

Multivariate dynamics of one-mode and two-mode networks: Explaining similarity in sports participation among friends

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Abstract

We examined social mechanisms that account for similarity in the social context of school-sponsored extracurricular sports activities among friends. We distinguish two social mechanisms: “shared sports activities that lead to friendship,” whereby friendship formation and maintenance are conditioned by joint sports participation, and “friendship that leads to shared sports activities,” a form of social influence whereby adolescents join or maintain certain sports activities based on their friends’ choices. Using a longitudinal sample of 1,776 10th graders at five high schools in Southern California, we employed a stochastic actor-oriented multivariate dynamic model to model the dynamic interplay between the two-mode affiliation network of adolescents’ participation in sports activities and the one-mode friendship network. As a corresponding descriptive method, we propose a quantitative measure for the relative strength of the two-mentioned mechanisms as explanations of the association between the one-mode and the two-mode network. Further, we introduce two specifications that represent homophily effects in the two-mode network and apply them to test gender homophily in sports participation. The results provide strong evidence for both mechanisms, with friendship leading to shared sport activities as stronger than shared sports activities leading to friendships in explaining adolescents’ friendships with co-participants.

Keywords: *peer influence, friendship networks, social context, stochastic actor-oriented network dynamic model, sports, extracurricular activity participation, two-mode homophily*

1 Introduction

Adolescent peer relations reflect a diversity of peer interactions in multiple contextual settings that encompass not only close friendships but also school-based amorphous groups or “crowds” (Brown et al., 1986; Brown & Lohr, 1987; Coleman, 1961). Peer networks may be formed and maintained at various contextual settings at school. For example, friendship groups may be nested within or overlapped with crowds that are formed in the contexts of various school-sponsored organized extracurricular activities (Fujimoto & Valente, 2013). Such overlapping relationships are strongly associated with behavioral similarity (Fujimoto et al., 2013) and contribute to the differentiation of one crowd from another. Organized activities provide adolescents with opportunities to spend time with members and to share experiences that are conducive to building and maintaining relationships, and also to support their friendships and to spend more time with their friends (Fredricks et al., 2002; Loder & Hirsch, 2003; Schaefer et al., 2011).

According to the theory of social production functions (SPF) (Lindenberg, 1991; 1996; 2001), individuals strive for two major goals: physical well-being and social approval. Participation in organized sports activities as well as friendships are multifunctional in that they produce both physical and social well-being (Nieboer & Lindenberg, 2002). The physical well-being is promoted because adolescents can achieve the instrumental goals of stimulation and activation by playing sports, together with friends, that produce arousal and pleasure. The adolescents’ social approval can be promoted by sports activities through several instrumental goals connected to sports. One instrumental goal is peer status, which may be enhanced by increasing their visibility among friends and peers (Eder, 1985) and excelling in sports. Another instrumental goal is behavioral confirmation, and may be provided by adolescents’ absorbing the shared values and norms associated with friends and other group members (Eccles & Barber, 1999) and expressing and refining their crowd identity (Barber et al., 2005; Eccles & Barber, 1999; Eccles et al., 2003). They also can achieve the goal of affection through feelings of friendship and camaraderie with their teammates, which may contribute to adolescents’ social/psychological development. Additionally, according to Frank et al. (2013), friendships provide a form of social capital (Portes, 1998) that entails resources to which adolescents gain access (Coleman, 1961). Those resources include the socio-emotional resources of comfort or support from friends, popularity as a means to pursue one’s peer status (Eder, 1985), and instrumental resources for help with coursework (Frank et al., 2008). This shows the manifold purposes that sports participation can have for adolescents, and its close association with friendship, and underlines the importance of studying the social organization of sport participation and friendship.

The network perspective holds that multiplex relationships, whereby individuals are connected through more than a single relationship, promote behavioral similarity (Krohn, 1986; Krohn et al., 1988), as social interaction is stronger for multiplex relationships than for uniplex relationships (Skvoretz & Agneessens, 2007). Multiplex peer relationships formed by both friendship and shared activities are expected to generate stronger peer interactions than either alone. Thus, multiplex relationships should more strongly influence behavior and affect the dynamic interdependency between friendships and participation in organized sports activities.

This study examines the social mechanisms that explain similarity in sports participation among friends. We distinguish two social processes, selection and influence, both of which may lead to adolescents' being friends with their sport co-participants. The first mechanism, selection, concerns the effects of joint sport activity on friendship. We test our first hypothesis about "friend selection due to shared sport context," proposing that adolescents who participate in the same sports tend to become friends because of this shared group context. The second mechanism, influence, concerns assimilation into the sports activities of their friends. We test our second hypothesis about "influence from friends on sport participation," proposing that individuals who are friends tend to choose the same sports to participate in.

