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# The co-evolution of early adolescent friendship networks, school involvement, and delinquent behaviors*

RÉSUMÉ

Cette étude examine les processus de sélection et d'influence liés à l'engagement scolaire et au comportement délinquant dans les relations d'amitié chez les adolescents. Nous appliquons des modèles d'analyse de réseaux dynamiques (Snijders, Steglich et Schweinberger, 2007) examinant la coévolution des comportements et des réseaux à un échantillon longitudinal de jeunes suédois (n = 445) observé pendant cinq ans. Les résultats indiquent que les choix des jeunes sont caractérisés par un fort niveau de réciprocité, de transitivité, d'homophilie de genre et d'homophilie fondée sur des niveaux semblables d'engagement scolaire et de comportement déviant. Des effets d'influence indiquent que les jeunes adoptent les comportements déviants de leurs amis. Le niveau d'engagement scolaire permet de prédire des changements dans le comportement déviant et ce dernier permet en retour de prédire une évolution dans l'engagement scolaire.

Friendships play a crucial role in the socialization of children and adolescents (Rubin, Bukowski, and Parker, 2006). This is partly due to the increasing amount of time youth spend with friends (Brown, 1990), as well as the support, companionship, and a sense of belongingness youth experience in these social interactions (Hartup, 1993). While friends may reinforce youths' behaviors in ways that lead to positive adjustment, these relationships may also contribute to the development of antisocial and deviant behaviors. However, the relative strength of friends' positive and negative influences on youth adjustment is not well understood. This is in large part due to the statistical difficulties associated with separating social influence processes from processes of partner selection (Cairns and Cairns, 1994). The present study overcomes statistical obstacles by utilizing new developed analytic techniques to disentangle these processes in order to simultaneously examine the relative contributions of peer influences relating to delinquent behaviors and school

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involvement in early adolescent friendship networks of an entire cohort of Swedish youth.

Behavioral and attitudinal similarities between youth and their friends, also referred to as homophily, have been well documented. Most empirical studies have focused on homophily related to antisocial behaviors and deviancy, including aggression (Cairns, Cairns, Neckerman, Gest, and Gariépy, 1988), delinquency (Burk, Steglich, and Snijders, 2007; Haynie, 2001; Kiesner, Cadinu, Poulin, and Bucci, 2002; Snijders and Baerveldt, 2003; Vitaro, Tremblay, Kerr, Pagani, and Bukowski, 1997), and substance use (Ennett and Bauman, 1994; Jaccard, Blanton, and Dodge, 2005; Kirke, 2004; Popp, Laursen, Kerr, Stattin, and Burk, 2008; Urberg, Degirmencioglu, and Pilgrim, 1997). Yet, homophily relating to various prosocial behaviors, such as school involvement, academic achievement, and educational motivation has also been reported (Kindermann, 2007, 1993; Ryan, 2001). Two distinct processes may account for this similarity: partner selection and social influence. *Partner selection* refers to the initiation of a relationship based on pre-existing similarity (Lazarsfeld and Merton, 1954). That is, adolescents may establish (or discontinue) a friendship depending on the characteristics or behaviors of potential relationship partners. *Social influence* refers to ensuing similarity based on pre-existing relationship ties (Friedkin, 1998). For instance, adolescents may adopt or assimilate the behaviors of peers with whom they already have a relationship. Both of these processes are posited as contributing to behavioral and attitudinal homophily among friends.

Sociological theories differ as to the importance of these two processes when explaining homophily related to delinquent and antisocial behaviors. Social control (or social bonding) theory (Gottfredson and Hirschi, 1990; Hirschi, 1969) posits youth select friends based on similar levels of engagement in delinquent behaviors. According to this perspective, friendships between delinquents may be attributed to both youth having weak connections (or bonds) with existing social institutions, such as school or structured activities in and outside the school context (see Agnew, 1993, for review). In contrast, differential association theory (Sutherland and Cressey, 1974; see Warr, 2002, for review) suggests youth learn delinquent behaviors through continued social interaction with antisocial peer associates. According to this theoretical perspective, youth are socialized by the delinquent behaviors of peer affiliates. The relative contributions of the processes proposed by these distinct theoretical frameworks in explaining antisocial and delinquent behaviors has been examined in many previous empirical studies, but has rarely been tested simultaneously.

Disentangling the effects of partner selection and peer influence requires sophisticated analytic techniques. Longitudinal social network analyses offer a promising analytic framework for investigating the complexities associated with delineating changes in friendship ties and changes in individual behaviors, while accounting for interdependencies between these two types of changes. These methods assume dyadic relationships are embedded within a larger social structure, comprised of a multitude of interconnected dyadic

relationships (see Carrington, Scott, and Wasserman, 2005; Wasserman and Faust, 1994). Dynamic social network models are required for examining the specific processes whereby friendships contribute to individual development. Such methods have been developed to examine social network evolution (Snijders, 2001, 2005) as well as the co-evolution of networks and individual behaviors (Snijders, Steglich, and Schweinberger, 2007; Steglich, Snijders, and Pearson, 2008). We utilize the latter of the two approaches in the present study.

This modeling approach offers several advantages compared to alternative statistical techniques previously used to examine selection and influence processes in friendship networks. First, these models are capable of accounting for various structural network effects (*e.g.*, reciprocity, transitive closure, etc.) in overlapping dyadic friendships and peer groups. Researchers examining peer group influence typically classify students into orthogonal groups, calculate an aggregate based on scores from all peer group members, and test whether the aggregate score predicts changes on a target participant's behavior. By doing so, ties between peer groups are excluded and the specific influence of individual peer group members is diluted. For example, the unique influence of one particularly delinquent friend may be "averaged out" by several other non-delinquent peer group members. The models used in this study do not require categorizing participants into distinct, non-overlapping peer groups. Another advantage of these models is their ability to simultaneously model interdependencies involving changes in network ties and individual behaviors. This allows for the examination of selection and influence processes for all participants in the entire friendship network. Due to the complexities associated with separating these processes, previous research has been limited in the detection of selection or influence processes in specific subgroups, thus reducing the generalizability of their findings. Finally, these methods incorporate a continuous-time modeling approach that provides more precise estimates of selection and influence because it reduces the variation of changes in friendship ties and changes in individual behaviors between assessments. These methods have been successfully applied to friendship networks in order to separate selection and influence processes related to delinquency (Burk, Steglich, and Snijders, 2007; Snijders and Baerveldt, 2003) and substance use (Pearson, Steglich, and Snijders, 2006; Snijders, Steglich, and Schweinberger, 2007; Steglich, Snijders, and West, 2006). Interested readers are referred to the referenced manuscripts for detailed descriptions of the statistical techniques.

