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A Network Method of Measuring Affiliation-based Peer Influence: Assessing the Influences of Teammates' Smoking on Adolescent Smoking

Kayo Fujimoto, Jennifer B. Unger, and Thomas W. Valente

Abstract

Using a network analytic framework, this study introduces a new method to measure peer influence based on adolescents' affiliations or two-mode social network data. Exposure based on affiliations is referred to as the "affiliation exposure model." This study demonstrates the methodology using data on young adolescent smoking being influenced by joint participation in school-based organized sports activities with smokers. The analytic sample consisted of 1260 American adolescents from age 10 to 13 in middle schools, and the results of the longitudinal regression analyses showed that adolescents were more likely to smoke as they were increasingly exposed to teammates who smoke. This study illustrates the importance of peer influence via affiliation through team sports.

Peers are one of the most significant influences on adolescent substance use. Numerous network studies (Alexander, Piazza, Mekos, & Valente, 2001; Ennett & Bauman, 1993; Ennett et al., 2006; Hall & Valente, 2007; Pearson et al., 2006; Urberg, Degirmencioglu, & Pilgrim, 1997; Valente, Unger, & Johnson, 2005) on the diffusion of adolescent substance use have analyzed friendship networks and identified various forms of network influence, such as the direct influence of friends or cliques, the structural influence of occupying specific network positions (e.g., popular students, students who bridge between peer groups, or isolates), or the selection of friends based on use status (Mercken, Snijders, Steglich, Vartiainen, & de Vries, 2010). In these network studies, one of the primary issues of network influence on health behavior change has been the mapping of social influence using social network measurements.

The standard network approaches for operationalizing network influence, however, have been limited primarily to friendship relations, which may be but one of the various forms of networks that influence an adolescent's substance use risk. Recent studies have taken a multi-dimensional approach to peer context that includes multiple social contexts for assessing the association between peer relationships and substance use (Ennett et al., 2008; Hussong, 2002). These studies have shown that social influence on substance use may not be limited to the network of close friendships but rather may extend to more distal peers even after controlling for the immediate friends' alcohol use.

The present study introduces a new method for measuring peer influence based on affiliation networks, which models the influence of the joint participation or co-membership with substance users on individual substance use. We conceptually distinguish peer influence based on affiliation (i.e., co-participation or co-affiliation with substance users) from the influence of having friends who use substances. Our study calls the former "affiliation peer

influence,” and the latter “relational peer influence.” “Affiliation peer influence” measures social influence that is conveyed through comparison to and co-participation with substance users. On the other hand, “relational peer influence” measures social influence through friendships with substance users, capturing “social influence conveyed over transmission of information, persuasion, or direct pressure” (p.103) (Valente, 2005). It should be noted that friendships may overlap with co-memberships, but we conceptually distinguish the mechanism of affiliation influence from the relational one to stress the importance of adolescents’ identification with crowd affiliation where adolescents’ peer membership can serve as a labeling of behavior (Brown, 1990; Hussong, 2002). More specifically, a social crowd may serve as a “reputation” that adolescents attach to their peers based on past behavior, and further suggesting that substance use may be a basis for adolescent crowd membership (Brown, 1990; Brown, Lohr, & Trujillo, 1990). Thus, social crowds can serve as a marker of behavior.

Measuring Peer Influence

Social Network Analysis

Social Network Analysis (SNA) provides methods for analyzing relational aspects of social structure based on relationships where structural variables are measured based on a distinct set of entities, which are referred to as “mode” (Wasserman & Faust, 1994). Network data derived from friendship nominations are often referred to as one mode data. Network data derived from joint affiliations are referred to as two mode because the data entails both individuals and groups (Wasserman & Faust, 1994). In the one-mode network, structural variables are measured on a single set of students (N). The data are represented as a sociomatrix X_{ij} , composed of N rows (nominating students) and N columns (nominated students), with the X_{ij} equal to 1 if a student n_i (row node) nominated a student n_j (column node) as a friend, and 0 otherwise.

