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Social network influences on adolescent substance use: Disentangling structural equivalence from cohesion

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ABSTRACT

This study investigates two contagion mechanisms of peer influence based on direct communication (cohesion) versus comparison through peers who occupy similar network positions (structural equivalence) in the context of adolescents' drinking alcohol and smoking. To date, the two contagion mechanisms have been considered observationally inseparable, but this study attempts to disentangle structural equivalence from cohesion as a contagion mechanism by examining the extent to which the transmission of drinking and smoking behaviors attenuates as a function of social distance (i.e., from immediate friends to indirectly connected peers). Using the U.S. Add Health data consisting of a nationally representative sample of American adolescents (Grades 7–12), this study measured peer risk-taking up to four steps away from the adolescent (friends of friends of friends of friends) using a network exposure model. Peer influence was tested using a logistic regression model of alcohol drinking and cigarette smoking. Results indicate that influence based on structural equivalence tended to be stronger than influence based on cohesion in general, and that the magnitude of the effect decreased up to three steps away from the adolescent (friends of friends of friends). Further analysis indicated that structural equivalence acted as a mechanism of contagion for drinking and cohesion acted as one for smoking. These results indicate that the two transmission mechanisms with differing network proximities can differentially affect drinking and smoking behaviors in American adolescents.

Introduction

A considerable amount of previous research has focused on the role that peers play in adolescent problem behavior; peer influence has been identified as a leading correlate of adolescent substance use behavior (Valente, Gallaher, & Mouttapa, 2004). Peer influence occurs when people change their behavior to be compatible with their friends. Many network studies of peer influence have examined friends' influence on adolescent problem behavior by showing a significant positive correlation between exposure to close friends' use of substances and the likelihood of individual substance use (Cleveland & Wiebe, 2003; Crosnoe, Muller, & Frank, 2004; Ennett et al., 2006; Fujimoto & Valente, in press; Urberg, Degirmencioglu, & Pilgrim, 1997), indicating that direct friendship relations matter in influencing individual behavior.

Peer influences are complex because they occur in a potentially wide variety of friendship and social network contexts, in which certain peers may be more influential than others. Previous network diffusion studies have also stressed the importance of positional influence and have identified various network positions such as occupying a central position (being popular), a marginal position (isolated or having few friends), or a bridging position (a liaison who bridges peer groups), as being risk factors for adolescent substance use (Alexander, Piazza, Mekos, & Valente, 2001; Ennett & Bauman, 1993; Ennett et al., 2006; Kobus & Henry, 2011; Pearson et al., 2006; Valente, Unger, & Johnson, 2005).

According to Burt (Burt, 1987, 2010; Burt & Uchiyama, 1989), structural equivalence (i.e., the similarity in two persons' network relations or being connected to the same people) can also be a source of peer influence. Structural equivalence influence is based in part on the competition that exists between people when they evaluate new and novel situations, "the more similar ego's and alter's relations with other persons – the more that alter could substitute for ego in ego's role relations, and so the more intense ego's feeling of competition with the alter, the more likely that ego will quickly adopt any innovation" (Burt & Uchiyama, 1989, p. 71).

The current study examines the contagion mechanisms of peer influence based on direct communication through cohesion and

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comparison through structurally equivalent peers. This study operationalizes peer influences on adolescent substance use derived from communication based on connection in friendship ties and comparison based on the extent that adolescents occupy equivalent positions in the social network. Debate over cohesion versus structural equivalence as competing contagion mechanisms has been a vital issue in social network research for a long time. Most existing studies, however, have been conducted in the field of inter-organizational research, and few studies have been conducted in the context of peer influence on adolescent problem behavior. One notable exception is a study that supported strong evidence of influence by cohesion but not structural equivalence on sexual activity and deviant school behavior among Flemish high school adolescents (Berten & Rossem, 2011).

The current study examines the two contagion mechanisms of cohesion and structural equivalence by taking an expanded egocentric network approach to measuring peer influence in terms of network proximity (i.e., from immediate friends to indirectly connected friends). This study uses the Add Health data, a nationally representative sample of U.S. middle and high school students. This study uses a network exposure model calculated on direct and indirect connections and then statistically tests peer influence using a logistic regression model of past-year drinking and current smoking.

Theories of peer influence and substance use

The two most well-known theories of peer influence on adolescent deviant behavior such as substance use are differential association theory (Sutherland, 1947; Sutherland & Cressey, 1978) and social learning theory (Bandura, 1977; Burgess & Akers, 1966). Differential association theory takes an interactionist approach by stressing the process of how individuals learn to behave deviantly, and posits that adolescents learn the norms, attitudes, techniques, rationalizations, and motives for delinquent behavior through interaction with intimate personal friends. Social learning theory emphasizes a social mechanism in the process of learning deviancy, and posits that adolescents learn deviant behavior by observing, modeling or imitating the behaviors of intimate others and its subsequent social reinforcement.