The present study also overcomes several limitations of previous research due to the unique design of the larger community-based research project from which the sample was drawn (see Kerr, Stattin, and Kiesner, 2007; Kiesner, Kerr, and Stattin, 2004). We examine dynamics in friendship networks delineated from (up to 23) nominations of in-school and outside school friendships across five annually collected waves of data. This is important because friendship nominations are typically restricted to three or five classmates or schoolmates. By limiting nomination data in this manner, researchers not only

severely hinder their ability to detect influences from possible peer group members, but they also create artificial borders that (potentially) exclude the most likely sources of negative peer influence; youth who spend time together in contexts outside of school (*e.g.*, Persson, Kerr, and Stattin, 2007). Additionally, the length of the study is unique because previous studies have tended to use short-term longitudinal data, typically consisting of two discrete time points. Successful unraveling of selection and influence processes requires meaningful, systematic changes in network ties and individual behaviors, respectively. By examining network and behavioral dynamics over five years (four periods of change), we are able to describe the dynamics of naturally-existing friendship networks during the crucial developmental period of early to mid-adolescence. Furthermore, the study followed an entire cohort of youth from a small community during this period. This design feature allows us to incorporate self-reported behavioral data of all participants, eliminating perceptual biases due to a target participant reporting on his or her friends' behaviors (*e.g.*, Aseltine, 1995). Taken together, the friendship networks included in this study provide more ecologically valid representations of naturally-existing friendships and peer groups during adolescence.

To summarize, the focus of the current study is to examine the relative importance of selection and influence processes relating to delinquency and school involvement in early adolescent friendship networks. Both processes have been empirically demonstrated to contribute to antisocial (Burk, Steglich, and Snijders, 2007; Kandel, 1978; Pearson, Steglich, and Snijders, 2006; Snijders and Baerveldt, 2003) and prosocial behaviors (Kindermann, 1993, 2007; Ryan, 2001). Adopting an actor-oriented social network perspective, we apply statistical techniques specifically designed to delineate these processes to longitudinal data of an entire cohort of youth to address three research questions. 1) How dynamic are early adolescent friendship networks? Considering the unique nature of the network sample, specific hypotheses are not posited, but we tentatively expect the networks to exhibit a moderate degree of stability due to pre-existing friendship ties, but also expect network growth and changes in friendship ties, particularly during the period of school transition, which corresponds to the period between Time 2 and Time 3 for the targeted cohort. 2) What are the most prominent features of network dynamics? Guided by previous research examining the nature of adolescent peer groups (*e.g.*, Brown, 1990; Dunphy, 1963) and empirical studies using similar techniques (Burk, Steglich, and Snijders, 2007; Pearson, Steglich, and Snijders, 2006; Snijders and Baerveldt, 2003), several effects were expected to emerge as significant predictors of friendship ties. Specifically, we anticipated tendencies for friendship nominations to be reciprocated, and for dyadic relationships to be embedded within cohesive peer group structures (*i.e.*, reciprocity and transitive network closure, respectively). We also expected a propensity of nominations to be among same age, same-sex schoolmates and classmates. 3) What are the relative contributions of friends' behaviors on early adolescents' school involvement and delinquency? Considering this is the first study to investigate the unique effects of selection and

influence processes relating to school involvement *and* delinquent behaviors, the relative importance of these processes for each behavior cannot be anticipated.

## Method

### *Participants*

The sample included 445 students (225 males and 220 females) attending 37 classrooms in 11 schools from a small city (population 26,000) in central Sweden. Students ranged in age from 9 to 14 years old ($M$ = 10.6 years) at the outset of the study. Participants were drawn from a large community-based longitudinal study examining adolescent psychosocial adjustment (see Kerr, Stattin, and Kiesner, 2007; Kiesner, Kerr, and Stattin, 2004). The unemployment rate and proportion of single-parent households in the community were similar to other communities in Sweden; mean incomes were about 4% lower than that in the rest of the country.

### *Instruments*

Questionnaires were administered by trained research assistants. Teachers were not present. Identical items were completed at each of the five annual waves of data collection.

*Friendship nominations.* Every year participants identified up to 3 important peers, defined as "someone you talk with, hang out with, and do things with"; as well as, up to 10 peers with whom they spent time with in school, and up to 10 peers with whom they spent time out of school. Participants were instructed that peers could be individuals that lived in different communities, be older or younger, boys or girls, but they could not be adults. While siblings and romantic partners could be nominated, only friendship nominations are included in the analyses. Thus, the friendship networks consisted of up to 23 nominations of friends each participant spent time with in school and in their free time.

Each of the five friendship networks are formally represented by directed adjacency matrices consisting of 445 x 445 dichotomous cells. That is, a friendship tie directed from actor $i$ (the nominator) to actor $j$ (the nominee) is either present ($x_{ij}$ = 1) or absent ($x_{ij}$ = 0). We also constructed two additional sets of matrices using the students' school and classroom information. These matrices were included because the friendship networks involved ties between students in different classrooms and schools. The dyadic covariate *schoolmates* is represented by four undirected adjacency matrices consisting of dichotomous cells (0 = two students in different schools; 1 = two students in

the same school). The dyadic covariate *classmates* is also represented by four undirected adjacency matrices (0 = two students in different classrooms; 1 = two students in the same classroom). These dyadic covariates were included to approximate a hierarchical "opportunity" structure based on school and classroom membership.

*Delinquent behaviors*. Every year participants completed seven items describing their engagement in delinquent activities. The time frame for all items was *during the last year*. These items were: "Have you taken things from a store, stand, or shop without paying?… taken money from home that was not yours?… participated in breaking into a home, shop, stand, storage building or other building with the intention of taking things?… taken a bicycle without permission?… taken part in a street fight in town?… taken part in threatening or forcing someone to do something that he or she didn't want to do?… taken part in stealing something from a car? Responses ranged from 1 (*no, it has never happened*) to 3 (*yes, several times*). Cronbach's alpha reliabilities ranged from .72 to .85. For the descriptive analyses, raw scores are reported; for the network-behavioral analyses, delinquency scores were classified into five categories (0 = 1.00, 1 = 1.01 to 1.50, 2 = 1.51 to 2.00, 3 = 2.01 to 2.50, and 4 = 2.51 to 3.00).

*School involvement.* Every year participants completed two items describing the degree to which they liked and were involved with school work. These items were: "How do you enjoy school? Do you do the best you can in school?" Items ranged from 1 (*very bad or almost never*) to 5 (*very good or most often*). Cronbach's alpha reliabilities ranged from .65 to .72. For the descriptive analyses, raw scores are reported; for the network-behavioral analyses, school involvement scores were similarly classified into ten categories.