In the two-mode network data, structural variables are measured on two sets of distinct nodes. For instance, the first mode is a set of N actors in a given network boundary, and the second mode is a set of M events with which the actors in the first set affiliated. Such two-mode networks are referred to as an affiliation network that records membership for each actor (indexed in row) with each event (indexed in column) in the $(N \times M)$ matrix form A_{ij} , with the entry of A_{ij} is equal to 1 if row actor n_i affiliated with column event j , and 0 otherwise. By multiplying an affiliation matrix A with its transpose (A_{ij}') , the resulting matrix $C_{ij} (=A_{ij}A_{ij}')$ is a symmetric, valued matrix where off-diagonal entries count the number of events jointly affiliated by all pairs of actors (adolescents in the present example), and diagonal entries count the total number of events with which each actor (adolescent) is affiliated. Both the sociomatrix X_{ij} and the co-membership matrix C_{ij} were used to specify the relational and affiliation peer influences using the Network Exposure Model.

Affiliation Exposure Model

We employed the Network Exposure Model (NEM) (Burt, 1987; Marsden & Friedkin, 1993; Valente, 1995, 2005) to examine network influence on smoking behavior. NEM is based on diffusion of innovation theory, which explains how new ideas and practices spread through social networks. The general formula of exposure E is defined as:

$$E = \frac{\sum_{j=1} W_{ij} Y_j}{\sum_{j=1} W_{ij}} \quad \text{for } i, j=1, \dots, N \quad i \neq j \quad (1)$$

where $\underline{E}$ is the exposure vector, W_{ij} is a social network weight matrix, and y_j is a vector of j 's behavioral attribute ($j = 1, \dots, N$). By specifying different weight matrices W , this model measures the levels of the given forms of social influence. "Relational exposure" uses the sociomatrix of friendship network nominations (X_{ij}) in place of W_{ij} , and measures the proportion of substance users in an adolescent's friend network. "Affiliation exposure" uses the co-participation matrix (C_{ij}) in place of W_{ij} . More specifically, by multiplying C_{ij} by each alter's attribute y_j (i.e., substance use) and normalizing it by the row-sum C_{i+} , the resulting affiliation exposure vector of F is defined as follows:

$$\underline{F} = \frac{\sum_{j=1} C_{ij} Y_j}{\sum_{j=1} C_{ij}} \quad \text{for } i, j = 1, \dots, N \quad i \neq j \quad (2)$$

Affiliation exposure (F) measures the percentage of events in which a given adolescent co-participates with substance users, as opposed to the (more familiar) percentage of substance users to whom the adolescent is exposed. In our application, affiliation exposure measures the percentage of sports (teams) that the student co-participates in with members who smoke. Note that the diagonal values (D) of C_{ij} ; $i=j$ are ignored for this computation, but will be included as a control variable for later statistical analysis. It should also be noted that although both measures are normalized (range from zero to one), they may have distinctly different distributions. In order to examine the effect of affiliation exposure in the context of understanding multiple risks for substance use, our affiliation exposure terms can be included as one of the covariates in a regression model in the follow:

$$y = \alpha + \sum_{j=1}^k \beta_j X_j + \beta_{k+1} \underline{E} + \beta_{k+2} \underline{F} + \beta_{k+3} D \quad (3)$$

The affiliation exposure term (F) is the main independent variable of the model in addition to the total number of events each person participated in (D), and relational exposure (E , where the specification of W is based on one-mode network), and additional risk factors X .

Application of Affiliation Exposure to Adolescent Smoking

It is generally agreed that participation in organized activities contributes to peer group formation by providing a context in which adolescents may interact on a regular basis and share experiences and goals (Eccles & Barber, 1999). These activities serve to generate a hierarchy of peer groups and concomitant peer status (Eder & Kinney, 1995), where popularity is determined by the visibility level among peer groups (Eder, 1985). Under such situations, activity participation helps form peer-group identity (Eckert, 1989; Fine, 1987) by providing individuals with an opportunity to identify with a group and thus absorb the shared values and norms associated within the specific activity-based culture (Eccles & Barber, 1999).

