doi: 10.1111/j.1467-9507.2009.00564.x

Friendship and Delinquency: Selection and Influence Processes in Early Adolescence

Andrea Knecht, *University of Erlangen-Nuremberg*, Tom A. B. Snijders, *University of Oxford and University of Groningen*, Chris Baerveldt, *Utrecht University*, Christian E. G. Steglich, *University of Groningen*, and Werner Raub, *Utrecht University*

Abstract

Positive association of relevant characteristics is a widespread pattern among adolescent friends. A positive association may be caused by the selection of similar others as friends and by the deselection of dissimilar ones, but also by influence processes where friends adjust their behavior to each other. Social control theory argues that adolescents select each other as friends based on delinquency. Differential association theory, on the other hand, argues that adolescent friends influence each other's delinquency levels. We employ new statistical methods for assessing the empirical evidence for either process while controlling for the other process. These methods are based on 'actor-oriented' stochastic simulation models. We analyze longitudinal data on friendship networks and delinquent behavior collected in four waves of 544 students in 21 first-grade classrooms of Dutch secondary schools. Results indicate that adolescents select others as friends who have a similar level of delinquency compared with their own level. Estimates of the social influence parameters are not significant. The results are consistent with social control theory but provide no support for differential association theory.

Keywords: adolescence; delinquency; peers/peer relations

Introduction

Parents have been worrying about their children's friends since time immemorial. Onlookers may, for similarly long periods, have had their doubts as to whether any supposedly bad behavior of the child was indeed copied from supposedly bad friends or had other sources. Similarity between friends is a well-established regularity in many aspects of behavior including delinquency (e.g., Aseltine, 1995; Baron & Tindall, 1993; Bender & Lösel, 1997; Dishion, Andrews, & Crosby, 1995; Fletcher, Darling, Steinberg, & Dornbusch, 1995; Haynie, 2001; Marcus, 1996; Ploeger, 1997; Reed & Rose, 1998; Thornberry, Lizotte, Krohn, Farnworth, & Jang, 1994; Vitaro, Tremblay, Kerr, Pagani, & Bukowski, 1997).

Correspondence should be addressed to Andrea Knecht, School of Business & Economics, University of Erlangen-Nuremberg, Findelgasse 7/9, D-90402 Nuremberg, Germany. Email: *andrea.knecht@wiso.uni-erlangen.de*

The question of whether this is due to peer influence or friendship selection has been much debated, albeit without an unequivocal conclusion. In the criminological literature, social control theory (Hirschi, 1969) has claimed that the association of delinquent behavior between adolescents and their friends is predominantly due to selection processes whereas differential association theory (Sutherland & Cressey, 1974) has argued the predominance of influence processes in explaining this association. A comparative assessment of the two mechanisms has been attempted (Baerveldt, Van Rossem, & Vermande, 2003; Matsueda, 1982), but it did not deliver firm conclusions. The possibility that selection and influence processes operate simultaneously (Matsueda & Anderson, 1998) has made the contrast between these positions less stark but has not made the question easier to solve.

There are three main types of processes that may explain similarity in behavior between peers. These are peer selection, peers' influence, and peers being subject to the same contextual influences (e.g., Feld, 1982; Hartup, 1996; Hartup & Stevens, 1997). The empirical research questions, which can be regarded as typical for studies of selection and influence, are related to the first two processes: (1) are adolescents' friendship choices affected by shared levels of delinquency? (2) Are adolescents' delinquency levels affected by their friends' delinquency levels?

A variety of methodological issues have impeded progress on deciding which of these processes is supported by empirical evidence as contributing to the explanation of peer similarity. Basic to these issues is the fact that each individual has the fourfold role of being potentially influenced by and potentially influencing others and of selecting and potentially being selected by others as friends, so that the convenient assumption of independent subjects, and even the separation between dependent and independent variables, contradicts the processes under study. Until recently, existing statistical methods did not allow analyzing selection and influence simultaneously. This article describes newly developed statistical models for the analysis of social networks coevolving with behavioral dimensions of the individuals in the network (Snijders, 2001; Snijders & Baerveldt, 2003; Snijders, Steglich, & Schweinberger, 2007a), which can be used to make empirical distinctions between peer selection and influence processes provided that adequate longitudinal network data are available (For a broad introduction to social network analysis see Wasserman & Faust, 1994.) in which a respondent can figure in all four roles—as a chooser of friends, as a potential friend for others, as a peer who influences, and as a peer who is influenced. Recently, the method has been applied to the study of selection and influence processes related to delinquency among Swedish adolescents (Burk, Steglich, & Snijders, 2007). We illustrate this method with a study of the joint dynamics of friendship relationships and minor delinquent behavior in first-grade classrooms of Dutch secondary schools (ages 12–13). The question of the extent to which peer similarity is the consequence of the same contextual influences outside school (Feld, 1982) is beyond the scope of this article and will not be addressed. However, it can reasonably be expected that much context-caused similarity will already be reflected in the initial measurement of the network-behavior data. The method used will control for this initial measurement, implying that these effects will not or only weakly contaminate the study of the subsequent dynamics.

Four reasons can be given for choosing Dutch secondary-school first graders as a study population. Firstly, in early adolescence, peers are very important for the development of behavior (e.g., Giordano, 2003; Steinberg & Sheffield Morris, 2001). The importance of peers fosters influence processes among them. Secondly, in the Dutch

school system most students who enter secondary school lose many of their former primary school relationships. A strong activity in new friendship formation may thus be expected. Thirdly, students spend much time at school and the classroom plays an important role in socialization and identity formation, thus providing a natural social group in which to study selection and influence processes (Kassenberg, 2002). Fourthly, although older adolescents may be more prone to show delinquent behavior, initiating and experimenting with (usually minor) delinquent behavior as part of identity formation starts in early adolescence (Moffitt, 1993) and may be triggered by the behavior of peers. It is not yet clear how important minor delinquency is in explaining peer relationships and, vice versa, how important peer relationships are in explaining minor delinquency in this age group.

Selection and Influence

A considerable body of earlier research addresses selection and influence processes. Adolescence literature (Giordano, 2003) suggests that both delinquency-based selection and peer influence cause the adolescent-peer association of delinquency levels. In developmental psychology both friendships and antisocial behavior are important topics (e.g., respectively, Dodge, Coie, & Lynam, 2006; Rubin, Bukowski, & Parker, 2006). The debate in developmental psychology addresses causes and consequences of friendship quality but also influence and selection processes. While developmental psychologists often assumed that the occurrence and quality of friendships has a positive influence on moral development and social adaptation, others (Hartup, 1996; Hartup & Stevens, 1997) stress that the outcome may also depend on with whom one is befriended. Hartup and Stevens explicitly state that friends may be a risk factor when they show antisocial behavior. They also acknowledge that children who have socialization problems have less choice in friends and tend to engage in friendships with problematic peers. Thus, selection processes may add to the similarity of problematic behavior levels between friends. Consequently, similarity may be caused by both influence and selection. Arguments can be found in classical criminological theories for both viewpoints as well. According to Hirschi's (1969) social control theory, people have a natural disposition to behave delinquently (Gottfredson & Hirschi, 1990). Strong social bonds, in particular with family and institutions, prevent delinquent behavior, and non-delinquent adolescents are less prone to associate with delinquent peers. Hirschi concludes that the relation among delinquents can only be explained by selection or, more precisely, by matching processes. Because non-delinquent students prefer non-delinquent friends, delinquent adolescents have to fall back on superficial relationships among themselves. In contrast, differential association theory (Sutherland & Cressey, 1974) suggests that delinquent behavior is acquired through socialization processes where definitions of appropriate behavior are learned. Whether values favoring delinquency are passed on depends on the degree of involvement in delinquent behavior of the friends in a consistent and intimate group. Social relationships with delinquent peers thus precede delinquent behavior, and the intimacy of the relationships of delinquent adolescents does not necessarily differ from that of non-delinquent adolescents. Hansell and Wiatrowski (1981) called these two phenomena, respectively, the 'social inability' model and the 'social ability' model. For the sake of argument, we follow the criminological literature in this article, keeping in mind that the debate is often more lenient than presented here, particularly in other disciplines.