### *Procedure*

All students in the 13 schools of this community enrolled in grades 4 to 12 were invited to participate in the study each year. Students were recruited in classrooms during school hours. Students were informed that participation was voluntary and confidential; they were assured that their answers would not be revealed to parents, teachers, the police, or anyone else. Parents were informed about the study in community meetings and through the mail, where they received a postage-paid card to return if they did not want their child to participate in the study. Parents and youth were informed that either was free to end participation in the study at any time. Youth were not paid for participation, but all students (participants and non-participants) were eligible for class parties and drawings provided by the project.

The target sample selected for this study consisted of all students in the 26 4$^{th}$ grade classrooms from the ten primary schools on the community ($n$ = 351). Of these, 251 adolescents (71.5%) participated in all five waves of

data collection, a precondition for inclusion in this investigation. All the friends nominated by this target group, who also participated in all five annual data collections, were also included in the study. So, the network sample ($n$ = 445) was identified using a modified "snowball" technique. This network mostly consisted of 9-11 year old students in the 4th grade ($n$ = 251; 124 males and 127 females) and 5th grade ($n$ = 138; 76 males and 62 females), but also included 12-14 year olds attending the 6th grade ($n$ = 47; 22 males and 25 females), 7th grade ($n$ = 6; 2 males and 4 females), and 8th grade ($n$ = 3; 1 male and 2 females). A logistic regression analysis contrasted the participants in the network sample from those who participated in at least one of the five waves of the overall study and were nominated by an individual in the target sample, but did not meet the selection criteria. This analysis failed to reveal statistically significant differences on any demographic characteristics or behavioral measures used in the study.

### *Plan of analysis*

The first set of analyses describes various structural characteristics of the friendship network and behavioral tendencies of the network actors. The second set of analyses involves specifying a model of network-behavioral dynamics implemented in the Simulation Investigation for Empirical Network Analyses (Siena) software program (Snijders, Steglich, Schweinberger, and Huisman, 2006). These models provide estimated parameters based on actors' decisions regarding changes in directed social network ties and changes in their own behaviors. These changes are represented in Siena by network and behavioral rate and objective functions. Network and behavioral rate functions represent the *number of changes* in network ties and individual behaviors, respectively; network and behavioral objective functions represent the *types of changes* in network ties and individual behaviors, respectively. Rate function parameters are typically constrained to be equal from one time point to the next (as in the present study), but may be allowed to depend on various individual attributes and behaviors. Network and behavioral objective function parameters, which are the focus of this study, represent the types of changes in the network and individual behaviors over time. These objective functions may be represented by various parameters. We briefly describe the model parameters used in the current study. More complete descriptions of the Siena program and estimable parameters are available elsewhere (Snijders, Steglich, Schweinberger, and Huisman, 2006; Steglich, Snijders, and Pearson, 2008).

The network objective function consists of parameters representing endogenous network effects, and various effects associated with dyadic and individual covariates. We include three endogenous network effects: density, reciprocity, and transitive triplets. *Density* describes the tendency of actors to have outgoing ties (*i.e.*, the degree of dyadic connection in a network). *Reciprocity* describes the tendency for actors to reciprocate a relationship (*i.e.*,

directed ties that are shared between dyadic partners). *Transitive triplets* (labeled transitivity hereafter) describes the tendency for actors to have triadic patterns of relations (*e.g.*, transitive network closure).

We also include two dyadic covariates, which describe attributes defined by pairs of actors. The main *dyadic attribute* effect represents tendencies to choose partners in the friendship network based on their connectedness in the dyadic covariate network. The two dyadic covariates included in the present study are *schoolmates* and *classmates*. These effects represent tendencies to nominate friends who attend the same school and same classroom, respectively. Due to the non-restrictive nature of the friendship nominations (*i.e.*, students could nominate any peer they spend time with), and consistent with previous findings (Burk, Steglich, and Snijders, 2007), we expect a tendency for adolescents to nominate schoolmates as friends, who may or may not be classmates.

We include four individual covariates: age, gender, school involvement and delinquency. These attributes are unique to an individual and may be constant (*e.g.*, gender) or changing characteristics (*e.g.*, delinquency). Three parameters are estimated for each: the *attribute ego* parameter (effect of the nominator's attribute on selection), the *attribute alter* parameter (effect of nominees' attribute on selection), and the *attribute similarity* parameter (tendency for adolescent to nominate friends with similar characteristics, homophilic selection). Using gender as an example (with males coded as 0 and females coded as 1), a positive gender ego effect indicates females tend to have a higher number of outgoing friendship nominations (*i.e.*, are more active in the network) than males. A positive gender alter effect indicates females tend to have a higher number of incoming friendship nominations (*i.e.*, are more popular in the network). A positive gender similarity effect indicates individuals tend to nominate others of the same gender (*i.e.*, partner selection based on homophily). The effects of individual covariates that change over time (*e.g.*, delinquency) may be interpreted in a similar manner.

The behavioral objective function also corresponds to a set of estimated parameters. Two of the attributes in this study are classified as dependent behavioral covariates: delinquent behaviors and school involvement. The *behavioral tendency* parameter models the overall tendency toward high values on a behavioral variable. A negative parameter estimate indicates a preference or trend for adolescents to report low levels of a specific behavior; a positive parameter estimate indicates a tendency for adolescents to report high levels on a specific behavior. The *behavioral similarity* parameter represents tendencies for actors to adopt the behaviors of others. So, a positive behavioral similarity effect represents a tendency for adolescent affiliates to become more similar over time (*i.e.*, social influence). Interactions between specific parameters may also be considered in these models. We include several interactions to model age and gender differences in school involvement and delinquency, as well as to examine interactions between the two behavioral measures.

## Results

### *Descriptive analyses*

Table I presents descriptive statistics of the structural characteristics of the friendship networks and individual behaviors.

TABLE I. – ***Descriptive statistics of network structure and individual characteristics***

| | Measurement point | | | | |
|---|---|---|---|---|---|
| | Time 1 | Time 2 | Time 3 | Time 4 | Time 5 |
| Network Structure | | | | | |
| Number of ties | 866 | 1,002 | 1,208 | 1,489 | 1,575 |
| Average degree | 2.37 | 2.60 | 3.04 | 3.78 | 4.06 |
| Density | .005 | .006 | .007 | .009 | .009 |
| Reciprocity index | .415 | .463 | .452 | .488 | .486 |
| Transitivity index | .312 | .384 | .370 | .446 | .456 |
| Individual Characteristics | | | | | |
| Adolescent age (in years) | 10.58 | 11.84 | 12.87 | 13.79 | 14.81 |
| Delinquency | 1.05 | 1.07 | 1.12 | 1.19 | 1.28 |
| School involvement | 4.66 | 3.95 | 3.79 | 3.62 | 3.50 |

*Notes* : $n = 445$. Number of ties represents the total number of network ties. Average outdegree represents the average number of outgoing network ties. Density describes the proportion of ties in relation to the total number of possible ties. The reciprocity index describes the proportion of reciprocated ties in relation to the total number of ties. The transitivity index describes the proportion of transitive triplets in relation to the total number of triadic configurations. Delinquency ranges from 1 (*none*) to 3 (*several times*). School involvement ranges from 1 (*very bad or almost never*) to 5 (*very good or most often*).