As an empirical example of applying our affiliation exposure model to examine affiliation peer influence, this study examines the likelihood of smoking as a function of co-participation in school-based activities with smokers. Among other extracurricular activities, we chose sports activities because of a tendency for athletes to have more risk-taking peers (Barber, Stone, Hunt, & Eccles, 2005) and to experience higher levels of peer pressure (Hansen, Larson, & Dworkin, 2003) than non-athletes.

Previous studies of organized activities have documented a conflicting picture of the influence of sports activities on adolescent problem behaviors. Some studies have shown a

protective effect of sports activities on substance use (Melnick, Miller, Sabo, Farrell, & Barnes, 2001; Pate, Trost, Levin, & Dowda, 2000), whereas other studies have found positive associations between sports activities and substance use (Eccles, Barber, Stone, & Hunt, 2003; Fredricks & Eccles, 2006), or no association (Bohnert & Garber, 2007; Osgood, Wilson, O'Malley, Bachman, & et al., 1996). Few studies of organized activities have measured peer influence on smoking due to the lack of information about the degree of exposure to smokers in sports activities (instead, measuring influence by simply counting or dummy coding each adolescent's activities). We address this issue by using an affiliation exposure model.

This study divides the types of sports into team sports and individual or competition sports. Prior research has shown that characteristics of organized youth sports (i.e., individual vs. team) are related to adolescent problem behavior (Peretti-Watel, Beck, & Legleye, 2002). The structure of interaction between teammates in a team sport (where cooperation or solidarity among teammates are more likely to occur) may be different from that in an individual sport (where individuals are competitors). Therefore, we assume that a different mechanism of peer influence operates depending on the type of sport, and hypothesize that adolescents who join team sports are more likely to be influenced by their teammates with regards to smoking compared to those who join individual sports.

With respect to gender, prior research has reported the importance of school-sponsored extracurricular activities on determining popularity and formation of peer status among middle-school girls (Eder & Kinney, 1995). Additionally, studies have emphasized the importance of group affiliation for girls' identities, which is closely linked to their smoking behavior. In part girls smoke to maintain their position in the social hierarchy or establish an image and social identity (Michell & Amos, 1997) as a means of group bonding (Stewart-Knox et al., 2005). Based on these findings, we expect that girls are more likely than boys to be influenced to smoke by participation in school-based activities with smokers.

Methods

Data

The study employed a secondary dataset, which was nested within a larger longitudinal school-based experimental trial of two social-influence prevention interventions (Johnson et al., 2007; Unger et al., 2004) and three network implementation methods (Valente, Hoffman, Ritt-Olson, Lichtman, & Johnson, 2003; Valente, Unger, Ritt-Olson, Cen, & Johnson, 2006) for smoking prevention strategies in an ethnically diverse, urban population of adolescents in California. Schools were eligible to participate if their student population was at least 25% Hispanic and/or Asian-American, and 24 public and private middle schools in and near the Los Angeles metropolitan area participated in this longitudinal study. The student recruitment procedure has been described elsewhere (Johnson et al., 2007) and was approved by the university's Institutional Review Board.

Three in-school student surveys were administered: a baseline (2001), 1-year follow-up survey (2002), and 2-year follow-up survey (2003). These surveys were conducted in 6th, 7th, and 8th grades in middle schools and measured gender, ethnicity, age, grades, sports activities participated, and smoking behavior. Additionally, two in-school social network surveys were administered (during health classes): a baseline network (2001) one-year follow-up network surveys (2002), which included the question, "Name your 5 closest friends in this class." From these answers, the friendship network was constructed for our analysis.