Empirical research has not yet provided definite evidence to decide between the competing criminological theories (Marcus, 1996). This is illustrated by the fact that Aseltine (1995), in his review study, concluded that the ability model was supported by empirical research whereas Baron and Tindall (1993) found support for the inability model. Also, there are some indications of influence and selection processes in school populations (Haynie & Osgood, 2005; Snijders & Baerveldt, 2003). However, the validity of the outcomes may differ, possibly depending on the research design and method used and on the population and type of delinquency being studied.

Many of the earlier studies had serious technical problems regarding the reliability of measures or research design. Firstly, until recently, most studies relied on peer reporting of delinquency levels, meaning that respondents were asked about the behavior of their friends. This is problematic because respondents overestimate the similarity between their own delinquent behavior and that of their contacts (e.g., Aseltine, 1995; Jussim & Osgood, 1989; Kandel, 1996; Reed & Rose, 1998)—the 'false consensus effect' (Ross, Greene, & House, 1977). This problem can be overcome by collecting data in a complete network design, where peers are also respondents. With such a design, possible others who were not nominated are also known, enabling us to show whether similarity is more likely to occur among friends compared with non-friends. Secondly, measures of relationships were often limited to the nomination of up to only three best friends, thus excluding other potentially influential contacts in the peer network and reducing the possibility of controlling for structural effects such as network closure (i.e., the phenomenon that friends of friends tend to be friends). Even with such sparse network data, some studies (e.g., Kandel, 1978) further reduced the data to mutually confirmed first choices. By allowing for more responses, a richer network structure can be assessed and more efficient use of the data can be made. Including relationship nominations that are not necessarily mutually confirmed takes into account the development of friendship relations. Thirdly, most network studies were cross-sectional, hampering the analysis of processes over time: cross-sectional analysis can provide evidence for an association between adolescent delinquency and peers' delinquency but cannot distinguish whether this association is caused by influence or selection. Longitudinal panel designs solve this problem. Fourthly, the few studies that were longitudinal were often case studies of one or two youth groups, and thus lacked statistical power to test influence and selection. Generalization to a population of classrooms is impossible when using such case studies. By analyzing the dynamics of multiple friendship networks in parallel groups, this problem can be addressed. Finally, studies on peer influence need to control for selection effects and vice versa, otherwise the investigated effect will be overestimated (Cohen, 1977; Hartup & Stevens, 1997; Kandel, 1978). By choosing a statistical approach that allows for simultaneous estimation of both effects, such overestimation is avoided. The method proposed in this article is designed specifically for the analysis of evolving networks and coevolving behavioral dimensions, and represents selection and influence processes simultaneously, thus controlling the estimation of parameters for each process and controlling each process for the other.

The study design chosen for addressing these issues is as follows. We used a longitudinal approach to detect the determinants of friendship formation and delinquency in a number of networks. We investigated 21 classroom networks in the first grade of secondary school (544 students), measuring delinquency levels and friendship nominations at four time points in one school year to obtain longitudinal information about behavior and network dynamics. The students nominated up to 12 best friends in

class and answered questions about their own delinquent behavior. We have complete network data with the class as network boundary. To model and analyze our data, we used recently developed methods for the joint analysis of social network and behavioral dynamics (Snijders et al., 2007a; Steglich, Snijders, & Pearson, in press).

Theory and Model

This section presents a non-technical account of the model for the coevolution of network and behavior (in our example, friendship and delinquency) in one group (here, the classroom). For the mathematical details, we refer to Snijders (2001) and Snijders et al. (2007a).

Selection and influence processes occur at the level of the individual adolescent, within the dynamically changing context of the peer group that is composed of similar individuals. The association of delinquency levels between friends is an emergent group-level property resulting from dynamics in the individual adolescent's relational properties (friendships) and behavioral properties (delinquency). For describing and modeling selection and influence processes, it is natural to formulate our theoretical modeling framework as based on individual actors making individual decisions while being embedded in the social network, which is changing as a consequence of what they themselves and the other actors do. Friendships are treated here as the result of unilateral dichotomous (friend/no friend) choices, as reported by the focal individual. Thus, what decisively matters for a friendship relationship to affect changes in friendship or behavior is whether this friendship is perceived to exist by the focal actor involved in the change. Confirmation by the partner is not necessary to have a friendship tie but constitutes an additional property of the relationship that we will control for (*reciprocity*). In terms of data structure, this means that we analyze friendship networks as directed graphs (Wasserman & Faust, 1994). Analyzing unilateral friendship choice (which may then be reciprocated or not) gives a more realistic account of friendship evolution. Friendship relations do not emerge out of the blue but may be proposed by one of the involved persons and evolve over time. The basic data structure is a panel dataset on relationships and behavior, which means that for a number of moments in time (in our case, four), the entire network (friendship) as well as the behavior (delinquency) of all individuals in the group are recorded. This data structure is obtained for a number of groups (school classes) that are regarded as replications of each other, and combined in a meta-analysis (Snijders & Baerveldt, 2003).

The model for a single group is defined as follows. Network ties are denoted by Y_{ij}, where i and j are individual actors, and $Y_{ij} = 1$ or 0, respectively, according to whether a friendship tie from i to j exists or not. This is said to be an outgoing tie for i and an incoming tie for j. The behavior of individual i is denoted Z_i, and this is assumed to be an ordered discrete variable with values 1, 2 to H for some integer $H \geq 2$. The total network is the matrix $Y = (Y_{ij})$; the behavior is summarized in the vector $Z = (Z_i)$. Because these are time dependent, we may write them as $Y(t)$ and $Z(t)$. States, that is, actual or potential outcomes of the stochastic processes $Y(t)$ and $Z(t)$, are denoted by the small letters y and z.

The analysis of selection and influence effects is based on a process model for the simultaneous dynamics in the friendship network and the level of delinquent behavior of the actors in the network (Snijders, 2001). This process, which can be simulated on a computer, unfolds between the observation moments of the panel waves. The model is called a stochastic actor-driven model, as it is stochastic in nature and is formulated

in terms of changes made by the actors in their outgoing ties and their behavior. The following assumptions are made. The mathematical details are elaborated in Snijders et al. (2007a), where generalizations of this model can also be found.

(1) The process ($Y[t]$, $Z[t]$) is a Markov process, with a continuous time parameter t. This means that changes can and will happen continuously between the observation moments, and the probabilities of changes depend, given all the available covariates, only on the current state ($y[t]$, $z[t]$) and not on the further past. This is a non-trivial assumption, but it is a natural first approximation, and it may be noted that practically all simulation models of individual development have this property.

(2) The process moves only in small changes, that is, at any time point t not more than one of all the variables Y_{ij} and Z_i can change. Moreover, at any time point the behavioral variable can be changed no further than to an adjacent category. Thus, at any time point, either nothing changes or one actor i changes his or her friendship tie to some other actor j, or one actor i changes his or her behavior by −1 or +1 (respecting the boundary values 1 and H of the behavior variable).