These theories identify a primary mechanism for transmitting deviant behavior among adolescents through personal peer networks based on friendship. They assume that intimate peer associations are keys to influencing individuals' deviant behavior, and a majority of prior studies in differential association or social learning tradition (Akers, Krohn, Lanza-Kaduce, & Radosevich, 1979; Akers & Lee, 1996; Haynie, 2001, 2002; Urberg, 1992) operationalize peer delinquency based on immediate friendship such as one's best friend or his/her few closest friends (Payne & Cornwell, 2007). These studies locate peer influence in the realm of direct face-to-face communication though cohesive friendship relations. Similarly, research in other traditions such as the diffusion of innovations also posits that individuals learn new behaviors by modeling the behavior of their peers, colleagues, and friends; or by direct communication, learning, and influence (Rogers, 2003; Valente, 1995). In the diffusion field, there has been a subset of research that specifically models how social networks structure the spread of ideas, innovations, and behaviors such as smoking and drinking (Valente, 2010).

Influence mechanisms in network diffusion

Network diffusion studies have been conducted to account for structural components of social influence by linking the pattern of social relations to similarities in attitude and behavior of actors in a network. Empirically, social influence has been operationalized using the two network concepts of cohesion and structural equivalence as mechanisms of social contagion (Burt, 1987; Marsden & Friedkin, 1993; Valente, 1995).

Cohesion as a contagion mechanism

Cohesion refers to actors being directly connected in a network. Cohesion implies that individuals have ties to others that provide social influence based on the solidarity derived from communication within a primary group (Marsden & Friedkin, 1993). In the context of adolescent substance use, cohesion implies that adolescents acquire information about their friends' attitudes or behaviors through direct communication, which then becomes a frame of reference leading to behavioral similarity. Previous studies have shown that adolescents are motivated to initiate substance abuse for desirable social consequences (such as peer acceptance and support) and peer influence is an important factor that explains adolescent substance use (Jenkins, 2001; Simons-Morton, Haynie, Crump, Eitel, & Saylor, 2001; Sussman et al., 1995; Valente et al., 2004).

Socialization alone, however, poorly predicts contagion in the absence of direct communication and does not explain the process of contagion when people do not talk to one another or even do not know one another (Burt, 2010). In such cases, comparison mechanisms might better explain contagion process. Classical theories of social psychology such as social comparison or reference group theory (Festinger, 1954; Kelley, 1966; Merton & Rossi, 1968; Newcomb, 1961; Sherif, 1968) posit that individuals evaluate themselves through comparison to others, which provides a benchmark for forming attitudes and behavior. Peer influence therefore, can occur when individuals are jointly located in structurally equivalent regions of the network, regardless of their direct connectivity.

Structural equivalence as a contagion mechanism

Structural equivalence (Burt, 1976; Lorrian & White, 1971; Sailer, 1978) is defined by the degree of similarity of actor network profiles in which two individuals are considered proximate to the extent that they have the same pattern of interpersonal relations with others (i.e., the same set of alters in the network). The mechanism of contagion through structural equivalence is driven by social comparison such as imitation and role playing (Leenders, 2002) or competition between ego and alter. Structurally equivalent actors are joint occupants of a network position and so are substitutable. This structural equivalence results in actors using one another to evaluate their beliefs, attitudes, and behaviors which can trigger egos' behaviors (Burt & Uchiyama, 1989).

In the context of adolescent substance use, structural equivalence as a mechanism of contagion reflects the idea that individuals who occupy the same position monitor one another's behavior and eventually adopt risk-taking health behaviors at about the same time (Valente, 1995). Here, peer pressure does not necessarily involve discussion or direct communication, but instead the comparison to people equivalently positioned in a network provides a benchmark for the ego's forming opinions and the displaying of similar behavior (Burt, 2010). For example, the knowledge of smoking behavior in a structurally equivalent alter may cause an adolescent to feel pressure to smoke, either by hearing about the behavior indirectly through mutual acquaintances, or through direct observation of public behaviors. Adolescents can also learn of structurally equivalent alters' behavior via direct interaction, but this overlaps with cohesion.

Disentangling structural equivalence from cohesion

Structural equivalence is conceptually independent from cohesion as a mechanism that drives contagion. One of the first studies to empirically demonstrate cohesion was the classic study of the diffusion of medical innovation by Coleman and colleagues, who showed that contagion by cohesion (communication mechanism) drove the adoption of tetracycline among physicians (Coleman, Katz, & Menzel, 1957, 1966). Burt re-analyzed the medical innovation data and showed that contagion via structural equivalence drove adoption (Burt, 1987; Burt & Uchiyama, 1989). Van den Bulte and Lilien showed that marketing effort drove adoption of tetracycline, not network influence (Van den Bulte & Lilien, 2001). By measuring cohesion as one- (direct) and two-step ties, however, Friedkin (1984) showed that structurally equivalent actors differed slightly from nonequivalent ones in their behavioral similarity.

Network analysts have stressed the challenge of separating both influence processes because of the confounded nature of cohesion and structural equivalence (Borgatti & Everett, 1992; Burt, 1987; Burt & Uchiyama, 1989; Friedkin, 1984; Leenders, 2002; Marsden & Friedkin, 1993; Mizruchi, 1990, 1993). Burt has described situations where structural equivalence and contagion cannot be disentangled by describing the three cases where structural equivalence overlaps, restricts, and extends the concept of cohesion (Burt, 1987; Burt & Uchiyama, 1989).