The sample consisted of 3,137 6th grade students who provided active consent and completed the baseline survey, of whom 2,602 (83%) remained until the one-year follow-up survey during the 7th grade, and 2,186 (70%) remained until the two-year follow-up survey during the 8th grade. Eight of the 24 schools were randomly assigned to a control condition and did not complete the social network surveys. Social network data were collected from the remaining 16 schools (consent rate was 77%). Of the 2,186 students who completed all three wave surveys, 663 (30%) students completed just the baseline network survey, 572 (26%) completed both baseline and the follow-up network surveys, 46 (2.1%) completed just the follow-up network survey, and 905 (41%) lacked network data. This study used students who completed all three wave surveys and at least one of the network surveys, totaling 1,281 possible cases nested within 16 schools. Attrition analysis showed that compared with the students who were successfully followed through the three waves, those lost to follow up were more likely to have tried smoking by 6th grade ($OR = 1.89$) and by 7th grade ($OR = 1.71$), less likely to be Asian ($OR = .51$), had lower academic grades ($OR = .58$), had lower socioeconomic status ($OR = 0.83$), and higher values of affiliation exposure at wave 2 ($OR = 1.46$), all of which had a probability less than .001.

Measurements

Smoking status was measured as a binary of the outcome of “ever smoked” (including “ever taking a puff,” “ever smoked whole cigarette,” and “smoked any cigarette in the last 30 days”), measured at three waves (6th, 7th, 8th grade), and each coded as no=0, yes=1. This dichotomous measure was chosen because it is a powerful risk factor for progression to regular smoking (Choi, Pierce, & Gilpin, 1997), and the proportion of monthly smokers was so low in 6th grade (2%) that an analysis of more frequent smoking would have had insufficient statistical power (Valente et al., 2005). The main explanatory variables are the affiliation exposures for three waves computed from team and individual sports activities. The survey asked students if they participated in each of these activities organized by school. We divided these sports activities into 8 team sports (basketball, baseball, cheerleading, field hockey, football, softball, soccer, and volleyball) and 5 individual/competitive sports (cross country, swimming, track, tennis, and wrestling). We took the natural logarithm of the scores of affiliation exposures to normalize the distributions. Additionally, we included a count of team and individual sports activities in which the student participated.

As a control variable, we used relational exposure. The measurement of friends' influence is limited to classroom nominations and so it may under-estimate the influence of relational exposure and so we need to be cautious in interpreting the results. Other control variables were age (coded as 10-11 years old versus 12 or more), gender (1: females; 0: males), ethnicity (Asian-American, Latino/Hispanic, White, and Multiethnic/other, including African-Americans), having a foreign-born parent (1: yes; 0: no), having a parent who is a college graduate (1: yes; 0: no), academic performance (coded as 0: mostly F's; 1: mostly D's; 2: mostly C's; 3: mostly B's; 4: mostly A's), number of rooms in the household (seven ordinal categorical variable), and having a parent who smokes (1: yes; 0: no). Following the findings of prior network studies (Alexander et al., 2001; Pearson et al., 2006; Valente et al., 2005), we also used popularity as a network control variable. Based on the network measure of centrality (Freeman, 1979), popularity was computed as the number of times a student was named as a friend (indegree) divided by class size. Finally, our statistical model included a set of dummy variables for each sport to control for the effects of a specific sport on smoking prevalence. Additionally, since our study uses a secondary dataset from a school-based experimental trial of two social-influence intervention programs (Johnson et al., 2007; Unger et al., 2004) and three network implementation methods (Valente et al., 2003; Valente et al., 2006), we have also controlled for the intervention by including a

variable that indicates which program students received (a dummy variable) and a variable of which implementation method of these programs they received (two dummy variables).

Statistical Analysis

To account for correlation between repeated binary responses for each student, we conducted logistic longitudinal regression analyses using Generalized Estimating Equations (Liang & Zeger, 1986) and subject-specific model (random effects model). We first used GEE analysis to examine if the level of school-sponsored sports activities an adolescent co-participated with smokers (affiliation exposures based on team and individual sports were examined separately) has an influence on smoking behavior, controlling for friends' influence, popularity, and demographics. To select the correlation structure in GEE, we used the QIC criteria (Pan, 2001), and chose to specify an exchangeable correlation structure that assumes that observations within a cluster in a given year have some common correlation, and used empirical variance estimators. The random effects model was then employed to examine the within-subject relationships. The analysis was conducted separately by gender as well. We used STATA 11 to compute the network exposures (through a MATA programming library) and to conduct the longitudinal analyses. To address the limitation in our network data, we conducted an iterative MCMC multiple imputation method for handling missing values in network measurements to obtain more valid statistical inference.