(3) Each actor gets, at random moments, the opportunity to change one outgoing tie: create one new tie, discontinue one existing tie, or leave all ties unchanged. The probabilities of the network changes made by actor i are determined by a vector of characteristics of this actor, denoted $s_{Yi}(y, z)$, and a vector of parameters β_Y indicating the weight of each of the elements of $s_{Yi}(y, z)$ in determining the probability. The characteristics will depend on the network position of actor i and on the behavior of this actor and of the other actors (in particular those tied to i); in particular, they can be dynamically changing over time. Examples of elements of $s_{Yi}(y, z)$ are the current number of friendship choices of i or the current average delinquent behavior of i's friends. Probabilities of moving toward the new state (y, z) are assumed to be proportional to the exponential function of the linear combination of parameters and positional characteristics, $\exp(\beta_Y' \, s_{Yi}[y, z])$. Higher values of the β_Y parameter of an element of $s_{Yi}(y, z)$ thus imply a stronger tendency for the network to change in such a way that this element of $s_{Yi}(y, z)$ becomes higher.

(4) Similarly, each actor gets, at random moments, the opportunity to change his or her behavior: the options are one unit up, one unit down (as long as this does not lead outside the range of Z_i), or no change. The probabilities of the behavior change of actor i are determined by a vector of characteristics of the actor, denoted $s_{Zi}(y, z)$, and a vector of parameters β_Z indicating the weight of each of the elements of $s_{Zi}(y, z)$ in determining the probability. Probabilities of moving toward the new state (y, z) are assumed to be proportional to the exponential function of the linear combination, $\exp(\beta_Z' \, s_{Zi}[y, z])$. Examples of components of $s_{Zi}(y, z)$ are the value z_i of i's behavior, or the product of z_i and the average delinquent behavior of i's friends. Higher values of the β_Z parameter of these components will imply a stronger tendency for the behavior to move into a direction of higher values of these components.

These assumptions can be loosely summarized by stating that changes in the network and the behavior occur on arbitrary moments between the observations, the probability distribution depends on the current state of the network and the behavior of all group members according to a Markov process, and these probabilities depend on the functions $\beta_Y' \, s_{Yi}(y, z)$ for network changes and $\beta_Z' \, s_{Zi}(y, z)$ for behavioral changes. These functions are called the *objective functions*, as they may be interpreted as

seemingly representing the objectives, or resultants of preferences and constraints, of the actors in their relational and behavioral choices, respectively.

These two types of changes distinguish the selection part of the model (assumption 3 above: network changes) from the influence part of the model (assumption 4 above: behavioral changes). The model defines a mutual dependence between the networks and the behavior because the current behavior will figure in the objective function for friendship dynamics whereas the existing network structure will figure in the objective function for behavioral dynamics. Determination of the characteristics $s_{Yi}(y, z)$ and $s_{Zi}(y, z)$, which drive the dynamics of networks and behavior, is explicated below in the sections on the selection part and the influence part of the model. The weight vectors β_Y and β_Z are the statistical parameters to be estimated from the data and to be statistically tested. A further set of statistical parameters consists of the rates of change, that is, the rates at which actors have the opportunity to change one of their network ties or their behavior. Generalizations (e.g., non-constant rates of change) are discussed in Snijders et al. (2007a).

In this framework, tendencies toward a positive association between adolescents' and friends' delinquency can be expressed in terms of tendencies in the two types of changes made by the actors, relational or behavioral. On the one hand, such an association can be brought about by a tendency of the actors to form and maintain friendships with those peers who have a similar delinquency level while abandoning friendships with peers who have a dissimilar delinquency level; this is covered by assumption (3) above. On the other hand, the positive association can result from adjustment to friends, that is, a behavioral tendency of the actors to adopt behavior that is more similar to the behavior of their network neighbors, as covered by assumption (4) above. Hence, a positive association between adolescents' and friends' delinquency will be explained as a compound outcome of several generative mechanisms, the relative importance of which we will assess by estimating specific parameters for each mechanism and testing these parameters for significance. We will now elaborate on the specification of the two model components.

The Selection Part of the Model

The selection part of the model is intended to explain friendship formation and maintenance, and is defined by listing the elements of the vector $s_{Yi}(y, z)$, which forms the basis for the network objective function. There are elements representing actor covariates, endogenous network, and tie history effects.

Following the inability model, we hypothesize that shared levels of delinquency of any two adolescents fosters friendship formation and maintenance between them. This effect is labeled *shared delinquency level*. Based on the same theory, we expect that adolescents with a higher level of delinquency are less socially involved because they are avoided by adolescents who are not delinquent. This hypothesis can be split into two effects. These are the *delinquency ego* and *delinquency alter* effects. More delinquent individuals find it more difficult to make friends (a negative effect for *delinquency ego*) and are less attractive as friends (a negative effect for *delinquency alter*). We also include actor covariate effects known from earlier studies. Literature provides many arguments why similarity between two actors enhances the chances to become friends (McPherson, Smith-Lovin, & Cook, 2001). One of the arguments is that similarity makes it easier to give behavioral confirmation and share activities. We hypothesize that increased likelihood of becoming friends holds for gender (*gender*

similarity) and ethnicity (*ethnicity similarity*) because these are basic social identification characteristics for adolescents (Baerveldt, Van Duijn, Vermeij, & Van Hemert, 2004; Clark & Ayers, 1992; Eisenberg, Martin, & Fabes, 1996; Hallinan & Teixeira, 1987; Hartup & Stevens, 1997; Lubbers, 2003).

In addition, endogenous network (or structural) effects are effects of the network on itself, expressing that the network acts as an opportunity set as well as a constraint on friendship formation (Snijders, 2001). Controlling for such endogenous network dynamic effects is an important way of taking into account the dependency of friendship ties within the school classes. The first element is the selectivity of the friendship relationship, implying that friendship networks will be rather sparse: friendship ties are not formed purely at random but mainly if there are antecedents for it in the network itself or in the attributes. The sparseness of the network is expressed by including the *outdegree* (number of choices made) in the model. A negative sign is expected, reflecting that the creation and maintenance of friendship ties to arbitrary others will be avoided. Following the literature on adolescence (Giordano, 2003), development (Hartup, 1996), and friendship dynamics in general (Van de Bunt, 1999), we further predict two more endogenous network effects. The *reciprocity* effect captures the tendency of an actor to reciprocate friendship choices made by others. We expect a positive effect of reciprocity on friendship formation, as reciprocity reflects mutual affection and trust (Leenders, 1996). Finally, to control for the effect of local clustering or transitive closure in friendship networks (Davis & Leinhardt, 1972), we include an effect of *transitivity*, measuring the tendency to call a friend's friend one's own friend. Here also we expect a positive sign.

We also include an effect of tie history in our model. It seems likely that students who have been friends in primary school will stay friends in secondary school (Lubbers, 2003). Their friendship has a history, which will give the relation a stronger continuity than newly formed friendships have. Therefore, having been friends in primary school is expected to be positively related to friendship formation and continuation.

The Influence Part of the Model

The influence part of the model captures the determinants of changes in delinquency levels and is defined by listing the elements of the vector $s_{Zi}(y, z)$, which forms the basis for the behavior objective function. These elements contain the hypothesized determinants of the probabilities of changes toward other values of the behavior variable. These determinants may include characteristics of the focal actor ('ego'), the current behavior of ego and of ego's friends. Theories about social influence can be expressed by including the latter type of effects, which imply a dependence of the behavior of the focal individual on the behavior of his or her friends. Following the ability model, we hypothesize that the average delinquency levels of friends positively affect an adolescent's delinquency level. In other words, adolescents whose friends have a high average level of delinquency have a higher tendency toward delinquent behavior. We label this effect *average delinquency of friends*.