*Network dynamics.* The indices describing network dynamics collectively indicate a gradual tendency toward network expansion. Specifically, the number of ties and average degree indicate the growth of the network is approximately 15%-20% annually. This expansion resulted in nearly twice as many network ties over the length of the study. Specifically, the number of friendship ties increased from 866 nominations at Time 1 to 1,575 nominations at Time 5. The indices reflecting the proportion of reciprocated friendships (reciprocity) and peer group structures (transitivity) also demonstrated gradual increases, with the exception of the period from Time 2 to Time 3, where both indices suggest a slight decline in reciprocated friendships and cohesive peer group structures. This curvilinear trend may be explained by school transition. The network consists mostly of $4^{th}$ and $5^{th}$ graders who attended primary schools at the outset of the study, but who changed schools following the completion of the $6^{th}$ grade. So, the decrease in reciprocated friendships and transitive relationships between Time 2 and Time 3 may be attributed to the increased opportunity for youth from primary different schools to form new friendships in secondary school with previously unknown others.

Figures Ia through 1e present sociograms of the friendship networks at each discrete time point. These graphical representations were created with the Visone software program (Brandes and Wagner, 2004) using a multi-dimensional scaling algorithm. For clarity, the network position of each adolescent (node) is constrained to be constant in each sociogram, with only the friendship ties between adolescents varying over time. Males are represented as light-colored nodes; females are represented as dark-colored nodes. These visual depictions not only reiterate the tendencies toward network expansion provided by the descriptive indices, but also provide evidence of several unique aspects of network structure, including the prevalence of nominations between cohesive peer group structures, the tendency for same-sex friendships and peer groups, and the existence of two distinct, yet interconnected network components. Further examination of the two components revealed adolescents in the smaller component (on the left) attended one school that was geographically more isolated from the other schools, which comprise the larger component (on the right). Taken together, the statistical and visual descriptions of these naturally-existing friendship networks support the notion that early adolescent peer groups are best characterized by a complex and dynamic nature.