In this study, friendships are represented by a one-mode network, and sports participation is represented by a two-mode affiliation network whereby the two modes are adolescents and various sports activities. The current study employs a stochastic actor-oriented dynamic network model (Snijders et al., 2010), also called a Siena model (for its implementation in the RSiena software, see Ripley et al., 2017), to estimate the dynamic interplay between participation in school-sponsored organized extracurricular sports activities and the formation and/or maintenance of friendships. Stochastic actor-oriented network dynamic models have contributed significantly to our understanding of peer influence as network researchers have used stochastic actor-oriented network-behavioral coevolution models (de la Haye et al., 2011; Snijders et al., 2007; Steglich et al., 2010) to separate peer influence from selection to explain behavioral similarity among friends.

A number of network researchers have applied actor-oriented coevolution models to understand network-behavior dynamics by disentangling the complex processes of "peer influence" (i.e., behavior change to be similar to those of one's friends) and "peer selection" (i.e., network change so that friends have similar behaviors) (Veenstra et al., 2013) and have demonstrated how these processes depend on types of substance use and the nature of friendship ties (Fujimoto et al., 2017; Knecht et al., 2010; Mercken et al., 2009b; Mercken et al., 2010; Mercken et al., 2013; Osgood et al., 2013). These studies, however, restrict the contextual setting to the friendship network as a driver of behavioral similarity.

The stochastic actor-oriented model for the co-evolution of a one-mode and a two-mode network was proposed by Snijders et al. (2013). Its first application for studying the co-evolution of friendships and activities was conducted by Lomi and Stadtfeld (2014). Our study uses this approach to address the distinction between selection and influence for the combined one-mode network and two-mode affiliation network data, and we refer to our approach as a "multivariate dynamic model." These two mechanisms, which lead to the association between a one-mode and a two-mode network, are also discussed theoretically by Easley and Kleinberg (2010, Section 4.3), although the term they use for the first mechanism, selection, is focal closure, while for the second mechanism, influence, they use affiliation closure. Lomi and Stadtfeld (2014) use the terms affiliation-based closure and association-based closure for the same two mechanisms. It may be noted that Lomi and Stadtfeld use the antecedent to define the names, whereas Easley and Kleinberg base the names on the consequences. Our model estimates the joint dynamics of a one-mode friendship network and a two-mode affiliation network of participation in sports activities to distinguish the extent to which adolescent co-participation in sports is a product

of selection versus influence, and to quantitatively assess the relative strength of these two mechanisms for producing the observed similarity between friendships and being involved in common sports activities.

The combination of a one-mode and a two-mode network is a basic instance of what is called by Wang et al. (2013) a multilevel network: a structure with several node sets, and networks defined on or between these node sets, where the meaning of the networks differs depending on the node sets they connect. This is further discussed in Snijders (2016), where the distinction is elaborated by the use of the term “multilevel” to indicate hierarchically nested structures.

The current study contributes to the existing literature in three ways. First, this study examines the generative mechanisms that link the social context of sports activities to the formation and maintenance of friendships. Rarely have any studies of activity participation and friendship addressed this issue, partly due to their being restricted to cross-sectional activity data, which made it impossible to address the selection/influence issue. Second, in modeling the sports activities as an endogenous two-mode network, a representation of homophily for the two-mode network is proposed. Third, as a descriptive counterpart for the analytic distinction between selection and influence in this co-evolution model, this study introduces a method that quantifies the extent to which homophily/similarity in sports participation among friends is accounted for by the two different social mechanisms, activity-based friendship selection and friendship-based activity assimilation. We adapt the method of Steglich et al. (2010) for numerically representing the network-autocorrelation of behavior, and generalize this to the case of one-mode–two-mode co-evolution.

In summary, this study employs a stochastic actor-oriented dynamic network modeling methodology for the co-evolution of a one-mode and a two-mode network (Snijders et al., 2013) to examine the social mechanisms of friendship selection based on the sports context and friends’ influence on participation in sports. We model the macro-level dynamic interdependency of social contexts of organized sports activities and friendship networks, grounded in the micro-mechanisms of individual actions, among adolescents at five high schools located in Southern California, United States.