To model the overall tendency of ego's delinquent behavior on delinquent behavior, we include two basic components in the objective function. One is a linear and the other is a quadratic component, defined by elements z_i and z_i^2 in the vector $s_{Zi}(y, z)$. These will be called *tendency delinquency* and *tendency delinquency squared* effects. Together, these can be interpreted as a curvilinear function expressing the result of

inclinations and constraints for the possible values of delinquent behavior, for an individual who scores average values on all other variables. When the coefficient of the quadratic term is negative, the function is unimodal, and current values of delinquency lower than the location of the mode predict higher values of delinquency, whereas for values higher than the location of the mode the individual is inclined to decrease his or her delinquent behavior. In other words, delinquency then can be regarded as a self-correcting process. On the other hand, if the coefficient is positive, the function is U shaped. Low values predict lower levels and high values predict higher values. This represents a self-reinforcing process. We have no expectation regarding the direction of these two basic parameters. In the influence part of the model, we also control for gender (South & Messner, 2000). This effect is labeled *male*. In line with Steffensmeier and Allan (1996) and Dodge et al. (2006), we expect boys to be more delinquent than girls. In this sample, it is not necessary to control for age because everybody within a classroom is of nearly the same age. The mathematical expressions for the elements in the objective functions are provided in the Appendix attached to this article.

Method

Sample

In The Netherlands, students usually enter secondary school at the age of 12. Secondary school is a new school for the students, where new classes are formed and many classmates meet for the first time. Classmates spend most of their time at school together. The sample comprises medium-sized schools. Every educational track was included. Some schools are private, of different denominations, whereas others are public; there are urban as well as rural schools.

We collected longitudinal (four waves) network data from 3171 students in 126 first-grade classrooms in 14 secondary schools in The Netherlands (Knecht, 2006). The data collection started in August and September 2003, in the first weeks of the new school year, using a standardized questionnaire. Subsequently, the same students were asked to fill in the questionnaire three more times at three-month intervals, resulting in four waves in the academic year 2003–2004. Six of the 126 classes did not participate in all waves or a high number of students were missing on the day of the survey, leaving us with 120 classes.

Measures

The main instrument was a self-completed questionnaire for the students. All data used in this study are self-reported. Relational questions about friendships with classmates and friendships in primary school were tested in earlier research (Baerveldt et al., 2003); all questions, including those regarding delinquency, were also tested in a pilot study. Trained assistants distributed the questionnaire and were available to answer students' questions. The assistants stressed that all information would be treated confidentially. The students usually filled in the questionnaire within 45 min (one class period). The percentage of those refusing to fill in the questionnaire at any given time was very low. Some of the students dropped out or were absent on the day of the survey. The students' response rate was quite high—never below 94 percent at any of the four measurement points. For an overview of the full sample see Table 1. We now describe the dependent, control, and background variables.

Table 1. Overview of Data

			Full sample 120 classes (N = 3017)			Subsample 21 classes (N = 544)		
	Coding	Wave	*M* or percent	*SD*	Missing in percent	*M* or percent	*SD*	Missing in percent
Dependent variables								
Friends of respondent	1–12	A	3.56	2.56	4.5	3.78	2.77	4.2
		B	4.19	2.55	9.0	4.31	2.79	7.9
		C	4.31	2.66	7.6	4.51	2.85	7.0
		D	4.06	2.51	7.2	4.24	2.70	6.4
Delinquency	1: none–5: high	A	1.25	.47	18.6	1.34	.57	6.1
		B	1.38	.57	21.2	1.51	.62	8.3
		C	1.46	.65	20.0	1.58	.74	7.4
		D	1.49	.71	19.6	1.62	.82	6.4
Control variables								
Gender	1: female 2: male		1: 49 percent		0.0	1: 45 percent		0.0
Ethnicity	1: Dutch 2: non-Dutch		1: 83 percent		7.7	1: 78 percent		7.5
Friends in primary school	1–12		1.76	1.84	4.5	1.67	1.89	4.2
Background variables								
Age	10–15 years	A	12.11	.49	5.6	12.12	.52	5.5
Socioeconomic status	1: low–4: high		2.56	.93	31.2	2.53	.94	32.4
Respondents with most friends in class		B	52 percent		12.3	50 percent		12.1
Respondents with most important friends in class		B	59 percent		16.0	57 percent		16.9

Friendship. The students' friendship relationships were assessed by asking about up to 12 best friends in class. The actual question was 'Who are your best friends in class?' In this way we obtained the information about the entire friendship network within a class. To respect the respondent's privacy we used an identification number for each student in a class. The identification number in combination with a code for each class allowed identifying each student in each wave.

Delinquency. The students were asked about offences committed in the last three months. Research (Köllisch & Oberwittler, 2004) shows that more realistic prevalence rates are obtained with paper-and-pencil interviews at school than with face-to-face interviews in households. We asked for frequency of stealing, vandalism, graffiti, and fighting, using five answer categories: 'never', 'once', 'two to four times', 'five to ten times', and 'more than 10 times' in the last three months. We treated these ordinally recorded frequencies as interval variables, assuming that these categories are roughly equidistant in perceived intensity. A delinquency scale was created by averaging the four items, with values ranging from 1 (no delinquency) to 5 (very high level of delinquency). Of the analyzed cases, we could replace 32 missing values by a corrected item mean, meaning that the imputed value is based on an item mean related to the mean value of the items that are known for this person (Huisman, 2000). The scale has sufficient internal cohesion (Cronbach's alpha ranges between .56 and .75) and is sufficiently one-dimensional (the first eigenvalue in a factor analysis is always above 1.8; the other eigenvalues are always below 1.0). Boys are generally more delinquent than girls.

Control Variables. Almost half of the students were girls. Dutch students were in the majority (83 percent). Being Dutch is defined as having at least one parent who was born in The Netherlands and speaking Dutch at home. The students were asked accordingly. To assess tie history, we asked students whether they have current classmates with whom they have been friends in primary school. Not all students reported having any classmates with whom they were friends already in primary school.

Background Variables. The students were on average 12 years and 1 month old at the first data collection. Socioeconomic status is assigned based on the father's and mother's job, educational level needed for this job, and job status. Most of the students have most of their friends and the most important friends in their class.

Statistical Procedure

The actor-driven dynamic statistical model of Snijders et al. (2007a), sketched in Section 3, is used to analyze the contributions made jointly by influence and selection processes in the observed dynamics of networks and delinquent behavior. To minimize the possibility of spurious findings due to effects of contextual variables, the data are analyzed per classroom so that only within-group comparisons are made. Because classrooms are small in size and changes in delinquency scores are not very frequent, an estimation method is necessary that makes optimal use of the information in the dataset. To this end, we employ the recently developed Markov chain Monte Carlo (MCMC)-based maximum likelihood estimation method (Snijders, Koskinen, & Schweinberger, in press), which is statistically more efficient than the estimation procedure of Snijders et al. (2007a). The currently available computer software for this method

yields good results only for classroom datasets that are sufficiently informative: for datasets with too many missing data or too few changes between subsequent waves, the algorithm is likely to run into convergence problems (and therefore likely to yield inconclusive results). We therefore selected a smaller number of classes from the original sample of 120 classes based on the following two pragmatic criteria. Firstly, we focused on classes with few missing values for delinquency to maximize the amount of information and to minimize the impact of missing data on the results. The total number of missing values on the delinquency scale per class over all waves does not exceed 12 for any of the included classes. Secondly, we chose classes where delinquency tends to change much over time and where, accordingly, the research question can be studied (note that delinquency does not play a major role in this age group; see the descriptive statistics above). The sum of absolute changes of delinquency scores in the observation period is at least 26 for all included classes. By applying the two criteria, we retain 21 classes, for all of which the estimation algorithm yielded converging estimates, used in the results reported below.