FIGURE Ia. – ***Friendship network at Time 1***

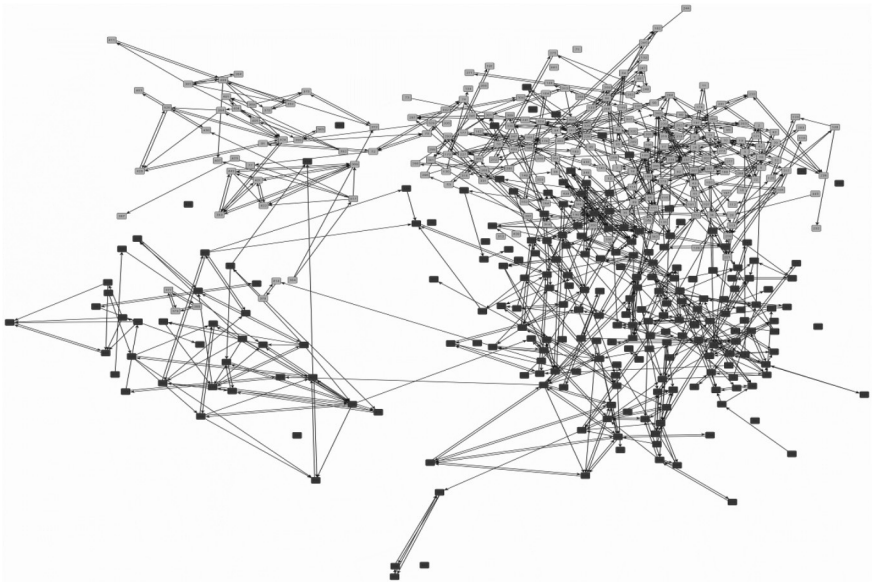


FIGURE Ib. – ***Friendship network at Time 2***

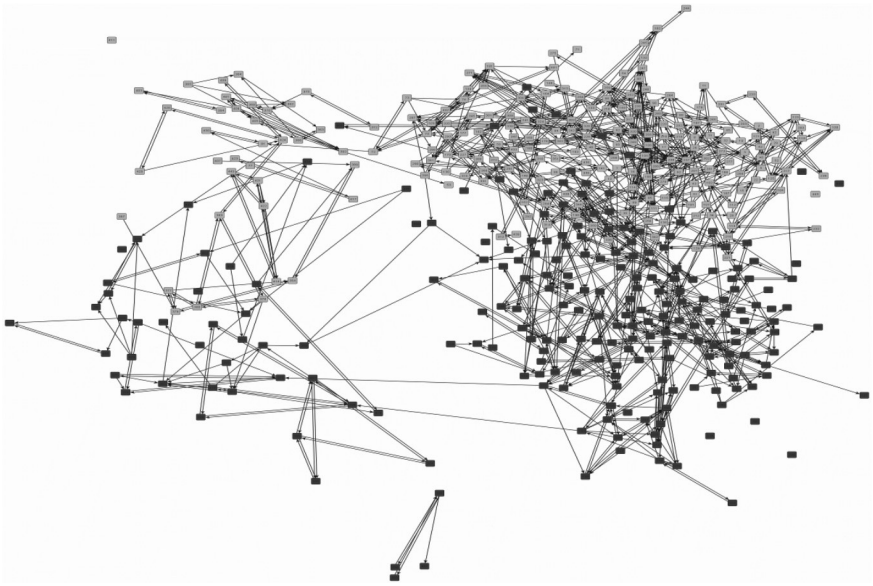


FIGURE Ic.– ***Friendship network at Time 3***

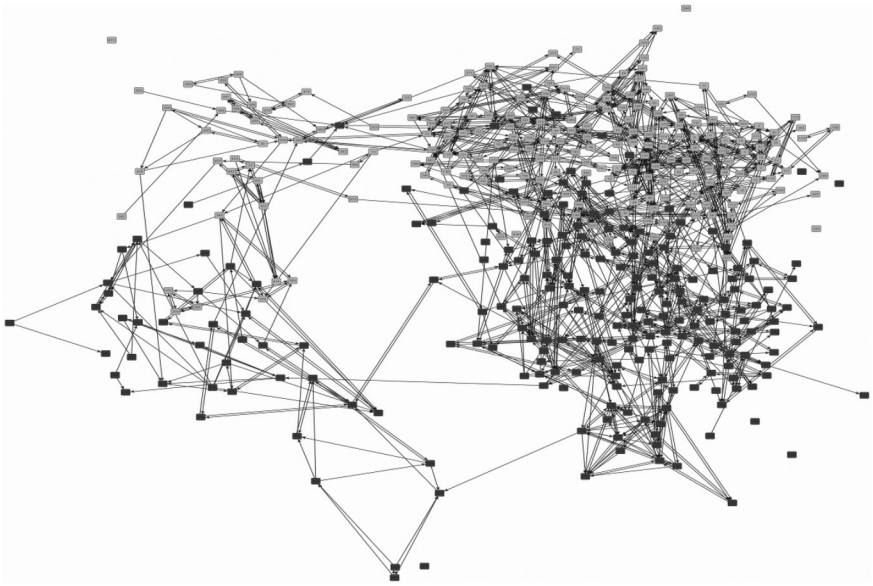


FIGURE Id. – ***Friendship network at Time 4***

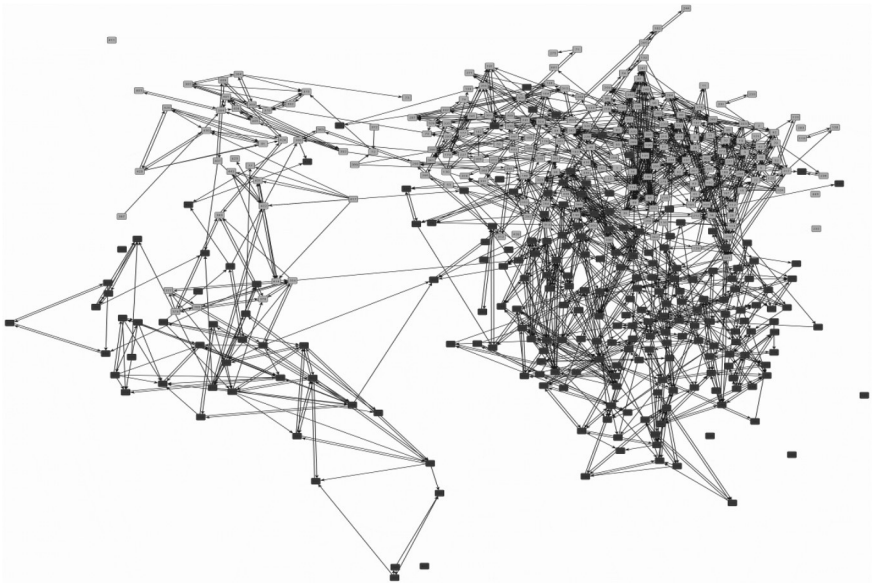
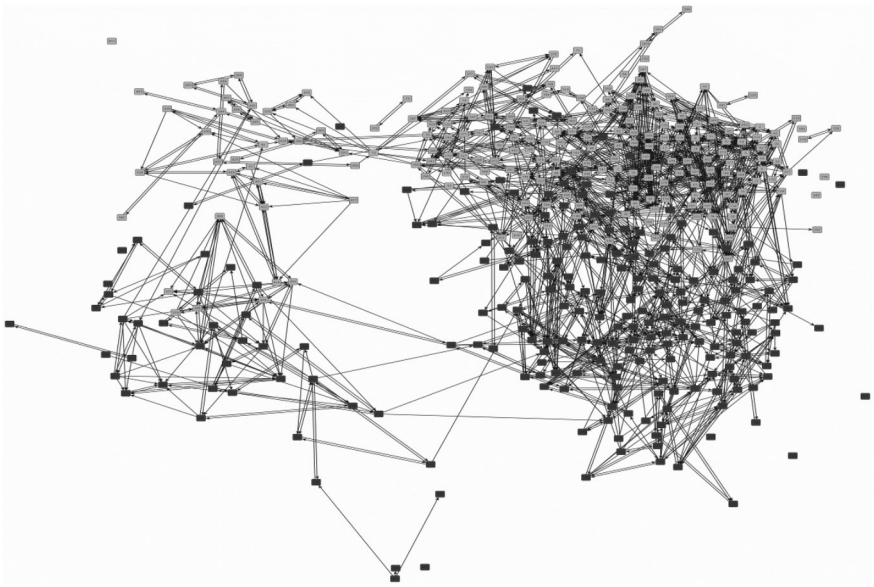


FIGURE Ie. – ***Friendship network at Time 5***



*Behavioral dynamics.* As indicated in Table I, individual scores of school involvement demonstrated a high prevalence and gradual decline. The reverse was true for delinquent behaviors, which demonstrated low prevalence and a gradual increase. Two repeated measures ANOVAs examined gender differences in school involvement and delinquency. In both analyses, a significant gender by time interaction emerged for school involvement, $F(4, 424) = 2.88$, $p = .023$, and delinquent behaviors, $F(4, 424) = 2.73$, $p = .029$. Follow-up contrasts revealed females reported higher levels of school involvement than males at Times 1, 2, and 3 (but not Times 4 or 5); males reported higher levels of delinquency at Times 2, 3, 4, and 5 (but not at Time 1). Figure II presents the means of the two behavioral covariates at each time point separately for males and females.

FIGURE II. ***Male and female school involvement and delinquent behaviors over time***

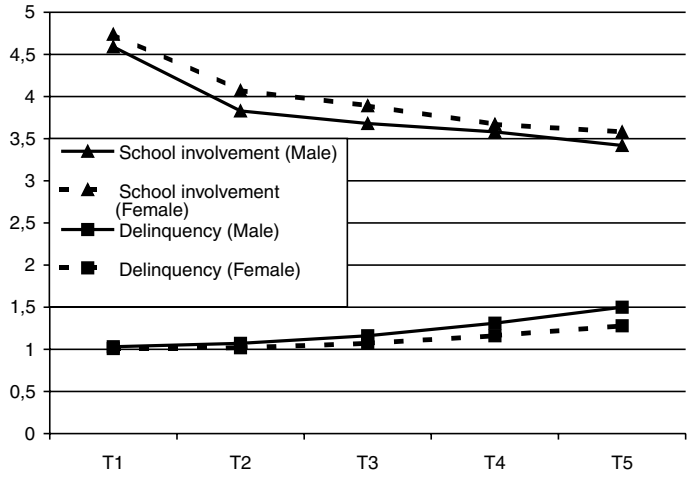



Table II presents concurrent and prospective correlations among and between delinquent behaviors and school involvement separately for males and females. Nonparametric correlations were performed due to the skewed nature of the two behavioral measures. Autoregressive correlations revealed a moderate degree of interindividual stability between annual measurements of the two behavioral measures for both females (*r*s = .31 to .64 for school involvement and *r*s = .32 to .56 for delinquency) and males (*r*s = .39 to .57 for school involvement and *r*s = .38 to .56 for delinquency). Concurrent correlations between school involvement and delinquency were generally higher than prospective associations between these two measures. Correlational contrasts failed to reveal any differences in these associations as a function of gender.