In Fig. 1, situation (A) illustrates the case where structural equivalence and cohesion are identical because ego and alter are directly connected to each other (cohesion) and have identical connections to others (structural equivalence). Situation (B) illustrates the case where cohesion drives contagion while structural equivalence does not because ego and alter have different connections (ignoring their mutual connection). Situation (C) illustrates the case where structural equivalence drives contagion while cohesion does not because ego and alter are not directly connected to each other but they have identical connections to others. Applying these three situations to the present study, situations B and C are distinguished as the main mechanism of contagion. In situation A, however, structural equivalence overlaps with cohesion, and this study provides a technique to disentangle them by calculating network exposures from indirect ties as well as direct ones (i.e., friends and friends of friends, and friends of friends of friends).

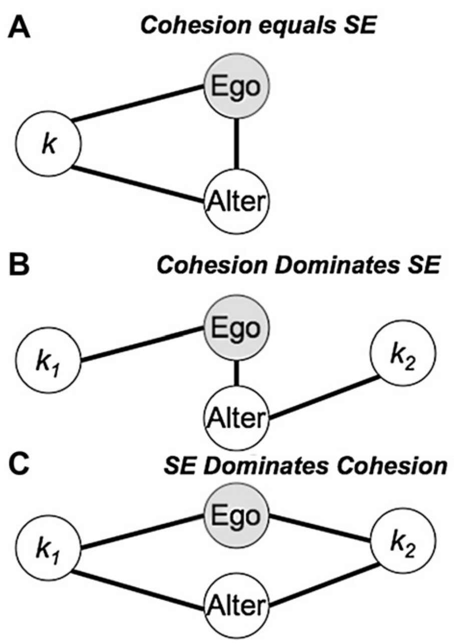

Fig. 1. Three kinds of social structural situations in which structural equivalence and/or cohesion predict contagion between ego and alter. Source: Drawn from Fig. 1 on page 1292 (Burt, 1987).

This study examines peer influence on two adolescent risk behaviors, alcohol use and cigarette smoking. Many studies have reported a strong, positive correlation between alcohol use and smoking, both of which are known to share a number of sociocultural risk factors (including family and peer influences, demographics, economics, and availability) (Bobo & Husten, 2000). The current study tests whether the process of peer influence (contagion) is different for the two behaviors and so addresses them separately.

This study has three main aims: First, to examine peer influence based on the two contagion mechanisms of cohesion and structural equivalence. Second, to disentangle structural equivalence from cohesion as a contagion mechanism by examining the extent to which behavior transmission attenuates as a function of social distance (i.e., from immediate friends to indirectly connected peers). Third, to examine whether cohesion and structural equivalence differ in terms of their influences on drinking and smoking.

Data and methods

Data

The U.S. National Longitudinal Study of Adolescent Health (Add Health) study consists of a nationally representative sample of adolescents who were in Grades 7–12 in randomly selected schools in the United States during 1994–1995 (Harris, 2009). Add Health uses the Quality Education Database, an exhaustive list of American high schools, as the primary sampling frame, and systematic sampling methods and implicit stratification to ensure that the 80 high schools selected are representative of US schools with respect to region of country, level of urbanization (defined by U.S. Census Bureau), size, school type (e.g., public, private, and parochial), and racial composition (Bearman, Jones, & Udry, 1997). All students from 7th through 12th graders who attended on the day of interview ($N = 90{,}118$) completed the 45-min paper and pencil In-School questionnaire from September 1994 through April of 1995. The In-School questionnaire asks students about general information such as basic demographic characteristics, friends, school life, and health related risk behavior including smoking and alcohol use. As a second component of Add Heath data, adolescents in grades 7–12 ($N = 20{,}745$ in 132 schools) were sampled from the pool of participants in the In-School Survey to participate in the In-Home Interview from April through December of 1995. At the In-Home Interview, students were asked more extensive questions on sensitive topics such as substance use and sexual behavior using an Audio Computer-Assisted Self Interview (ACASI) to insure confidentiality.

The current study used both the In-School Survey and the Wave I In-Home Interview Data. The In-School Survey asked students to nominate their 5 best male and 5 best female friends from a school roster (up to 10 friends total) and these friendship nominations were recorded by student identification number (aid) in the school rosters, allowing the creation of social network data. We used this complete In-School network information to compute network characteristics and network exposure measures (discussed below). The In-School Survey data were also used to measure student's demographic information such as age, sex, ethnicity, academic grade, and parental education as well as to compute school prevalence of drinking and smoking. We used the Wave I In-Home

Interview data for the dependent variables of drinking alcohol and smoking cigarette, which were collected after the In-School Survey data collection. Additionally, Wave I In-Home Interview data were used to extract other psychosocial information (emotional states, public assistance, access to alcohol or tobacco) not available in the In-School Survey data.