This selection is unrelated to delinquency similarity between friends; therefore, it will not lead to bias with respect to the hypotheses about delinquency-related selection and influence. However, the selection potentially biases the estimation of the extent of social influence because in those classes with a small amount of change on delinquent behavior, influence—interpreted here as changes in behavior depending on the behavior of friends—cannot have been large. Interpretation of the results should take into account that the research population has been reduced to the set of classrooms with relatively high changes in delinquency level. Our results can only be generalized to classes where there is change in delinquency.

Table 1 shows how the subsample relates to our whole dataset on a series of descriptive statistics. The sample matches the dataset in background variables. The adolescents in the subsample nominate slightly fewer others as friends, and they are slightly more delinquent than all adolescents in the dataset. The first difference is not significant, however. The latter difference could be expected, given the selection criterion and the fact that delinquency is overall rare. Because non-delinquent students can only change their delinquency score by becoming more (not less) delinquent, selection on the total amount of change favors delinquent classes.

For the analyses of our selected classes we follow a strategy of forward model selection (Snijders et al., 2007a) by first fitting a simple model that does not contain any effects representing friendship selection based on delinquency or influence of friends on delinquent behavior. Such a model corresponds with the overall null hypothesis that friendship and delinquent behavior evolve independently and are not connected by selection or influence processes. This model contained effects of *outdegree*, *reciprocity*, *transitivity*, *gender similarity*, *ethnicity similarity*, and *friends in primary school* for the friendship dynamics and effects of *tendency delinquency*, *tendency delinquency squared*, and *male* for the behavioral dynamics. After estimating this simple model (results not reported), we tested the significance of two alternative operationalizations of the selection paradigm as well as two alternative operationalizations for the influence paradigm with a score test (Snijders et al., 2007a). This test assesses the improvement of fit that would be obtained by extending the model through inclusion of the tested effect without control for the other three tested effects. This allows a choice between the operationalizations according to the best model fit. The first selection operationalization presumes that individuals prefer to be friends with others at the same level of delinquent behavior (*similarity* effect), the second that

individuals do not have to be exactly similar but that those with higher levels of delinquent behavior have a stronger preference for friends who also have higher levels of delinquency (*shared delinquency level* effect). Of the two influence operationalizations, the first presumes that individuals tend to adjust their delinquency level to the level of delinquency of their friends (again a *similarity* effect), the second that individuals with friends who, on average, have a higher level of delinquent behavior tend to acquire a higher level of delinquency but not necessarily completely similar to their friends' level (*average delinquency of friends* effect). These alternatives have the same interpretation for practical purposes but different mathematical expressions for the model specification, so that there are no good prior grounds for choosing between them. Comparing results of the score tests, we chose the effects that showed a higher degree of model fit increase and added these to the model. These were the *shared delinquency level* effect for selection and the *average delinquency of friends* effect for influence.[1] By including these in the same model, the selection and influence processes are controlled for each other and thus can be distinguished—which was not possible when using earlier models. The choice of the best-fitting representations leads to a chance capitalization, which is accounted for by applying a Bonferroni correction when interpreting the final results.

The model fitting itself follows a two-stage procedure. Firstly, the friendship-delinquency coevolution process is analyzed by fitting the same model for each class separately. The analyses are carried out using the maximum likelihood option in SIENA version 3.1 (Snijders, Steglich, Schweinberger, & Huisman, 2007b). Subsequently, the different classes' estimation results are aggregated in a meta-analysis according to Snijders and Baerveldt (2003), employing principles going back to Cochran (1954). In this meta-analysis, it is assumed that parameter values may differ across classrooms; the estimates obtained are the sum of true parameter values and random error. The population means and standard deviations of the true parameter values are tested and estimated for each effect separately. The test of the mean values is based on the *t*-ratio of estimated mean parameter to standard error (approximately in a normal distribution); the test of the variance is carried out by means of a *chi*-squared test, of which only the *p* value is reported here.

Results

Table 2 presents the results obtained by the meta-analyses of the SIENA results. We report the estimated mean parameters with their standard errors, the estimated between-classroom standard deviations of the parameters, corrected for the standard errors of the estimates per class, and the *p* values of the tests that the parameter variance is 0. Most of the effects in this model are significant, as most parameter estimates are more than 1.96 times their standard errors, indicating significance on the 5 percent level.

Results for Selection Process

The hypothesis tested in the selection part is that students tend to be friends with others who have a similar delinquency level to theirs. Results for the *shared delinquency level* effect in Table 2 show that more delinquent adolescents have a greater tendency to have friends with a higher level of delinquent behavior. The effect has such a high *t*-ratio (4.0) that its significance is not affected when a Bonferroni

Table 2. Results of Meta-analysis of SIENA Analyses (21 Classes)

	Estimated mean parameter	*SE*	Estimated true *SD*	*P* value of test that variance of parameter is 0
Selection part				
Shared delinquency level	.160***	.037	<.001	.402
Delinquency ego	−.002	.091	.37	<.001
Delinquency alter	−.077	.044	.15	.019
Outdegree	−1.907***	.027	<.001	.044
Reciprocity	.847***	.053	.16	.011
Transitivity	.194***	.009	.03	.002
Gender similarity	.637***	.081	.32	<.001
Ethnicity similarity	.108	.056	.18	.010
Friends in primary school	.409***	.072	.21	.295
Influence part				
Average delinquency of friends	.032	.156	<.001	.998
Tendency delinquency	−.535***	.071	.16	.045
Tendency delinquency squared	−.000	.062	.19	.092
Male	.387***	.161	.53	.378

* $p < .05$, ** $p < .01$, *** $p < .001$.

correction is applied to reflect that the best fitting operationalization was chosen out of two operationalizations of selection and influence. The other effects related to delinquency, *delinquency ego* and *delinquency alter*, are not significant. To illustrate the delinquency-related contribution to the network objective function, consider Figure 1. A qualitative difference can be observed between non-delinquent adolescents (level 1) for whom attractiveness of potential friends decreases with delinquency level and strongly delinquent adolescents (levels 3 through 5) where attractiveness increases with delinquency of alter. Taken together, we found weak evidence that higher levels of delinquency decreases attractiveness to be chosen as a friend as indicated by the *delinquency alter* effect.