TABLE II. – ***Spearman's rank-order correlations between delinquent behaviors and school involvement for males and females***

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
|---|---|---|---|---|---|---|---|---|---|---|
| (1) Delinquency T1 | ---- | .37** | .28** | .29** | .20** | -.15* | -.16* | -.08 | -.16* | -.14* |
| (2) Delinquency T2 | .47** | ---- | .32** | .29** | .26** | -.11 | -.14* | -.02 | -.06 | -.04 |
| (3) Delinquency T3 | .39** | .38** | ---- | .47** | .39** | -.12 | -.19** | -.21** | -.23** | -.24** |
| (4) Delinquency T4 | .24** | .22** | .42** | ---- | .56** | -.20** | -.26** | -.31** | -.30** | -.31** |
| (5) Delinquency T5 | .25** | .23** | .32** | .56** | ---- | -.22** | -.26** | -.32** | -.33** | -.42** |
| (6) School involvement T1 | -.14* | -.15* | -.12 | -.08 | -.06 | ---- | .31** | .28** | .25** | .24** |
| (7) School involvement T2 | -.10 | -.20** | -.22** | -.17* | -.19** | .39* | ---- | .52** | .37** | .36** |
| (8) School involvement T3 | -.16* | -.14* | -.34** | -.31** | -.20** | .15* | .49** | ---- | .57** | .50** |
| (9) School involvement T4 | -.20** | -.16* | -.32** | -.39** | -.32** | .18** | .42** | .57** | ---- | .64** |
| (10) School involvement T5 | -.07 | -.07 | -.10 | -.26** | -.31** | .16* | .33** | .46** | .51** | ---- |

*Notes*: Correlations for males are presented below the diagonal ($n$ = 225) ; correlations for females are presented above the diagonal ($n$ = 220).
* $p < .05$ ** $p < .01$.

## *Models of network and behavioral dynamics*

*Specification of Siena model.* To ensure a network approach is appropriate for these data, we use the forward model selection procedure described by Snijders, Steglich, and Schweinberger (2007) to specify a final network-behavioral model. This procedure consists of three general steps. The first step tests whether more complex network structuring (*i.e.*, transitivity) increases the fit of the model. The second step tests whether network evolution is independent of behavioral evolution. The final step includes building a model that includes all parameters of interest.

Initially, we test a dyad interdependence model to examine whether our data exhibit more complex dependence structures. Score tests (Schweinberger, 2008) are used to test the significant contributions of specific parameters. We tested the transitivity parameter to determine if this effect significantly contributed to the fit of a model that included parameters estimating effects of network density and reciprocity, selection effects of dyadic (schoolmates and classmates) and individual covariates (age and gender). The test statistic was significant, $\chi^2(1) = 3916.17$, $p < 0001$, indicating that a model, which assumes independence between all dyads is inadequate for these data. Thus, our data contain triadic relationship structures (peer groups). Table III presents the parameter estimates of this model of network evolution.

TABLE III. – ***Parameter estimates of network evolution***

| Parameters | Estimate | Standard error | *t*-value |
|---|---|---|---|
| *Rate function* | | | |
| Rate period 1 | 10.732 | 0.827 | |
| Rate period 2 | 17.616 | 1.520 | |
| Rate period 3 | 22.634 | 1.177 | |
| Rate period 4 | 14.445 | 0.995 | |
| *Objective function* | | | |
| Density | -2.651 | .037 | 71.66*** |
| Reciprocity | 2.737 | .050 | 54.73*** |
| Transitivity (transitive triplets) | 0.281 | .014 | 20.79*** |
| Schoolmates | 1.124 | .117 | 9.57*** |
| Classmates | 0.542 | .361 | 1.50 |
| Age ego (activity) | -0.082 | .033 | -2.49* |
| Age alter (popularity) | 0.235 | .029 | 8.22*** |
| Age similarity (selection) | 2.279 | .258 | 8.84*** |
| Gender ego (activity) | 0.258 | .053 | 4.81** |
| Gender alter (popularity) | -0.247 | .056 | -4.43** |
| Gender similarity (selection) | 0.927 | .047 | 19.63*** |

*Notes* : The <I>t-values refer to tests based on the *t*-ratio defined as parameter estimate divided by standard error.
* $p < .05$ ** $p < .01$ *** $p < .001$.

Next, joint score tests are used to examine interdependence between network and behavioral evolution. We tested if the behavioral tendency parameters of school involvement and delinquency significantly contributed to the fit of the model that included all of the parameters in the previous model (and transitivity). This joint test statistic was statistically significant, $\chi^2(2) = 68.56$, $p < 0001$ (as were the single score tests), indicating interdependence between network and behavior evolution. This warrants the use of network-behavioral models, which include all network and behavioral parameters of interest, and serves to determine more precisely the strength of diverse components of the influence and selection processes.

So, the final model includes parameters estimating endogenous network effects (*e.g.*, reciprocity, transitivity); selection effects based on school and classroom membership; network activity, popularity, and selection effects based on adolescent age, gender, school involvement and delinquent behaviors; influence effects relating to school involvement and delinquent behaviors; and interaction effects between individual covariates and behavioral variables. By including all these parameters in a single model, we are able to simultaneously estimate the unique effects attributable to each parameter and ascertain their relative contributions and importance. Table IV presents the objective function parameter estimates included in the final Siena model. It should be noted that network and behavioral rate functions and quadratic

behavioral effects (see Snijders, Steglich, Schweinberger, and Huisman, 2006) are excluded in the table, but included in the model.