After merging separate data files (In-School survey, network nomination, and In-Home Interview) via valid identification number (aid), the sample consisted of 15,355 students. To compute the network measures, analyses were restricted to the 112 schools (14,011 students) with greater than a 70 percent response rate based on other literature (Kossinets, 2006). Due to the complex sampling frame of Add Health, analyses were restricted to the 106 schools with an individual-level sampling weight (Chantala, 2006; Chantala & Tabor, 1999), leaving a final analytic sample of 13,187 students. The final sample did not differ statistically from the more complete sample of the merged In-School survey with In-Home Interview data ($N = 15{,}355$) on past-year drinking or current smoking.

Measures

Outcome variables

The study outcomes were (1) "past-year drinking" and (2) "current smoking." Adolescents reported how many days on which they (1) drank beer, wine, or liquor during the past twelve months and (2) smoked a cigarette for the past 30 days. Based on examining the distributions, we dichotomized each variable as "drank alcohol past-year or not" and "smoked cigarette past month or not."

Measures of network influence

Network measures were: (a) "cohesion exposure" through direct contacts (E_C) and (b) "structural equivalence exposure" through peers who occupy structurally equivalent position (E_S). We computed these measures using the network exposure model (Burt, 1987; Marsden & Friedkin, 1993; Valente, 1995, 2005), which is designed to measure the extent to which an ego is exposed to alters with specific behavioral attributes (Supplementary material). Exposure is calculated by multiplying the social network influence weight matrix (which can be direct ties or other measures) by a vector indicating whether each student engages in that behavior. Cohesion and structural equivalence exposure were calculated for both alcohol and cigarette use for direct ties and then for increasing distances up to path length four. To measure alters' drinking level, the ordinal scale of the past-year drinking and smoking (from In-School survey data) was used in order to capture alters' drinking or smoking levels rather than just ever drank or smoked. Each drinking and smoking scale was collapsed into an ordinal scale ranging from 0 to 6: 0 = never, 1 = 1–2 days in the past 12 months, 2 = once a month or less (3–12 times in the past 12 months), 3 = 2–3 days a month, 4 = 1–2 days a week, 5 = 3–5 days a week, and 6 = everyday.

Cohesion exposure (E_C)

The "cohesion exposure" (E_C) was computed by using an adjacency matrix, X_{ij}, as a specification of social network influence weight matrix, with $X_{ij} = 1$ if an actor i nominates an actor j as a friend, and $X_{ij} = 0$ otherwise. It measures the degree to which adolescents are exposed to their friends who drink alcohol by computing the average drinking level among all nominated friends for each student. The cohesion exposure measure used in this study is analogous to the friends' influence measures commonly used in past network influence studies (Alexander et al., 2001; Ali & Dwyer, 2009; Crosnoe, 2006; Haynie, 2001).

Structural equivalence exposure (E_S)

Computation of the "structural equivalence exposure" (E_S) requires the specification of a structural equivalence matrix that represents the profile similarity measure between all pairs of actors based on an adjacency matrix of X_{ij}. To prevent overlap between structural equivalence and cohesion, the modified structural equivalence measure was used which calculates structural equivalence only for non-adjacent actors (Leenders, 2002). In this measure, non-adjacent actors who are exactly equivalent have proximity 1, other non-adjacent pairs of actors have equivalence proximity ranging from 0 to 1, and adjacent actors always have proximity 0 (Supplementary material). Based on this modification, the structural equivalence exposure of E_S measures the degree to which adolescents are exposed to the behavior by their non-adjacent structurally equivalent peers net of their direct friends.

Network proximity measured as social distance

Prior research indicates that adolescents are embedded in multiple social contexts in peer networks (Ennett et al., 2008; Hussong, 2002), and hence peer influence can range from the more immediate peer structure of close friends to more distant peer structures that involve less one-on-one interaction. For instance, Payne and Cornwell (2007) parsed the peer context that exists beyond friends in terms of various social distances from the adolescent by measuring peer risk-taking at two or three steps removed from the adolescent. They reported not only a profound influence of close friends, but also indirect peer relations (friends of friends) that exercise independent influences on adolescent delinquency. In order to examine the influence of peers at various social distances from the adolescent, this study computed the shortest paths between all students, which is called the geodesic distance in social network analysis (Wasserman & Faust, 1994). The level of drinking and smoking for friends up to four geodesic steps away from an adolescent was calculated. Steps are inclusive, so the average level of drinking (or smoking) for ego at three steps included: friends, friends of friends, and friend of friend of friends (Supplementary material).

Using the most distal peer influence estimates (i.e., distance ≤ 4) as the network baseline, estimates at fewer steps were compared. If cohesion influence was strong for two or three steps from the adolescents, this provides support for situation B (cohesion is the active mechanism). If cohesion influence was weak or non-existent, this provides support for situation C (structural equivalence is the active mechanism). If both local cohesion and local structural equivalence were weak, there was no influence; whereas if both were strong, then it supports an interpretation of cohesion influence.