To get a better understanding of the strength of the *shared delinquency level* effect, we compare it with the *gender similarity* effect by looking at their effect sizes. A 95 percent confidence interval is computed by adding plus or minus two times the standard error multiplied with the standard deviation (see fourth column in Table 2) of the delinquency variable to the mean parameter that is also multiplied by the standard deviation. Because the *shared delinquency level* effect is based on a product, we take the squared standard deviation of delinquency across the observation points. This is used as an approximate effect size. For the *shared delinquency level* effect we obtain a confidence interval of .041, .111; for *gender similarity* this is .238, .400. The interval for the delinquency interaction is completely below the interval for gender similarity. This indicates that the selection effect based on gender is larger than the one based on delinquency. We find a strong negative *outdegree* effect (–1.907), as expected. A tie to an arbitrary other student, without specific individual or network characteristics adding

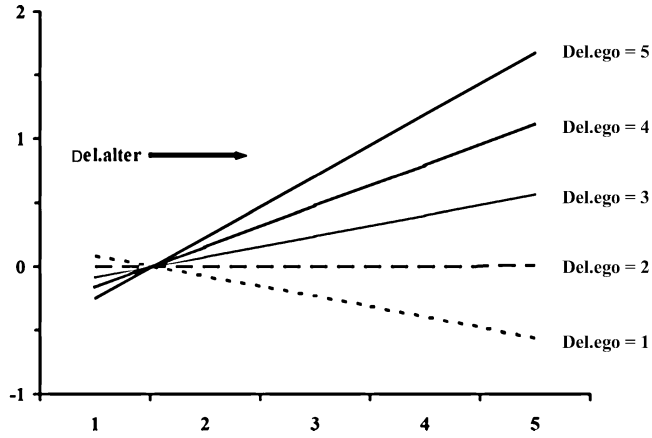

Figure 1. Joint Contribution of the Shared, Ego, and Alter Effects of Delinquency to the Network Objective Function for Various Ego-alter Configurations.

to his or her attractiveness, will be avoided. For *reciprocity* (average parameter estimate .847) and *transitivity* (.194) we find the expected positive effects. Having the same gender is an important criterion for friendship selection; boys prefer to be friends with boys, and girls with girls. The average *ethnicity similarity* effect is not significant, but this effect does differ between schools (variance $p = .010$). Finally, if available in the new class, friendships from primary school are likely to be maintained in secondary school.

Results for Influence Process

Our second main hypothesis is that students adjust their own behavior in accordance with the average behavior of their friends. This hypothesis is captured in the influence part of the model. There is no support for the hypothesis that adolescents adjust their delinquent behavior in order to become similar to their friends. The *tendency delinquency* effect is significantly negative, indicating that delinquent behavior is on average unattractive to this population. The *tendency delinquency squared* effect is not significant. Gender has an effect on delinquency level ($p < .001$). Given the same conditions, boys tend to develop higher levels of delinquency than girls.

Between-class Variances

We found significant ($p < .05$) variance between classes for all effects except of the following ones: *shared delinquency level*, *friends in primary school*, *average delinquency of friends*, *tendency delinquency squared*, and *male*. A significant between-class variation in the parameter for a particular effect points to differences between the classrooms in this aspect of the network-behavior coevolution process. An approximate 95 percent confidence interval for the parameter (assuming normality) can be obtained by adding two estimated true standard deviations below and above the estimated average parameter. When this interval is mainly positive or mainly negative, it indicates an effect of a consistent sign but of varying magnitude. This is the case for the *delinquency alter* effect, which is predominantly negative. When it contains important

ranges of positive as well as negative values, on the other hand, it suggests the existence of qualitatively different processes in different classrooms. This is the case here for the *delinquency ego* effect and the *tendency delinquency squared* effect. The parameter estimates for the latter effect (estimated mean −.000, estimated standard deviation .19, leading to an interval from −.38 to +.38) suggest that in some classrooms the feedback effect may be negative, corresponding to random deviations of delinquency levels around a stable average, whereas in other classrooms it may be positive, corresponding to a polarized classroom where some students have reached and remain at a relatively high level of delinquency while the rest (presumably the majority) of the classroom fluctuates around low delinquency levels. This merits further research, but exploration of this issue with the current dataset would be mainly speculative, and in the context of this article we refrain from it.

Correlations of parameter values by class characteristics such as average delinquency level per class, average socioeconomic status of parents per class, class size, educational level, proportion of non-Dutch students in the class, and proportion of males in the class were assessed in an exploratory way in order to specify the differences in selection and influence processes between classes. No significant effects were found (parameter values not reported). However, a positive correlation between class size and the value of the *shared delinquency level* effect was found, suggesting that selection processes based on delinquency are stronger in larger classes. This might be interpreted by the wider choice of possible friends in larger classes, giving more opportunity to select friends who are similar.

Discussion

The purpose of this study was to investigate the dynamics of delinquent behavior among young adolescents with a new statistical methodology for the investigation of selection and influence processes in networks observed according to a panel design. The statistical model, as defined for a single group, can be regarded as a stochastic simulation model representing the observed differences in networks and behavior at consecutive observation points as the net result of many small changes occurring continuously between the observations. In this model, the probabilities of changes in the network and behavior depend on the current state of network and behavior combined. Such a model can represent selection processes, influence processes, and combinations of the two. The application of this type of model allows the testing and estimation of specified parameters. These parameters represent the weights of the behavior of self and peers in the selection and deselection of friends, as well as the weights of the behavior of friends on the behavior of the focal individual. This is done in such a way that the estimation of selection and influence processes is controlled for the other process and for other effects related to the network (reciprocity, transitivity) and to individual or dyadic attributes. The inclusion of selection and influence processes in one model safeguards against overestimating the effect of either when only one is examined in a model and gives the possibility to disentangle selection and influence processes.

We examined to what extent and how friendship selection is based on the combination of personal and peer delinquency and to what extent friends have an influence on adolescents' level of delinquency. In this way we wanted to explain the causes for a positive association between adolescents' and friends' delinquency in early adolescence, differentiating between selection and influence processes. Following social

control theory (Hirschi, 1969), we hypothesized that students with lower delinquency levels are more likely to become friends with others who have lower delinquency levels. Thus, a positive association of an adolescent's and a peer's delinquency level fosters friendship formation. Following social learning theories such as differential association theory (Sutherland & Cressey, 1974), we hypothesized that friends adjust their own delinquent behavior to the average delinquent behavior of their friends, thus becoming more similar to them. We tested these hypotheses with longitudinal multiple network data that gave us information from all adolescents in a friendship network within a classroom about their friendship relationships to classmates and their delinquent behavior at four time points within one school year.

Results indicate that delinquency plays a role as a selection criterion for friendship. We found that adolescents tend to make friends with others who have a similar delinquency level, and we found weak support that delinquent students are less attractive as friends. This part is consistent with the inability model derived from social control theory and in line with Baron and Tindall (1993), who also found support for social control theory when examining the strength of ties in relation to delinquent attitudes. Another part of the inability model, that adolescents are socially less involved, was not supported by our data. Furthermore, we found other aspects such as reciprocity, transitivity, same gender, and tie history contributing to friendship choices, corresponding with earlier research on friendship. The effect size of the interaction effect between own and other's delinquent behavior on friendship choice appeared to be of smaller magnitude compared with the effect of gender similarity on friendship choice.

The illustration of the selection effect in Figure 1 suggests a polarization of network members into two groups. The non-delinquent majority of students shows an aversion to delinquent friends. These are the students who score 1 on the scale—69 percent of our sample in the first wave, decreasing to 55 percent in the fourth wave. In contrast, the minority of very delinquent students, scoring 3 through 5 on the scale, shows a preference for delinquent friends. This minority consists of 6 percent in the first wave, increasing to 15 percent in the fourth wave. In between these groups, the students who score 2 on the scale show indifference (or insensitivity) to their friends' delinquency; on average, this middle group consists of 30 percent of the students.

The second main hypothesis—which relates to the ability model and thus to social learning theories such as differential association theory—on the influence of friends on delinquent behavior was not supported by the data. This finding is remarkable as the research population had to be reduced to a set of classrooms with high changes in delinquency. In these classes higher rates of social influence were to be expected compared with the classes that were excluded. We only found delinquency level to be influenced by gender. Boys' delinquency levels are higher on average than girls' delinquency, and it also increases more than girls'.

