smoking initiation. *Developmental Psychology*, 3, 327–334.
- Crosnoe, R. (2000). Friendships in childhood and adolescence: The life course and new directions. *Social Psychology Quarterly*, 63, 377–391.
- Crosnoe, R., & Needham, B. (2004). Holism, contextual variability, and study of friendships in adolescent development. *Child Development*, 75, 264–279.
- Curran, P. J., Bauer, D. J., & Willoughby, M. T. (2004). Testing and probing main effects and interactions in latent curve analysis. *Psychological Methods*, 9, 220–237.
- Curran, P. J., & Hussong, A. M. (2003). The use of latent trajectory models in psychopathology research. *Journal of Abnormal Psychology*, 112, 526–544.
- Dishion, T., Andrews, T., & Crosby, L. (1995). Antisocial boys and their friends in early adolescence: Relationship characteristics, quality, and interactional process. *Child Development*, 66, 139–151.
- Duncan, S. C., Duncan, T. E., & Hops, H. (1996). Analysis of longitudinal data with accelerated longitudinal designs. *Psychological Methods*, 1, 236–248.
- Eder, D. (1985). The cycle of popularity: Interpersonal relations among female adolescents. *Sociology of Education*, 58, 154–165.
- Ennett, S. T., & Bauman, K. E. (1993). Peer group structure and adolescent cigarette smoking: A social network analysis. *Journal of Health & Social Behavior*, 34, 226–236.
- Ennett, S. T., & Bauman, K. E. (1994). The contribution of influence and selection to adolescent peer group homogeneity: The case of adolescent cigarette smoking. *Journal of Personality & Social Psychology*, 67, 653–663.
- Ennett, S. T., Bauman, K. E., Hussong, A., Faris, R., Foshee, V. A., DuRant, R. H., et al. (2006). The peer context of adolescent substance use: Findings from social network analysis. *Journal of Research on Adolescence*, 16, 159–186.
- Fang, X., Li, X., Stanton, B., & Dong, Q. (2003). Social network position and smoking experimentation among Chinese adolescents. *American Journal of Health Behavior*, 27, 257–267.
- Giordano, P. C. (2003). Relationships in adolescence. *Annual Review of Sociology*, 29, 257–281.
- Hartup, W. W. (1996). The company they keep: Friendships and their developmental significance. *Child Development*, 61, 1–13.
- Haynie, D. L. (2001). Delinquent peers revisited: Does network structure matter? *American Journal of Sociology*, 106, 1013–1057.
- Heatherton, T. F., Kozlowski, L. T., Frecker, R. C., & Fagerstrom, K. O. (1991). The Fagerstrom Test for Nicotine Dependence: A revision of the Fagerstrom Tolerance Questionnaire. *British Journal of Addiction*, 86, 1119–1127.
- Hoffman, B. R., Sussman, S., Unger, J. B., & Valente, T. (2006). Peer influence on adolescent cigarette smoking: A theoretical review of the literature. *Substance Use and Misuse*, 41, 103–155.
- Horton, N. J., & Lipsitz, S. R. (2001). Multiple imputation in practice: Comparison of software packages for regression models with missing variables. *The American Statistician*, 55, 244–254.
- Knoke, D., & Kuklinski, J. H. (1982). *Network analysis*. Beverly Hills, CA: Sage.
- Kobus, K. (2003). Peers and adolescent smoking. *Addiction*, 98 (Suppl 1), 37–55.
- Krohn, M. D., Massey, J. L., Skinner, W. F., & Lauer, R. M. (1983). Social bonding theory and adolescent cigarette smoking: A longitudinal analysis. *Journal of Health & Social Behavior*, 24, 337–349.
- Maggs, J. L., & Hurrelmann, K. (1998). Do substance use and delinquency have differential associations with adolescent peer relations. *International Journal of Behavioral Development*, 22, 367–388.
- Michell, L., & Amos, A. (1997). Girls, pecking order and smoking. *Social Science and Medicine*, 44, 1861–1869.
- Moody, J. (2000). *SPAN: SAS programs for analyzing networks* [web page]. URL: [http://www.sociology.ohio-state.edu/jwm/soc\\_net\\_methods.htm](http://www.sociology.ohio-state.edu/jwm/soc_net_methods.htm).
- Moody, J. (2001). Peer influence groups: Identifying dense clusters in large networks. *Social Networks*, 23, 261–283.
- Pearson, M., & Michell, L. (2000). Smoke rings: Social network analysis of friendship groups, smoking, and drug-taking. *Drugs: Education, Prevention, and Policy*, 7, 21–37.
- Pearson, M., & West, P. (2003). Drifting smoke rings: Social network analysis and Markov processes in a longitudinal study of friendship groups and risk-taking. *Connections*, 25, 59–76.
- SAS (2002–2003). *SAS 9.1 for Windows*. Cary, NC: SAS Institute, Inc.
- Savin-Williams, R. C., & Berndt, T. J. (1990). Friendship and peer relations. In S. B. Feldman & G. R. Elliott (Eds.), *At the threshold. The developing adolescent* (pp. 277–307). Cambridge, MA: Harvard University Press.
- Scott, J. (2000). *Social network analysis: A handbook* (2nd ed.). London: Sage.
- Sellstrom, E., & Bremberg, S. (2006). Is there a “school effect” on pupil outcomes? A review of multilevel studies. *Journal of Epidemiology and Community Health*, 60, 149–155.
- Steglich, C., Snijders, T., & Pearson, M. (2004). *Dynamic networks and behavior: Separating influence from selection*. Unpublished manuscript available at [http://stat.gamma.rug.nl/snijders/SSP\\_total.pdf](http://stat.gamma.rug.nl/snijders/SSP_total.pdf).

- Thissen, D., Chen, W.-H., & Bock, R. D. (2003). *Multilog* (Version 7). Lincolnwood, IL: Scientific Software International.
- Thissen, D., & Orlando, M. (2001). Item response theory for items scored in two categories. In D. Thissen, & H. Wainer (Eds.), *Test scoring* (pp. 73–140). Hillsdale, NJ: Erlbaum.
- Urberg, K. A., Luo, Q., Pilgrim, C., & Degirmencioglu, S. M. (2003). A two-stage model of peer influence in adolescent substance use: Individual and relationship-specific differences in susceptibility to influence. *Addictive Behaviors*, 28, 1243–1256.
- Valente, T. W., Gallaher, P., & Mouttapa, M. (2004). Using social networks to understand and prevent substance use: A transdisciplinary perspective. *Substance Use and Misuse*, 39, 1685–1712.
- Wasserman, S., & Faust, K. (1994). *Social network analysis: Methods and applications*. New York: Cambridge University Press.