Other variables

Existing studies have shown that an adolescent's risk-taking behavior was associated with occupying a specific network position. This study also considered positional measures as it has been pointed out that the homogeneity of positional equivalent actors may be attributed in part to particular type of structural attribute such as occupying central positions in which they are embedded (Marsden & Friedkin, 1993), and hence it was desirable to conduct analyses that simultaneously measure cohesion, equivalence, and network characteristics such as centrality and marginality (Friedkin, 1984). Specifically, we controlled for indegree as a measure of centrality by counting the frequency of being nominated as a friend. The log of the indegree was taken to approximate a normal distribution. To measure structural marginality, our study used a dummy variable of being an isolate (someone who neither sent nor received any friendship ties within school).

Socio-demographic control variables were age (in years), sex (1 = female; 0 = male), ethnicity (dummy variables for African

American, Asian, White, and Others with Hispanic as reference category), academic grade (average GPA), parental education (maximum level in the household where 1 = less than high school; 2 = high school graduate, 3 = some college, 4 = college graduates, and 5 = graduate education), public assistance (1 = resident mother or father receive public assistance; 0 = not receive), emotional state (modified version of CES-D designed to measure depressive symptomatology), access to alcohol or cigarettes (1 = easily accessible; 0 = not easily accessible), and school-level variables of the prevalence of drinking or smoking (percentages of past-year drinkers or smokers). We have written a program to compute network exposures of cohesion and equivalence using MATA language in the STATA statistical software.

Statistical analysis

Logistic regression analysis was conducted to model the association between network exposures and drinking and smoking. To accommodate the complexity of the Add Health data, we conducted design-based statistical analysis (Chantala, 2006; Chantala & Tabor, 1999) so that the estimates of population parameters and standard errors are unbiased. To correct for design effects and unequal probability of selection, the analysis adjusted for region of country (Northeast, Midwest, South, and West) as a stratification variable, the school identifier as primary sampling unit (or cluster variable), and individual-level sampling weights during estimation. Additionally, this study imputed any missing values for at least one of the covariates (required for approximately 17 percent of our sample) by using switching regression, an iterative multivariable regression technique of multiple imputations by chained equations (Royston, 2004) implemented in Stata 11.

Results

Table 1 shows descriptive statistics for the variables used in the analyses, and Table 2 shows the mean school-level Spearman's rank correlations among cohesion and structural equivalence exposures with different distances. The lower triangle reports the correlations for drinking and the upper triangle reports correlations for smoking.

The results can be characterized by the following three tendencies. First, for both cohesion and structural equivalence exposures, correlations between an adjacent degree within the same exposure (for example, the correlation between E_C of distance one and E_C of distance two) tended to be moderately-to-highly related (see directly below or above the diagonal). These correlations were $R_{21} = 0.60$, $R_{32} = 0.52$, $R_{43} = 0.71$, $R_{65} = 0.64$, $R_{76} = 0.58$, $R_{87} = 0.68$ for drinking, and $R_{12} = 0.56$, $R_{23} = 0.46$, $R_{34} = 0.71$, $R_{56} = 0.61$, $R_{67} = 0.52$, $R_{78} = 0.66$ for smoking. Second, between cohesion and structural equivalence exposures, correlations within the same distance (for example, correlations between E_C of distance one and E_S of distance one) tended to be moderately-to-highly related except in the case of distance four. These correlations were $R_{51} = 0.73$, $R_{62} = 0.73$, $R_{73} = 0.43$ for drinking, and $R_{15} = 0.78$, $R_{26} = 0.77$, $R_{37} = 0.50$ for smoking. Lastly, the exposure correlations for smoking tended to be higher than those for drinking.

Next, we fitted logistic regression models to estimate odds ratios for both drinking and smoking independently, and cohesion and structural equivalence exposures in their own separate models. For the model with cohesion exposure, we fitted varying distance cohesion measures (up to four steps) in separate models since the longer distances include the shorter ones. Similarly, for the structural equivalence models, we fitted varying distance structural equivalence measures in separate models. Thus in total 16 models were fitted: four cohesion models for drinking, four cohesion models for smoking, four structural equivalence models for drinking, and four structural equivalence models for smoking. All sixteen models included the control variables. Table 3 reports the odds ratios for the 16 models with the odds ratios for the control variables being the ones from the model with cohesion exposure at distance one.

The odds ratios for cohesion exposure to drinking were significant for all distances, with the highest in magnitude at distance one (OR = 1.57; $p < 0.001$), followed by distance two (OR = 1.44; $p < 0.001$), distance three (OR = 1.17; $p < 0.01$) and distance four (OR = 1.16; $p < 0.01$). The magnitude of the effect size tended to decrease with each step up to distances of three, which indicates that adolescents tended to be influenced by their direct friends or indirect friends, such as the friends-of-a-friend (≤2 distances), but

Table 1
Descriptive statistics (percentage or mean with SD, min, max) for outcome, demographic, and network measures (N = 13,187).