This empirical study faces some limitations. Firstly, our focus was on friends within school classes. Although relationships within a classroom form an important social environment for adolescents, they do not represent their entire social world of peers. In addition, it has been pointed out that friends from outside the school should not be disregarded, as they may be more likely to behave delinquently (Dishion et al., 1995). We did test whether delinquent students reported most of their friends and their most important friends to be from outside the class. This was not consistently the case. Secondly, one assumption of social control theory (Hirschi, 1969) is that relationships among delinquent adolescents are of poor quality. Because we do not have information

on the intimacy of the relationship, frequency of contact, or other measures of friendship quality, we are not able to test that part of the theory.

The focus of our study was on young adolescents who are on average 12–13 years old. Our results apply to this population where delinquency levels are rather low on average and for those classrooms where there are changes in delinquency. The importance of delinquency may differ for other age groups. For instance, Burk et al. (2007) found selection as well as influence processes related to delinquency in a study that included adolescents up to the age of 18 years.

Here we presented a new statistical method for data with a complex dependence structure; more research is needed to gain a better understanding of its properties. In particular, the sensitivity of the results for the model assumptions is an important issue. Studying this issue will also shed more light on the question of how to specify the model to obtain robust results. It will also be important to develop effect size measures. Our empirical application of the new method taught us that not more than a small fraction of the data should be missing and that there should be enough total variation over time in the behavior variable. In our study these requirements led to a relatively large loss of analyzable classrooms. In our network questionnaire, information was requested about within-classroom friends only. For future work it is advisable to do everything possible to limit the extent of missing data and, when feasible, to collect network information for larger units (e.g., in each school being studied, the network between students in all first-grade classrooms). This will increase the amount of information on the network change as well as on the behavioral change, thereby also diminishing the loss (if any) in analyzable networks. It will also diminish problems associated with the problems in determining the network boundary.

To combine this model across groups, this article employed a simple meta-analysis procedure. It would be interesting to combine the groups using a random coefficient model, combining the actor-oriented dynamic network model presented here with the ideas of hierarchical linear and non-linear modeling. If the requirements of such methods are met, the statistical power is higher than that in the simple meta-analysis. Such methods are not yet available, however. The advantage of the meta-analytic approach is that it requires weaker assumptions than a random coefficient model.

The strength of the article includes the attempt to overcome methodological problems of earlier studies with our statistical methodology and research design. One strong point of the design is the use of longitudinal network data collected for a relatively large number of classrooms, which seems to be the most accurate way to track down the processes that lead to a positive association between adolescents' and their friends' delinquency. Another strong point is the use of self-reported data in order to avoid the known problems of overestimating the similarity of the friend's behavior to the respondent's behavior when using perceived peer data.

The results can be summarized by concluding that for the dynamics of delinquency between young adolescents in the general population, selection processes and social control theory should be considered as theoretical explanations for the similarities between friends in their levels of delinquency. We found support for selection processes in line with social control theory but no support for influence processes as predicted by differential association theory. We see the SIENA program and its underlying model for the coevolution of networks and behavior as a promising tool in the study of selection and influence processes. Its future application can hopefully yield further conclusions about the balance between selection and influence, which may well be different in other populations and for other dependent behavior variables.

References

Aseltine, R. H. (1995). A reconsideration of parental and peer influences on adolescent deviance. *Journal of Health and Social Behavior*, *36*, 103–121.

Baerveldt, C., Van Duijn, M. A. J., Vermeij, L., & Van Hemert, D. A. (2004). Ethnic boundaries and personal choice. Assessing the influence of individual inclinations to choose intra-ethnic relationships on pupils' networks. *Social Networks*, *26*, 55–74.

Baerveldt, C., Van Rossem, R., & Vermande, M. (2003). Pupils' delinquency and their social networks. A test of some network assumptions of the ability and inability models of delinquency. *Netherlands' Journal of Social Sciences*, *39*, 107–125.

Baron, S. W., & Tindall, D. B. (1993). Network structure and delinquent attitudes within a juvenile gang. *Social Networks*, *15*, 255–273.

Bender, D., & Lösel, F. (1997). Protective and risk effects of peer relations and social support on antisocial behaviour in adolescents from multi-problem milieus. *Journal of Adolescence*, *20*, 661–678.

Burk, W. J., Steglich, C., & Snijders, T. A. B. (2007). Beyond dyadic interdependence: Actor-oriented models for co-evolving social networks and individual behaviors. *International Journal of Behavioral Development*, *31*, 397–404.

Clark, M. L., & Ayers, M. (1992). Friendship similarity during early adolescence: Gender and racial patterns. *Journal of Psychology*, *126*, 393–405.

Cochran, W. G. (1954). The combination of estimates from different experiments. *Biometrics*, *10*, 101–129.

Cohen, J. M. (1977). Sources of peer group homogeneity. *Sociology of Education*, *50*, 227–241.

Davis, J., & Leinhardt, S. (1972). The structure of positive interpersonal relations in small groups. In J. Berger (Ed.), *Sociological theories in progress* (Vol. 2, pp. 218–251). Boston, MA: Houghton Mifflin.

Dishion, T. J., Andrews, D. W., & Crosby, L. (1995). Antisocial boys and their friends in early adolescence: Relationship characteristics, quality, and interactional process. *Child Development*, *66*, 139–151.

Dodge, K. A., Coie, J. D., & Lynam, D. (2006). Aggression and antisocial behavior in youth. In W. Damon, & R. M. Lerner (Series Eds.), & N. Eisenberg (Vol. Ed.), *Handbook of child psychology: Vol. 3. Social, emotional, and personality development* (6th ed., pp. 719–788). New York: Wiley.

Eisenberg, N., Martin, C. L., & Fabes, R. A. (1996). Gender development and gender effects. In R. C. Calfee, & D. C. Berliner (Eds.), *Handbook of educational psychology* (pp. 358–396). New York: Macmillan.

Feld, L. S. (1982). Social structural determinants of similarity among associates. *American Sociological Review*, *47*, 797–801.

Fletcher, A. C., Darling, N. E., Steinberg, L., & Dornbusch, S. M. (1995). The company they keep: Relation of adolescents' adjustment and behavior to their friends' perceptions of authoritative parenting in the social network. *Developmental Psychology*, *31*, 300–310.

Giordano, P. C. (2003). Relationships in adolescence. *Annual Review of Sociology*, *29*, 257–281.

Gottfredson, M. R., & Hirschi, T. (1990). *A general theory of crime*. Stanford, CA: Stanford University Press.

Hallinan, M. T., & Teixeira, R. A. (1987). Students' interracial friendships: Individual characteristics, structural effects and racial differences. *American Journal of Education*, *95*, 1563–1583.

Hansell, S., & Wiatrowski, M. D. (1981). Competing conceptions of delinquent peer relations. In G. F. Jensen (Ed.), *Sociology of delinquency, current issues* (pp. 93–108). Beverly Hills, CA: Sage.

Hartup, W. W. (1996). The company they keep: Friendships and their developmental significance. *Child Development*, *67*, 1–13.

Hartup, W. W., & Stevens, N. (1997). Friendships and adaptation in the life course. *Psychological Bulletin*, *121*, 355–370.

Haynie, D. L. (2001). Delinquent peers revisited: Does network structure matter? *American Journal of Sociology*, *106*, 1013–1057.

Haynie, D. L., & Osgood, D. W. (2005). Reconsidering peers and delinquency: How do peers matter? *Social Forces*, *84*, 1109–1130.