Results

Descriptive Statistics

The analytic sample consisted of 1260 valid cases out of 1281 possible cases (21 cases contained missing values on at least one of the predictor variables and were removed from the statistical analysis). Table 1 provides a description of the sample characteristics and tests of differences in proportions or means of variables used in our study.

Longitudinal Statistical Analyses

In the initial longitudinal analyses, we included the effect of team sport affiliation exposure and individual sport affiliation exposure (as well as corresponding number of sports joined) separately in the model. We found that the former effect was significant for both the GEE and Random Effect Models (REM) at the alpha level of .05 (two-sided test), but not for the latter one, which supports our earlier hypothesis that adolescents who join team sports are more likely to be influenced by their teammates with regards to smoking compared with those who join individual sports. The subsequent section only reports the results of the effect of affiliation exposure based on team sports on smoking. Table 2 provides the longitudinal results (Odds Ratios) of GEE and REM. Alpha was set at .05, and thus all results reported as significant have a probability less than .05.

GEE Population Averaged Effect

The GEE results showed that there was a significant positive effect of affiliation exposure (co-participating team sports activities with smokers) on an adolescent's smoking behavior. The estimated population-averaged odds ratio was 1.16. On the other hand, the results also showed a significant negative effect of the number of teams participated in on smoking, that is, as participation in team sports increased, the likelihood of smoking decreased ($OR = .76$). These results indicate that both diagonal and off-diagonal information in the co-membership matrix (C) in our affiliation exposure model provide different mechanisms of affiliation-based peer influence, and so should be included simultaneously in the regression. As for the main effects of control variables, females ($OR = .76$), Asian Americans ($OR = .46$), and adolescents who had better academic performance ($OR = .70$) were less likely to smoke,

whereas those who are older ($OR = 1.37$), whose parent(s) smoke ($OR = 1.87$), who were exposed to more friends who smoke ($OR = 1.09$) were more likely to smoke. To estimate the clinical magnitude of affiliation exposure, we calculated unstandardized regression coefficients for the variables in the model. The risk of smoking increased .15 times for each one unit increase in affiliation exposure, .31 times for one unit increase in age, .62 times for one unit increase in parental smoking, and .08 times for one unit increase in friends' influence. These results indicate that affiliation exposure creates about half as much increased risk in smoking as age, yet also constitutes one of the few modifiable risk factors in the model.

Similar analyses stratified by gender revealed that there was a significant effect of affiliation exposure among girls ($OR = 1.21$), but not among boys ($OR = 1.12$). This implies that girls were more likely to be influenced by their team mates' smoking behavior than boys. Other covariates indicating individual sports, intervention programs, and implementation methods were not significant (results not shown).

Random Effects

Our GEE results may be a product of both within-subject and between-subject relationships (Twisk, 2003). A REM in which the effects of covariates are conditioned upon adolescent-specific effects was estimated to minimize potential selection effects due to differences between adolescents in their pattern of activity participation (Darling, 2005). REM provided results consistent with the GEE ones ($ICC = .69$), but produced stronger effects for affiliation exposure than the GEE ones. Such difference in magnitude could be due to the heterogeneity in the propensity to smoke (Zeger & Liang, 1992). It also must be noted that although estimated odds ratio for affiliation exposure was larger for the REM, the standard errors of the estimates were almost twice as much as those of the GEE and had wider confidence intervals. Additionally, we ran a three-level random effect model by treating the 16 schools at the highest level, and found that the estimated standard deviation for the school level random effect was nearly zero, and the results of a fixed effect model showed that the school effect was not significant (global Wald $\chi^2 = 11.80$; $p = .69$), which indicates that a three-level model is not appropriate in this study.