	Percentage or mean (SD; min, max)	
Past drinking (last 12 months)	46%	
Current smoking (last 30 days)	24%	
Age	15.04 (1.70; 10, 19)	
Female	52%	
Ethnicity		
Hispanic	19%	
African American	19%	
Asian	7%	
White	51%	
Others	4%	
Grades (GPA)	2.55 (0.91; 0.25, 4.00)	
Parental education	3.05 (1.21; 1, 5)	
Public assistance	9%	
Emotional state (CES-D)	11.09 (7.50; 0, 56)	
Popularity (indegree)	4.48 (3.79; 0, 34)	
Isolates	4%	
	Drinking	Smoking
Easy access to alcohol or cigarettes	30%	30%
Prevalence of drinkers or smokers	51%	33%
Cohesion exposure (E_C)		
1 Distance	1.02 (1.03; 0, 6)	0.95 (1.33; 0, 6)
≤2 Distances	1.08 (0.71; 0, 6)	0.97 (0.79; 0, 6)
≤3 Distances	1.01 (0.63; 0, 6)	0.97 (0.72; 0, 6)
≤4 Distances	0.99 (0.63; 0, 6)	0.96 (0.71; 0, 6)
Structural equiv. exposure (E_S)		
1 Distance	1.21 (1.10; 0, 6)	1.14 (1.47; 0, 6)
≤2 Distances	1.27 (0.85; 0, 6)	1.16 (1.06; 0, 6)
≤3 Distances	1.20 (0.80; 0, 6)	1.15 (1.01; 0, 6)
≤4 Distances	1.19 (0.80; 0, 6)	1.14 (1.01; 0, 6)

Table 2
Mean school-level Spearman's rank correlations among exposure measures for past drinking (lower triangle) and smoking (upper triangle) (schools = 106).

Exposure measures	1	2	3	4	5	6	7	8
1. E_C Distance 1	1.00	0.56	0.26	0.18	0.78	0.42	0.23	0.33
2. E_C Distances ≤ 2	0.60	1.00	0.46	0.37	0.37	0.77	0.27	0.30
3. E_C Distances ≤ 3	0.33	0.52	1.00	0.71	0.02	0.20	0.50	0.05
4. E_C Distances ≤ 4	0.22	0.37	0.71	1.00	−0.13	0.09	0.15	−0.07
5. E_S Distance 1	0.73	0.36	0.02	−0.17	1.00	0.61	0.45	0.63
6. E_S Distances ≤ 2	0.42	0.73	0.22	0.05	0.64	1.00	0.52	0.57
7. E_S Distances ≤ 3	0.25	0.29	0.43	0.07	0.51	0.58	1.00	0.66
8. E_S Distances ≤ 4	0.32	0.25	−0.01	−0.17	0.67	0.57	0.68	1.00

Table 3
A summary of logistic regression analysis: odds ratios for 16 cohesion and structural equivalence exposures up to distance four ($N = 13{,}187$).

Covariates	Past drinking	Current smoking
Age	1.20*** (0.03)	1.09*** (0.02)
Female	0.92 (0.05)	0.91 (0.07)
Ethnicity		
African American	0.64*** (0.06)	0.57*** (0.09)
Asian	0.57*** (0.10)	0.72 (0.15)
White	1.10 (0.10)	1.60*** (0.20)
Other	1.07 (0.17)	1.15 (0.22)
Grade (GPA)	0.87*** (0.03)	0.73*** (0.03)
Parental education	1.02 (0.03)	1.03 (0.03)
Public assistance	0.81 (0.09)	1.11 (0.17)
Emotional state (CES-D)	1.04*** (0.00)	1.05*** (0.00)
Popularity (indegree)	1.15*** (0.03)	1.06* (0.03)
Isolates	1.60** (0.28)	1.27 (0.29)
Accessibility	1.99*** (0.15)	1.58*** (0.11)
Prevalence	5.73*** (1.74)	6.42*** (2.46)
Cohesion exposure (E_C)		
Distance 1	1.57*** (0.07)	1.50*** (0.05)
Distances ≤ 2	1.44*** (0.08)	1.40*** (0.08)
Distances ≤ 3	1.17** (0.06)	1.09 (0.06)
Distances ≤ 4	1.16** (0.06)	1.08 (0.06)
Structural equiv. exposure (E_S)		
Distance 1	2.36*** (0.12)	1.99*** (0.06)
Distances ≤ 2	2.30*** (0.19)	1.83*** (0.09)
Distances ≤ 3	1.90*** (0.14)	1.59*** (0.07)
Distances ≤ 4	1.88*** (0.14)	1.59*** (0.07)

Note: ( ) indicates standard deviation; for ethnicity, Hispanic/Latino was used for the reference category. The odds ratios for the control variables were based on using cohesion exposures at distance one. The table does not include cohesion and structural equivalence exposures in the same analysis/model.
$^{**}p < 0.01$; $^{***}p < 0.001$.

less influenced by including the friend-of-a-friend-of-a-friend ($\leq$3 distances) or including the friend-of-a-friend-of-a-friend-of-a-friend ($\leq$4 distances) for their drinking behavior.