TABLE IV. – ***Network and behavioral parameter estimates of the final model***

| Parameters | Estimate | Standard error | *t*-value |
|---|---|---|---|
| *Network dynamics* | | | |
| Density | -2.727 | .230 | 11.84*** |
| Reciprocity | 2.592 | .073 | 35.43*** |
| Transitivity (transitive triplets) | 0.081 | .019 | 4.22** |
| Schoolmates | 1.005 | .125 | 8.03*** |
| Classmates | 0.257 | .445 | 0.62 |
| Age ego (activity) | -0.079 | .036 | -2.19* |
| Age alter (popularity) | 0.240 | .033 | 7.37*** |
| Age similarity (selection) | 1.936 | .184 | 10.54*** |
| Gender ego (activity) | 0.213 | .076 | 2.78** |
| Gender alter (popularity) | -0.111 | .063 | -1.76 |
| Gender similarity (selection) | 0.795 | .073 | 10.87*** |
| Delinquent ego (activity) | -0.039 | .128 | -0.31 |
| Delinquency alter (popularity) | 0.152 | .037 | 4.07** |
| Delinquent similarity (selection) | 1.548 | .440 | 3.51** |
| School involvement ego (activity) | 0.004 | .021 | 0.21 |
| School involvement alter (popularity) | 0.037 | .022 | 1.16 |
| School involvement similarity (selection) | 0.353 | .140 | 2.52* |
| *Behavior dynamics* | | | |
| Delinquency tendency | -0.435 | .060 | -7.20*** |
| Delinquent similarity (influence) | 1.444 | .643 | 2.24* |
| Delinquency x age | 0.152 | .075 | 2.02* |
| Delinquency x gender | -0.212 | .091 | -2.34* |
| Delinquency x school involvement | -0.008 | .001 | -7.50*** |
| School involvement tendency | 0.125 | .050 | 2.51* |
| School involvement similarity (influence) | 0.300 | .189 | 1.58 |
| School involvement x age | -0.007 | .034 | 0.21 |
| School involvement x gender | 0.062 | .045 | 1.38 |
| School involvement x delinquency | -0.064 | .030 | -2.12* |

*Notes* : Rate function parameters and quadratic behavioral effects are included in the model, but omitted from the table.
* $p < .05$ ** $p < .01$ *** $p < .001$.

*Network evolution.* Endogenous network dynamics are represented by three parameters: density, reciprocity, and transitive triplets. *Density* describes the tendency of actors to have outgoing ties (*i.e.*, the degree of dyadic connection

in a network). As expected, the density parameter was significantly negative, indicating that adolescents do not tend to nominate just anyone as a friend (*e.g.*, relationships have costs). *Reciprocity* describes the tendency for actors to reciprocate a relationship; *transitivity* describes the tendency for adolescent friendships to form cohesive peer group structures. Both parameters were significant and positive. The reciprocity parameter indicating a strong preference for reciprocated friendships and the transitivity parameter indicating a tendency for transitive closure (*i.e.*, actors prefer relationships with their friends' friends). Two dyadic covariates (*schoolmates* and *classmates*) represent tendencies to nominate friends who attend the same school and same classroom, respectively, and are included to approximate an exogenous hierarchical structure based on proximity and opportunity. As expected, the effect for schoolmates was positive and statistically significant, while the effect for classmates was nonsignificant. This indicates that early adolescents tend to establish friendships with others in the same school, who are not necessarily classmates. This pattern of statistically significant results emerged in both the model of network evolution (see Table III) and the final model of network-behavioral co-evolution.

Next, parameter estimates of network tendencies involving age and gender are described. In the model of network evolution (see Table III) all three effects (attribute ego, alter, and similarity) emerged as significant for both adolescent age and gender. For age, the positive alter effect indicates that older adolescents tend to be nominated more often than younger ones (*i.e.*, are more attractive partners); the negative ego effect indicates a tendency for older adolescents to nominate fewer friends than younger youth (*i.e.*, are less active). The age similarity effect indicates a strong preference for adolescents to nominate friends who are of similar age. For gender, the negative alter effect indicates a tendency for males to receive more nominations than females (*i.e.*, males are more popular); the positive ego effect indicates that females tend to nominate more friends than males (*i.e.*, females are more active). The highly significant similarity effect indicates a strong preference for adolescents to nominate same-gender friends. A similar pattern of results emerged in the final network-behavioral model.

Table IV presents the final model that included the effects associated with two behavioral covariates: delinquent behaviors and school involvement. For delinquency, the significant and positive alter effect indicates that adolescents with higher levels of delinquency are more attractive friendship partners than non-delinquents (*i.e.*, delinquents are more popular). The negative, albeit nonsignificant, ego effect indicates that delinquents have a slight tendency to be less active in the network than non-delinquents. The similarity effect suggests adolescents tend to nominate friends with similar levels of delinquency. For school involvement the nonsignificant alter and ego effects indicate adolescents with varying levels of school involvement to not systematically differ as a function of network activity or popularity. The significant similarity effect indicates a tendency for adolescents to nominate friends who are similarly involved in school. Taken together, these results

indicate that adolescents tend to nominate friends who attend the same school, are of the same age and gender, and are similar in terms of school involvement and delinquent behaviors.

*Behavioral evolution.* As expected, the behavioral tendency parameters for delinquent behaviors and school involvement were both statistically significant. As shown in Table I, delinquency was positively skewed at each measurement point; school involvement was negatively skewed. The negative value of the delinquency parameter indicates a propensity for actors to report low levels of delinquent behaviors at each time point. The positive value of the school involvement parameter indicates a propensity for actors to report high levels of school involvement. Concerning parameters representing social influence, the effect for delinquency was positive and statistically significant; the effect for school involvement was positive, but did not reach a conventional level of statistical significance. This indicates that individuals adopt the delinquent behaviors and school involvement of those they nominate as friends, with a stronger tendency for peer influence involving delinquency than school involvement.

In addition, we included six interactions to approximate age and gender differences in the behavioral variables, as well as to examine the dynamic interplay between school involvement and delinquency. The first three interactions involved delinquency. The delinquency by age interaction represents age differences in the prevalence of delinquent behaviors. The delinquency by gender interaction represents gender differences in delinquent behaviors. The delinquency by school involvement interaction represents the effect of school involvement on changes in delinquency. The three interactions including school involvement may be interpreted in an identical manner. The interactions involving age and gender were included to approximate the differences observed in the individual behaviors described earlier; the interactions between the two behavioral covariates were included to examine the direction of effects between delinquency and school involvement. Both of these latter effects emerged as negative and statistically significant, indicating low levels of school involvement predicted changes (increases) in delinquent behaviors, and high levels of delinquency predicted changes (decreases) in school involvement.

## Discussion

The primary goal of the present study was to simultaneously examine selection and influence processes related to school involvement and delinquent behaviors in early adolescent friendship networks. To accomplish this goal, we applied models of network-behavioral dynamics to a five-year longitudinal sample of an entire 4$^{th}$ grade cohort of Swedish youth from a small community. In addition, we described structural characteristics of these networks and behavioral tendencies of the adolescent participants. The results are discussed in terms of the three specific research questions posed at the outset.

The first question involved describing the structural characteristics and dynamics of early adolescent friendship networks. As expected, the descriptive indices and sociograms revealed a pre-existing network that gradually expanded from one year to the next. This growth cumulatively resulted in almost twice as many friendship ties over the course of five years. While descriptive indices based on the number of unilateral nominations did not provide evidence that school transition interrupted network expansion, reciprocity and transitivity indices did indicate that reciprocated ties and cohesive peer group structures were temporarily disrupted by the transition from primary to secondary schools. Furthermore, the rate function parameters in the model of network evolution suggested increased changes in network ties during and immediately following the transition. Taken together, these results not only provide insights into understanding the dynamics of naturally-existing early adolescent friendship networks, but also provide some indication as to the extent to which friendship network dynamics are affected by school transition.