Validity of the Measures

We conducted additional analyses to check if the estimate for affiliation exposure is a valid estimate of team smoking. First, we assessed validity by changing the affiliation network boundaries and computing separate affiliation exposures based on classroom versus school boundary (the boundary used for the analysis). The results showed that odds ratio for the class-based affiliation exposure was 1.11 ($SE = .04$; $p < .01$) for GEE and 1.21 ($SE = .08$; $p < .01$) for REM, which were smaller in magnitude compared to the school-based affiliation exposure ($OR = 1.16$; $SE = .06$, $p < .01$ for GEE, and $OR = 1.31$; $SE = .11$; $p < .01$ for REM). These results indicate that the school-based affiliation exposure is more strongly associated with smoking than the classroom-based affiliation exposure, which implies that the measure captures a non-individual risk factor (which is the participation of individuals in sports) that exposes them to different risk behaviors, and so helps provide support for the validation of the measure.

The second approach to assess validity was to compare the magnitude of affiliation exposure estimates based on team sports (where solidarity among teammates are more likely to occur) are higher than those based on individual sports (where individuals are competitors), and we have shown this was the case. The third validity assessment was conducted by re-computing gender-bounded affiliation exposures by limiting network boundary to within-gender to explore the previous finding of the modest increment in estimating smoking risk for girls.

More specifically, we computed affiliation exposure for girls by specifying only girls as rows in the affiliation matrix and excluding boys who co-participated in teams. We then conducted separate regression analysis by gender. The results showed that the odds ratios for girls-only affiliation exposure were significant for both GEE ($OR = 1.31$; $SE = .09$, $p < .001$) and REM ($OR = 1.63$; $SE = .21$; $p < .001$), whose magnitudes were higher (and more statistically significant) than our reported mixed-gender affiliation exposure ($OR = 1.21$; $SE = .09$; $p < .05$ for GEE and $OR = 1.40$; $SE = .18$; $p < .01$ for REM). On the contrary, for boys, the odds ratios for boys-only affiliation exposure were not significant for both GEE and REM as in the case of the non-significant effect of mixed-gender affiliation exposure on boys' smoking. These results indicate that being exposed to teammate smokers of the same gender was significant only for girls, and these effects were stronger for girls-only boundary specification, which was consistent with previous literature that stress the importance of group affiliation for girls' identities (which is closely linked to their smoking behavior) and so could support the validity of our measure.

Finally, to check the validity of the risk measurement, we specified a new dependent variable, susceptibility to smoking as measured by any equivocal response to the question "do you intend to smoke in the next 12 months." (Pierce, Choi, Gilpin, Farkas, & Merritt, 1996) (7 % of the sample indicated they intended to smoke). The GEE and REM models test the hypothesis that adolescents were more likely to be susceptible to smoke as they were increasingly exposed to teammates who smoke. The results showed that odd ratios was 1.14 ($SE = .08$) for GEE and 1.20 ($SE = .12$) for REM, both of which were significant at $\alpha = .05$ for one-sided test. Although the magnitude of influence and significance level was weaker than in the behavioral model, these results lend additional support for the validity of affiliation exposure.

Discussion

We have developed a new approach of measuring exposure using affiliation network analysis. To demonstrate its utility we examined the influence of joint participation in school-based organized sports activities with smokers on individual smoking among young adolescents. The results indicate that adolescents may be influenced to smoke by observing their sports teammates smoke and this tendency might be stronger among girls.

The results, however, are tempered by some limitations to the dataset available for this study. First, our statistical analysis did not address the possible overlap of the affiliation exposure measure with friendships. A Spearman's correlation to analyze the possible overlap between relational and affiliation exposures showed that the relational exposure was weakly but significantly correlated (perhaps due to large sample size) with affiliation exposure ($r_s = .12$ for the wave 1, $r_s = .22$ for the wave 2). Future studies could advance the network exposure research by combining both sociometric and affiliation information. Second, the study results may be biased by attrition. Attrition analysis showed that students lost to follow-up had a greater risk of smoking and other attributes that characterize smokers. If these students had been followed, the associations might potentially have been even stronger, but future studies are needed to determine whether this is the case. Third, the participants received a smoking prevention program and therefore being exposed to these programs could limit the generalizability of our findings. Although our results indicated that affiliation-based peer influence appears to operate even after controlling for these program effects, it is also possible that the program interacted with our network measures. If this is the case, smoking prevention programs implemented in the context of school-organized sports teams could be effective. Finally, a potential limitation of the analyses is that it is difficult to determine the potential influences of other team members who were not captured by the survey. By extension, our analysis has a limitation in accurately knowing how many