The odds ratios for cohesion exposures to smoking were statistically significant up to distance two (but not significant for distances greater than two) with the highest in magnitudes at distance one (OR $=$ 1.50; $p < 0.001$), followed by distance two (OR $=$ 1.40; $p < 0.001$). These results indicate that adolescents tended to be influenced mainly by their direct friends or indirect, the friends-of-a-friend ($\leq$2 distances) for their smoking behavior. While cohesion influence on drinking could be extended up to four distances with decreasing levels of influence, cohesion influence on smoking only extended two steps (based on the criterion of statistical significance).

The odds ratios for structural equivalence exposure to drinking were statistically significant for all distances, with the highest in magnitude at distance one (OR $=$ 2.36; $p < 0.001$), followed by distance two (OR $=$ 2.30; $p < 0.001$), distance three (OR $=$ 1.90; $p < 0.001$) and distance four (OR $=$ 1.88; $p < 0.001$). These results indicate that the higher the degree of drinking exposure to non-adjacent structurally equivalent peers, the more likely an adolescent was to drink. Similar to the results of cohesion exposures for drinking, the magnitudes of the effect size decreased with each step up to three steps, which indicate that adolescents tended to be influenced by their non-adjacent structurally equivalent peers up to two steps away from him or her, but then less influenced by their structurally equivalent peers beyond that for their drinking behavior.

We obtained similar results for the odds ratios for the structural equivalence exposure to smoking as we did with the structural equivalence exposure to drinking: exposure effects were statistically significant for all distances with the highest in magnitude at distance one (OR $=$ 1.99; $p < 0.001$), followed by distance two (OR $=$ 1.83; $p < 0.001$), distance three (OR $=$ 1.59; $p < 0.001$) and distance four (OR $=$ 1.59; $p < 0.001$).

Comparing cohesion with structural equivalence for both drinking and smoking, the magnitude of the effect sizes tended to be larger for structural equivalence than cohesion at each distance (although standard errors were also larger for the former especially for drinking). These results indicate that the influence of structural equivalence exposure may have more explanatory power than cohesion exposure. These results appear to be counterintuitive considering that the structural equivalence exposure excludes any directly tied friends' influence. However, it is reasonable to assume that a friendship network is characterized by tightly knit clusters, groups, or components, and therefore many short paths may exist between non-adjacent adolescents who are more likely to occupy equivalent positions at distance of three or four paths (via common friends).

More importantly, the structural equivalence measure is sensitive to pairs of isolates (actors with no ties in the network). Pairs of isolates are trivially structurally equivalent (Borgatti & Everett, 1992), and how isolates are treated as structurally equivalent hinges upon whether or not we expect high levels of similarity between pairs of isolated actors (Mizruchi, 1993). In our data approximately four percent of students were isolates, and so some of the structural equivalence effect might be from pairs of isolates. It is also true that the structural equivalence effect captures the joint popularity of a pair of adolescents on the similarity of drinking or smoking behavior since the equivalence proximity measure contains information about incoming nominations (which reflects popularity and prestige in the network). With increasing distances a pair of popular adolescents indirectly nominated by other adolescents is likely to be structurally similar in their patterns of nominations. (And in these data popular students were more likely to drink and smoke.)

The next analysis attempted to disentangle structural equivalence from cohesion by systematically comparing the odds ratios of both exposures at various distances independently for drinking and smoking. Distances of four were used as the baseline threshold and these values (1.16 for cohesion drinking, 1.08 for cohesion smoking, 1.88 for SE drinking, 1.59 for SE smoking) are subtracted from the odds ratios at closer distances. Then, we compared the relative odds ratios for cohesion exposure and those for structural equivalence exposure for a given distance by subtracting the odds ratio for the structural equivalence exposure (adjusted structural equivalence at each distance) from the odds ratio for cohesion exposure (adjusted cohesion at distance four). Therefore, the zero value indicated equal strength between cohesion and structural equivalence, with negative values indicating that structural equivalence is stronger, and positive values indicating that cohesion is stronger (Supplementary material). Here, the relative magnitude of the odds ratios was the focus and so statistical significance levels are ignored. The results showed that relative odds ratios (difference in the odds ratios between cohesion and structural equivalence adjusted at distance four) were -0.07 at distance one, -0.14 at distance two, and -0.01 at distance three for drinking, and 0.02 at distance one, 0.08 at distance two, and 0.01 at distance three for smoking. These results indicate that for drinking, structural equivalence as a contagion mechanism was activated, whereas for smoking, cohesion as a contagion mechanism was activated, implying different contagion mechanisms for different behaviors.

Discussion

This study has examined the effects of cohesion and structural equivalence exposures on adolescent drinking and smoking. The results indicate that structural equivalence exposures had stronger associations than cohesion ones, consistent with other empirical studies (Mizruchi, 1993). The results also indicate that peer influence based on structural equivalence may better explain adolescents' drinking or smoking behavior than that based on cohesion in the context of adolescent friendships at school.[1] This study suggests that perhaps there are different contagion mechanisms driving social influence for drinking and smoking. The approach used to compare cohesion with structural equivalence may be used to investigate other "observationally inseparable" social influence mechanisms. A caveat to the interpretation of these findings is in order: drinking and smoking are similar in many ways: their rates increase with age during adolescence; in many schools both are considered normative behaviors (or deviant ones); and both are illicit for adolescents. Moreover, both behaviors are observable and may indicate membership in certain groups or subcultures. For example, it may be expected that adolescents who identify with being a punk rocker are expected to smoke and so adolescents who identify with this group are more likely to be friends and be smokers. These common factors may have attenuated the differences between these two mechanisms.