The second question concerns identifying the most prominent features of network dynamics. As expected, significant tendencies for reciprocated friendship ties and cohesive peer group structures emerged, as did tendencies for adolescents to nominate same age, same-sex schoolmates, who were not necessarily classmates. Several additional age and gender differences also emerged. Males and older adolescents were more popular (*i.e.*, they received more nominations); whereas, females and younger adolescents were more active in the friendship network (*i.e.*, they gave more nominations). When delinquent behaviors and school involvement were included, homophilic selection effects based on both covariates emerged, as well as a tendency for delinquent youth to be more popular than non-delinquents. Collectively, these results suggest effects of reciprocity and transitivity are the most prominent predictors of friendship ties, followed by tendencies to nominate same age, same-sex schoolmates and other peers with similarity levels of delinquency behaviors.

The third question, which relates to the primary study objective, involves the relative contributions of friends' behaviors on early adolescents' school involvement and delinquent behaviors. Our findings provide indirect support for competing psychological and sociological theories of problem behavior. For instance, one of the main findings in the present study is that adolescents are influenced by the delinquent behaviors of their friends above and beyond the influence of school involvement. This is in line with differential association theory (Sutherland and Cressey, 1974), which asserts that adolescents learn problem behaviors from friends and other peer affiliates. On the other hand, we also found that adolescents select friends based on delinquent behaviors and school involvement, which is the mechanism predicted by social bonding (or social control) theory (Gottfredson and Hirschi, 1990; Hirschi, 1969). These seemingly conflictual results suggest an integrated perspective is required to explain the development of delinquency (see Erickson, Crosnoe, and Dornbusch, 2000). Taken together, these findings suggest friends' negative

influence plays a relatively stronger role in behavioral changes, when effects of both school involvement and delinquent behaviors are simultaneously examined.

Several caveats must be acknowledged. First, the sample was limited to youth who participated in all five waves of the longitudinal project from which they were drawn. This restrictive selection criterion necessarily limited the overall size of the network and may have excluded potentially influential friendship ties. While participants did not significantly differ from non-participants, limited generalizability of our findings is one of the consequences for this network delineation strategy. Second, participants were drawn from a small community in central Sweden. Although they were representative of the population from which they were drawn, it will be up to future scholars to determine whether the findings from this sample generalize to youth living in other settings, particularly those in communities that are more urban and transitory. Third, the social networks analyzed in this study were exclusively based on unilateral friendship nominations. While some previous research suggests differences between unilateral and reciprocated friendships related to selection and influence processes (*e.g.*, Burk, Steglich, and Snijders, 2007), we did not differentiate between these two types of friendships in the present study. While the distinction between unilateral and reciprocated friendship ties is important, models including effects distinguishing between these two types of friendship did not converge using this network sample, so future studies are required to determine whether the processes differ for the two types of nominations. Finally, we did not include relationships with parents, teachers, siblings, romantic partners, or other close peers. The attributes and behaviors of these relationship partners also exert influences on adolescent behaviors (*e.g.*, Kindermann, 2007), but the relative importance of various relationships was not considered here. Future studies are not only needed to replicate the findings of the current study, but also to examine the contributions of parents, peers, and other important individuals on adolescent adjustment.

Despite these limitations, this study also has several strengths. Perhaps the most important advantage of the present study pertains to the community-based longitudinal design. This allowed us to examine naturally-existing friendship networks of an entire cohort of youth from a small community. This feature provided a more ecologically valid representation of adolescent friendships compared to the majority of previous studies limited to friendships within schools or classrooms. In addition, the actor-oriented network-behavioral models used in this study offer several advantages compared to alternative statistical methods. First, the capability of this modeling technique provides a more elegant means of accounting for the complex dependence structures inherent in changing friendship ties and changing individual behaviors. Previous research has been limited to examining these processes in stable peer groups (*e.g.*, Ennet and Bauman, 1994) or estimating the strength of effects between newly formed or pre-existing friendships (*e.g.*, Kandel, 1978). By performing a single analysis on the entire network sample, we were

able to compare the relative strength of parameters estimating selection and influence. Second, this analytic approach provides more precision in the simultaneous estimation of selection and influence processes by utilizing a continuous time Monte Carlo Markov Chain process. Panel data is collected at discrete time points (typically, at one year increments or at the beginning and end of a school year) and the timing of changes in friendship ties and changes in the individual behaviors that occur throughout the year are not accurately depicted. Finally, the actor-oriented models allow us to include the simultaneous estimation of selection and influence processes to be assessed related to multiple behaviors. That is, in the present study we included measures of both prosocial and antisocial behaviors.

The findings of the present study also have practical implications for future sociometric research, as well as intervention and prevention efforts. Previous research has identified demographic characteristics such as gender, age, school, classroom, and neighborhood as among the most important determinants of friendship (Coleman, 1961; Dunphy, 1963; Kandel, 1978). This has led contemporary researchers to exclusively study adolescent peer groups with sociometric methods based on the classroom setting. However, results of the current study suggest this may not be the case. Although we found effects indicating early adolescent nominate peers attending the same school, we did not find evidence for these youth to nominate peers in the same classroom. This suggests future sociometric research should not necessarily restrict children's friendship nominations to peers attending the same classroom, especially if the goal is to identify social influence based on behaviors that predominantly occur outside the school context, such as delinquency and substance use. Furthermore, identifying the relative importance of selection and influence effects has important implications for the implementation of intervention and prevention programs. If homophilic selection effects are found to be more important, this suggests a focus on preventing the establishment of antisocial relationships; whereas, if influence is deemed to be the relatively more important mechanism, this suggests a focus on disrupting relationships that have already formed. In the present study, we found effects for both processes related to delinquency, with selection demonstrating slightly stronger effects. However, this pattern has been found to differ when other problem behaviors (*i.e.*, substance use) are examined. A failure to understand the relative strength of these processes has previously led to unsuccessful intervention and prevention of delinquency (Dishion, McCord, and Poulin, 1999).

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In conclusion, one of the greatest analytic challenges facing social scientists is incorporating interdependence in the study of developmental phenomena. This is especially true when analyzing changes in individual behaviors due to changes in friendships, which are embedded within changing peer

groups. Often, friendship nomination data are underutilized due to the apparent lack of appropriate analytic tools. This paper described newly developed statistical methods capable of modeling interdependencies between changes in social network ties and changes in individual behaviors in order to delineate selection and influence mechanisms. We applied these techniques to adolescent friendship networks, but it is well-suited for use with many different developmental phenomena. These models represent an important step in elucidating various processes and mechanisms related to interpersonal influence.

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