students were on each team, and the application of the proposed measure has a limitation in accounting for such missing information. Future studies should attempt to assess the smoking behaviors of entire sports teams.

Despite these limitations, the empirical example demonstrates the usefulness of the affiliation exposure model to examine peer influence based on two-mode network data. Methodologically, the strength of the measure is its ability to separate the effect of the number of activities participated in (diagonal values in co-participation matrix C) from the degree of exposure to substance users in activities (off-diagonal values in co-participation matrix C multiplied by smoking behavior) in the framework of network exposure model, and then include both information in subsequent regression analysis. These two pieces of information may be correlated to some extent since as adolescents participate in more activities, they are more likely to be exposed to teammate substance users, but they measure different constructs.

We have shown the results of validity checks in the estimates in the context of peer influence through co-participating teams on individual smoking. In modeling peer influence using Social Network Analysis, the validity of measures and parameter estimates hinge upon the specification of a social influence weight matrix W (see formula 1), the elements of which represents the influence pattern present in the network. To date, various ways of operationalizing W matrix have been introduced for one-mode network data (Leenders, 2002; Valente 1995), and debates have centered around influence process based on “communication” (W matrix is specified as an adjacency matrix to represent direct influence from alters) versus that based on “comparison” (W matrix is specified as structural equivalence matrix that represents influence from alters who occupy similar positions as ego), which are usually highly correlated. In the case of two-mode network, the current paper has introduced a new specification of an affiliation-based social influence weight W matrix, which constitutes an alternative source of social influence.

Finally, we have applied the affiliation exposure model to the study of peer influence through organized sports activities, but the method could be expanded to include other types of joint participation in various activities with public health relevance, such as participation in intervention sessions (e.g., Alcoholic Anonymous), online membership (e.g., online weight loss groups), or community groups. With regards to the issue of child development, adolescents participate in activities based on various interests (religious groups, Girl and Boy Scouts, community service clubs (e.g., Key Club), career-oriented clubs (e.g., Future Business Leaders of America, Junior Achievement), cultural clubs (e.g., French club, Spanish club, Chinese club), arts clubs (band, choir, drama, art), leadership clubs (e.g., student council), or just about any interest. Thus, the utility of our method could be extrapolated to any group activity, regardless of their content.

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Appendix

The following codes represent Pseudo-code to compute affiliation exposure.

To generate the F-matrix:

FOR all pairs of EGOs (where $i \neq j$)

Count the number of events shared between the two EGOs

Place count in the corresponding cell of matrix ($=C_{ij}$)

ENDFOR

FOR all rows of matrix C

Compute sum of all cells in the row

Divide each cell by the sum

ENDFOR

To compute exposure using F-matrix:

Substitute the F-matrix for the W-matrix

Compute the exposure normally

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Table 1
Percentage or Mean Demographic, Psychological, and Network Characteristics of
Students who Completed All Three Survey Waves and One or More Social Network
Forms (N=1,260)