Conversely, alcohol and tobacco use are different in that tobacco use may be perceived as problematic for athletes due to comprised lung capacity yet alcohol use may not be perceived in the same way. Moreover, moderate or responsible drinking is encouraged in the broader society (though not for adolescents) whereas no such promotion exists for tobacco (except for tobacco company promotions). It is quite likely that adolescents have seen many alcohol advertisements yet somewhat fewer tobacco ones.

Another caveat to the interpretation of our results is that our analysis does not include both cohesion and structural equivalence exposures in a single model and this may have implications for the central aim of disentangling structural equivalence from cohesion. Additionally, the time frame for alcohol use is different from smoking (past-year versus past month), which may partially explain the different results for contagion mechanism for drinking and smoking.

The results are tempered by some limitations to data availability and some methodological issues. First, this study was limited by the Add Health data sample design in that students from a broad age range are included in the analyses. During adolescence, social networks evolve and change at the same time as the prevalence of smoking and drinking increases. Therefore, the amalgamation of all age groups might have masked age-dependent factors in the influence process. Future research would benefit by examining age-dependent variation in results (if there are any).

Second, this study used the network exposure model to measure peer influence based on cohesion and structural equivalence. This approach is not sensitive to larger sub-group contexts such as being a member of a school gang, or belonging to organized activities (Fujimoto, Unger, & Valente, 2012), or identifying with certain groups. Moreover, the model does not incorporate structural information about how the network alters are connected to one another, whether tightly entwined with one another or disconnected. The network exposure approach does not incorporate other structural dimensions of the overall network structure such as whether the individual is a member of a cohesive sub-group, or a bridging person, or someone on the periphery.

Third, this study was also limited because the data are cross-sectional and not longitudinal. The information of complete friendship nomination data were collected only for the In-School survey, but subsequent In-Home interview data were collected beginning several months after the start of in-school data collection. An analysis of longitudinal data might yield insights into the dynamics of how individuals move between groups or how their exposures change over time.

Fourth, these results are limited in their ability to understand the process of peer selection. It has generally been agreed that both processes of selection and influence are important in accounting for the similarity in substance use among adolescents (Engeles, Knibbe, Drop, & de Haan, 1997; Ennett & Bauman, 1994; Fisher & Bauman, 1988; Hall & Valente, 2007; Mercken, Candel, Willems, & de Vries, 2009; Urberg et al., 1997), and it would be important to take selection process into consideration in assessing peer influence for future study.

Lastly, this study employed a modified measure of structural equivalence with different distances. However, computing structural equivalence in this manner can change the results but not the essential nature of structural equivalence—that is, it still remains a local concept although the data are treated as "global," and so the modified measure necessarily confounds similarity with proximity (Borgatti & Everett, 1992). Given this limitation, more abstract conceptions of general equivalences such as structural isomorphism, positional or regular equivalence, and role equivalence may be better suited to measuring non-cohesive structural similarity (Borgatti & Everett, 1992).

Despite these limitations, this study demonstrates the utility of examining peer influence process based on communication and comparison, and opens the door to disentangling these two processes as contagion mechanisms in the diffusion of drinking and smoking among adolescents. Such studies would inform policy implications for school-based alcohol prevention programs that include the social influence model. The importance of structural equivalence influences indicates that peers may influence one another in complex ways that extend beyond simple communication of values, norms, and beliefs. The comparison of contagion mechanisms indicates a more cognitively complex contagion process, and this will likely require increasingly complex interventions be developed. Further, since different mechanisms drive different behaviors, interventions may need to be designed differently.

The debate between cohesion versus structural equivalence as contagion mechanisms is far from over. This study provides but one data point in a series of comparisons between competing theoretical models of what drives social influence: communication or comparison. Clearly both are at work in many settings and for many behaviors. We have proposed a way of comparing the two processes within the same study, and suggested that they may operate differently for different behaviors. This seems both intuitive and practical, yet extending this analytic approach longitudinally will likely be quite challenging. Nonetheless, how adolescents and other populations perceive and internalize the behaviors of others to make decisions that affect their health is a critical avenue for future research.

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[1] As Mizruchi (1993) has pointed out, however, the relative contributions of the two contagion models to predict similarity in behavior is a theoretical issue—that is, how two-step ties are defined as indicative of cohesion or structural equivalence. Additionally, as Burt and Uchiyama (1989) noted, network structure of the study population may determine the power of empirical research in testing two network concepts against one another (cohesion versus structural equivalence).

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Appendix A. Supplementary material

Supplementary material associated with this article can be found online at doi:10.1016/j.socscimed.2012.02.009.

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