2 Theoretical framework

2.1 Homophily in social context

Social contexts are joint activities organized around social, psychological, legal, or physical objects; Feld (1981) called these focal activities, or *foci*. An individual’s choices, when forming relationships, tend to be channeled in these foci that, in turn, bring sets of people together (Feld, 1982). Foci often have some type of homogeneity due to their content, which will bring together individuals with specific characteristics. Homophily, or the principle of “birds of a feather flock together,” operates in structuring various types of network ties, which influence the information that people receive, the formation of their attitudes, and their experiences in interaction (McPherson et al., 2001). Physical proximity, an important component of most foci, is the most basic source of homophily (McPherson et al., 2001; van Duijn et al., 2003). This is because proximity provides individuals with the opportunity to discover similarities and shared interests through sharing activities. Thus, physical proximity

increases the likelihood of befriending someone (Leenders, 1996) and influences the dynamics of friendship choices (Hallinan, 1976; Leenders, 1996; Preciado et al., 2012; van Duijn et al., 2003). Shared organized sports activities can be considered foci, as they provide a joint activity and a physical context in terms of a spatial location. The shared activity and implied propinquity are likely to channel social interactions and thereby influence the dynamics of the friendship network.

Social contexts are comprised not only of a spatial dimension and concrete interaction opportunities but also of symbolic features that are intrinsic to situations in which the social network is nested (Doreian & Conti, 2012). Participation in organized activities at school can signal symbolic features that are characteristic of a particular “crowd” type. For instance, playing popular sports can signal the high peer status of the athletically oriented crowd type (e.g., jock) (Brown & Lohr, 1987) and characterize group members in the leading crowds at schools (Coleman, 1961; Eckert, 1989). Participation in specific sports constitutes peer networks, wider but still cohesive, playing a role in the formation and maintenance of close friendships. These networks are represented mathematically by the one-mode projection of the two-mode network. In such a network, all members are not necessarily directly linked to each other by friendship; instead, cohesion is based on interpersonal agreements among members and coordinated collective activity (Friedkin, 1998). Thus, the two-mode network of sports participation in a school setting may indeed be regarded as a social network in the sense that it implies meaningful social interaction.

This study aims to explain the structural dynamics between organized sports activities and friendships in a model that assumes that, between the moments of observation, change occurs by repeated individual choices regarding sports participation and friendship. The social context consists of the one-mode friendship network and the affiliation with sports, regarded as a two-mode network. The choices depend on the network and affiliation contexts existing at the moment that the choice is being made. We consider two social mechanisms, selection and influence, to explain the similarity in sports participation among friends.

First, we posit that adolescents seek out friendships, among other means, in the social context of organized sports activities. We expect that friendship ties are more likely to occur and be maintained when a pair of adolescents share the same sports activities (i.e., when both participate in the same organized sport). We call this the mechanism of “shared sports activities leading to friendship” (context-based selection) whereby friendship formation and maintenance are conditioned by the settings of sports activities. Accordingly, we hypothesize:

Hypothesis 1: Participation in the same organized sport activities leads to friendship development and maintenance.

Second, we posit that a pair of adolescents who have a friendship tie are likely to select into the same sports context and to stay with shared types of sport contexts. We call this the mechanism of “friendship leading to shared sports activities” (‘friendship-based context assimilation’), whereby adolescents are influenced to adopt the same sports context or choose to stay in the same context as their existing friends. Accordingly, we propose:

Hypothesis 2: Existing friendships lead adolescents to participate in the same organized sports activities.

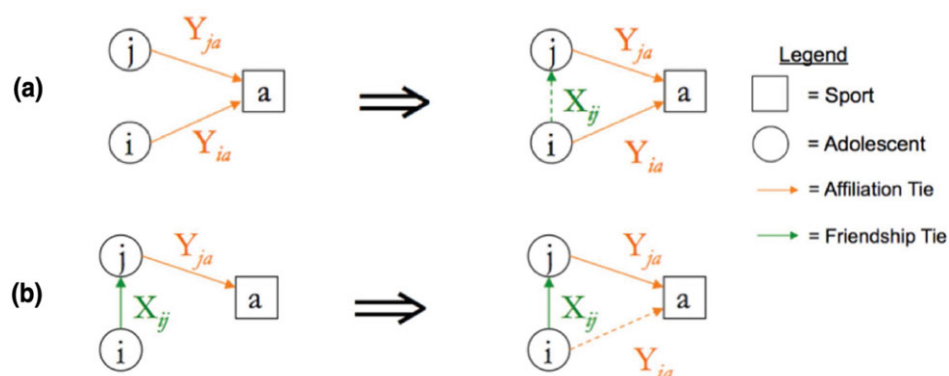


Fig. 1. Illustration of social mechanism of (a) “shared sports activities leading to friendship” and (b) “friendship leading to shared sports activities.” Solid lines represent existing ties, and dotted lines represent formed ties.

Graphically, Hypothesis 1 is presented in Figure 1(a), and Hypothesis 2 is presented in Figure 1(b).

3 Method

3.1 Data collection

Data were collected among adolescents in five southern California (Los Angeles County) high schools in the El Monte Union High School District (EMUHSD) as a part of a larger social network study (Valente et al., 2013). EMUHSD is a district in which 75%–90% of adolescents are eligible for a free or reduced-cost lunch. Study procedures and data collection instruments were approved by the Committee for the Protection of Human Subjects at the University of Southern California.