	Baseline	One-year follow-up	Two-year follow-up	Test of differences
Ever smoked	8.41%	14.60%	19.29%	p<.001
Mean Age	11	--	--	
Female	54.92%	--	--	--
Asian-American	19.37%	--	--	--
Latino/Hispanic	40.24%	--	--	--
White	9.05%	--	--	--
Multiethnic/other (incl. African American)	31.35%			
1 Parent foreign born	83.49%	--	--	--
1 Parent college graduate	41.67%	--	--	--
Mean academic performance	3.08	--	--	
Mean rooms in house	3.87	--	--	--
Parent(s) smoke	31.90%	--	--	--
Mean % of relational exposure	9.46%	16.15%	--	p<.001
Normalized mean popularity	14.93%	13.52%	--	p<.001
<i>Team sports</i>				
Mean number of sports	1.94	2.10	1.65	p<.001
Mean % of affiliation exposure	6.90%	13.68%	13.25%	p<.001
<i>Individual/competitive sports</i>				
Mean number of sports	.59	.76	.63	p<.001
Mean % of affiliation exposure	4.18%	8.48%	8.53%	p<.001

Note: academic performance was coded 0: mostly F's; 1: mostly D's; 2: mostly C's; 3: mostly B's; 4: mostly A's. Rooms in house were coded by seven ordered categorical from 1 rooms to 7+ at maximum.

Table 2
Odds Ratios of the GEE and Random Effects Models, Indicating the Effect of Affiliation Exposures based on Team Sports and Number of Team Sports Joined, Controlling for Friends' Smoking, Demographic, and Network Characteristics on Repeated Responses regarding Smoking Status

Explanatory variables	Both genders N=3780 (1260*3)	Only girls N=2076 (692*3)	Only boys N=1704 (568*3)
Age (12+)	1.37* (.19; 1.05, 1.80)	1.72** (.34; 1.17, 2.52)	1.18 (.23; .80, .73)
Female	.76* (.11; .58, .99)	--	--
Asian-American	.46** (.12; .28, .76)	.60 (.22; .29, 1.22)	.40* (.14; .20, .82)
Latino/Hispanic	.93 (.14; .69, 1.25)	.69 (.15; .45, 1.04)	1.19 (.26; .78, 1.81)
White	.68 (.18; .40, 1.15)	.46 (.20; .20, 1.09)	.90 (.31; .45, 1.79)
1 Parent foreign-born	.93 (.17; .65, 1.33)	.60* (.15; .37, .99)	1.35 (.37, .79, 2.31)
1 Parent college graduate	.81 (.12; .60, 1.10)	.90 (.20; .58, 1.38)	.78 (.16, .52, 1.17)
Academic performance	.70*** (.06; .60, .82)	.70** (.09; .54, .91)	.68*** (.07; .55, .84)
Rooms in house	.96 (.04; .88, 1.04)	.87 (.06; .76, 1.00)	1.03 (.06; .91, 1.16)
Parent(s) smoke	1.87*** (.25; 1.43, 2.43)	2.19*** (.42; 1.51, 3.19)	1.60* (.31; 1.10, 2.33)
Popularity	1.00 (.01; .98, 1.01)	1.00 (.01; .98, 1.02)	1.00 (.01; .98, 1.02)
Relational exposure	GEE 1.09** (.03; 1.03, 1.15)	1.12** (.04; 1.04, 1.21)	1.06 (.04; .99, 1.14)
	REM 1.17** (.06; 1.06, 1.28)	1.23** (.08; 1.07, 1.40)	1.11 (.07; .98, 1.27)
Number of sports	GEE .76* (.09; .60, .96)	.64** (.11; .45, .89)	.89 (.16; .63, 1.26)
	REM .62* (.13; .41, .94)	.47** (.13; .27, .82)	.83 (.27; .44, 1.55)
Affiliation exposure	GEE 1.16** (.06; 1.05, 1.27)	1.21* (.09; 1.04, 1.39)	1.12 (.08; .97, 1.28)
	REM 1.31** (.11; 1.10, 1.55)	1.40** (.18; 1.09, 1.80)	1.22 (.15; .95, 1.56)

Note: () indicates standard errors, lower and upper 95% confidence intervals of odds ratio; Odds ratios of control variables are based on GEE; Above results also control for the effects of a specific sport, intervention, and implementation methods. Academic grade was coded as 0, mostly F's; 1, mostly D's; 2, mostly C's; 3, mostly B's; and 4, mostly A's.

*
p<.05

**
p<.01

p<.001 for two-sided test