Hirschi, T. (1969). *Causes of delinquency*. Berkeley, CA: University of California Press.
Huisman, M. (2000). Imputation of missing item response: Some simple techniques. *Quality and Quantity*, *34*, 331–351.
Jussim, L., & Osgood, D. W. (1989). Influence and similarity among friends: An integrative model applied to incarcerated adolescents. *Social Psychology Quarterly*, *52*, 98–112.
Kandel, D. B. (1978). Homophily, selection, and socialization in adolescent friendships. *American Journal of Sociology*, *84*, 427–436.
Kandel, D. B. (1996). The parental and peer contexts of adolescent deviance: An algebra of interpersonal influences. *Journal of Drug Issues*, *26*, 289–315.
Kassenberg, A. (2002). *Wat scholieren bindt. Sociale gemeenschap in scholen* [What binds pupils? Social communities in schools]. Groningen: University of Groningen.
Knecht, A. (2006). *The dynamics of networks and behavior in early adolescence [2003/04]*. Utrecht: University of Utrecht.
Köllisch, T., & Oberwittler, D. (2004). Wie ehrlich berichten männliche Jugendliche über ihr delinquentes Verhalten? Ergebnisse einer externen Validierung [How honestly do male adolescents report their delinquent behavior? Results of an external validation of self-reported delinquency]. *Kölner Zeitschrift für Soziologie und Sozialpsychologie*, *56*, 708–735.
Leenders, R. T. A. J. (1996). Evolution of friendship and best friendship choices. *Journal of Mathematical Sociology*, *21*, 133–148.
Lubbers, M. J. (2003). Group composition and network structure in school classes: A multilevel application of the *p** model. *Social Networks*, *25*, 309–332.
Marcus, R. F. (1996). The friendships of delinquents. *Adolescence*, *31*, 145–158.
Matsueda, R. L. (1982). Testing control theory and differential association: A causal modeling approach. *American Sociological Review*, *47*, 489–504.
Matsueda, R. L., & Anderson, K. (1998). The dynamics of delinquent peers and delinquent behavior. *Criminology*, *36*, 269–308.
McPherson, M., Smith-Lovin, L., & Cook, J. M. (2001). Birds of a feather: Homophily in social networks. *Annual Review of Sociology*, *27*, 415–444.
Moffitt, T. E. (1993). Adolescence-limited and life-course persistent antisocial behavior: A developmental taxonomy. *Psychological Review*, *100*, 674–701.
Ploeger, M. (1997). Youth employment and delinquency: Reconsidering a problematic relationship. *Criminology*, *35*, 659–675.
Reed, M. D., & Rose, D. R. (1998). Doing what Simple Simon says? Estimating the underlying causal structures of delinquent associations, attitudes, and serious theft. *Criminal Justice and Behavior*, *25*, 240–274.
Ross, L., Greene, D., & House, P. (1977). The false consensus effect: An egocentric bias in social perception and attribution processes. *Journal of Experimental Social Psychology*, *13*, 279–301.
Rubin, K. H., Bukowski, W. M., & Parker, J. G. (2006). Peer interactions, relationships, and groups. In W. Damon, R. M. Lerner, & N. Eisenberg (Eds.), *Handbook of child psychology: Vol. 3. Social, emotional, and personality development* (6th ed., pp. 571–645). New York: Wiley.
Snijders, T. A. B. (2001). The statistical evaluation of social network dynamics. *Sociological methodology*, *31*, 361–395.
Snijders, T. A. B., & Baerveldt, C. (2003). A multi-level study of the effects of delinquent behavior on friendship evolution. *Journal of Mathematical Sociology*, *27*, 123–151.
Snijders, T. A. B., Koskinen, J. H., & Schweinberger, M. (in press). *Maximum likelihood estimation for social network dynamics*. *Annals of Applied Statistics*.
Snijders, T. A. B., Steglich, C., & Schweinberger, M. (2007a). Modeling the co-evolution of networks and behavior. In K. van Montfort, H. Oud, & A. Satorra (Eds.), *Longitudinal models in the behavioral and related sciences* (pp. 41–71). Hillsdale, NJ: Lawrence Erlbaum.
Snijders, T. A. B., Steglich, C., Schweinberger, M., & Huisman, M. (2007b). *Manual for SIENA version 3.1*: University of Groningen: ICS/Department of Sociology; University of Oxford: Department of Statistics
South, S. J., & Messner, S. F. (2000). Crime and demography: Multiple linkages, reciprocal relations. *Annual Review of Sociology*, *26*, 83–106.
Steffensmeier, D., & Allan, E. (1996). Gender and crime: Toward a gendered theory of female offending. *Annual Review of Sociology*, *22*, 459–487.

Steglich, C., Snijders, T. A. B., & Pearson, M. (in press). Dynamic networks and behavior: Separating selection from influence. *Sociological Methodology*.
Steinberg, L., & Sheffield Morris, A. (2001). Adolescent development. *Annual Review of Psychology*, *52*, 83–110.
Sutherland, E. H., & Cressey, D. R. (1974). *Criminology* (9th ed.). Philadelphia, PA: Lippincott.
Thornberry, T. P., Lizotte, A. J., Krohn, M. D., Farnworth, M., & Jang, S. J. (1994). Delinquent peers, beliefs, and delinquent behavior: A longitudinal test of interactional theory. *Criminology*, *32*, 47–83.
Van de Bunt, G. (1999). *Friends by choice. An actor-oriented statistical network model for friendship networks through time*. Amsterdam: Thela Thesis.
Vitaro, F., Tremblay, R. E., Kerr, M., Pagani, L., & Bukowski, W. M. (1997). Disruptiveness, friends' characteristics, and delinquency in early adolescence: A test of two competing models of development. *Child Development*, *68*, 676–689.
Wasserman, S., & Faust, K. (1994). *Social network analysis. Methods and applications*. Cambridge: Cambridge University Press.

Note

1. It may be noted that in the sections on the selection and influence part of the model, the selection and influence effects were indicated by terms corresponding to these chosen effects rather than by terms for the non-chosen similarity effects.

Appendix. Formulae for elements of the model

The elements of the vectors $s_{Yi}(y, z)$ and $s_{Zi}(y, z)$, of which weighted sums are used as the objective functions for changes in network ties and in behavior are listed under the section: 'Theory and Model'. The corresponding formulae are listed below. The delinquency variable is supposed to be (for each classroom separately) grand mean centered in these formulae.

Selection part of the model

Outdegree	$\Sigma_j\, y_{ij}$
Reciprocity	$\Sigma_j\, y_{ij}\, y_{ij}$
Transitivity	$\Sigma_{j,k}\, y_{ij}\, y_{jk}\, y_{ik}$
Gender or ethnicity similarity	$\Sigma_j\, y_{ij}\, m_{ij}$

where $m_{ij} = 1$ if i and j have the same gender/ethnicity, and 0 otherwise.

Delinquency ego	$\Sigma_j\, y_{ij}\, z_i$
Delinquency alter	$\Sigma_j\, y_{ij}\, z_j$
Shared delinquency level	$\Sigma_j\, y_{ij}\, z_i z_j$

where z_i and z_j indicate the delinquency of individuals i and j.

Influence part of the model

Tendency delinquency	z_i
Tendency delinquency squared	z_i^2
Average delinquency of friends	$z_i\, (\Sigma_j\, y_{ij}\, d_j\, /\, \Sigma_j\, y_{ij})$ (defining 0/0 = 0)
Male	$z_i\, g_i$

where $g_i = 1$ if i is male, and 0 if i is female.