3.2 Study sample

The data for this study came from a longitudinal sample of 10th grade adolescents who were interviewed in fall (October) 2010 as a baseline and in spring (May) 2011 as a follow-up at all five schools in the district. A pool of 1,789 students consented to participate in the study. The proportion of 10th graders who consented for each school was 78%, 86%, 69%, 86%, and 86%. 10th graders provided friendship nominations at both time points. Of the baseline sample, 88.0% completed the follow-up survey, 8.8% completed only the baseline survey, and 3.2% completed only the follow-up survey. By including those who completed only the baseline or only the follow-up in the estimation process (Huisman & Steglich, 2008) with those who completed both the baseline and the follow-up, the final sample consisted of 1,776 adolescents.

3.3 Measures

To collect one-mode friendship network data, we provided respondents with a grade roster that contained all of the adolescents' IDs and photos and asked them to write

the roster IDs of up to seven close friends in the same grade and then to write the ID numbers of up to 12 additional friends. Thus, this study includes all friendship nominations with a maximum of 19. We created friendship networks at two time points for each school.

To collect two-mode affiliation network data of sports participation, we provided respondents with 16 sports and asked them to mark all of the sports and teams at their school in which they participated during the past 12 months. These sports were basketball, baseball, cheerleading, cross-country, dancing, exercising, field hockey, football, hiking, soccer, softball, swimming, tennis, running, volleyball, and wrestling. Our selections of organized school activities were predefined based on our preliminary studies. Prior to collecting the baseline data, a focus group discussion forum collected preliminary survey data, whose results were used as a guideline in finalizing our baseline questionnaire items of 16 sports. Additionally, we referred to similar questionnaire items that ask for organized sports from previously conducted studies at the same study site in Los Angeles. Our data does not distinguish between multiple teams that may exist for any given sport in the same school. Having multiple teams might have different implications for discerning selection from influence, but this information is not available.

Two-mode network data were created at both time points for each school, with rows representing the adolescents and columns representing the 16 sports activities in which the adolescents participated. Additionally, we measured the demographic variables of gender (female = 1, male = 0), race or ethnicity (Hispanic = 1, non-Hispanic = 0), and self-reported academic grades, which were coded as 1 (mostly Ds or Fs) to 4 (mostly As).

3.4 *Stochastic actor-oriented multivariate dynamic model*

The network structure in our study has two node sets, called “modes” in social network terminology: adolescents and sports. The friendship network consists of ties between adolescents and therefore is a one-mode network, while the sport network consists of affiliation ties between adolescents and school-organized sports, hence is a two-mode network. To test the two hypotheses, we need to control adequately for the dynamic process of the evolution of the friendship network and the sports participation network. To achieve this, our study employed a stochastic actor-oriented multivariate network dynamic model as explained in Snijders et al. (2013). The general class of stochastic actor-oriented network models (Snijders, 2001; Steglich et al., 2010) posits that actors make changes in their outgoing ties in a sequence of many small steps where the probability distribution of the changes is based on so-called evaluation functions, and the network constitutes each person’s changing social environment. The evaluation function expresses individual’s short-term goals and constraints and determines the likelihood of creating specific new ties or maintaining existing ties, depending on the characteristics of the actors and the current local network structures. This study examines the network dynamics of the combined friendship and sports affiliation networks (multivariate dynamic model) by specifying the evaluation functions that represent the mechanisms that govern an individual’s action when creating and maintaining one-mode and two-mode network ties. A more detailed mathematical

formulation of our multivariate dynamic model is found in the online supplemental material.

In our multivariate dynamic model, the one-mode friendship network and the two-mode sports affiliation network together constitute the changing social environment, with the ties in the two-mode network being interpreted as directed from the actors to the sports activities. There are separate evaluation functions for the friendship network and the sports activities network. The sequential, unobserved choices made by the actors are changes either in their outgoing friendship ties or in their sports activities; interdependence between the actors, and between the two networks, follows from the specification of the evaluations functions which are dependent, for each actor, on his or her combined neighborhoods in the friendship as well as sports activities networks. The observed data are not the actual individual small steps but, instead, the snapshots of the networks taken at the moment of data collection. It should be noted that the context defining the probabilities for the changes is not the last observed state of the two networks but the current unobserved state at the moment the choice is made.

3.5 Specification of multivariate dynamic models

The specification of the actor-oriented model is defined by the evaluation functions, and these evaluation functions are defined as linear combinations of effects, which are functions of the current network structure as perceived from the point of view of individual actors, as explained in Snijders et al. (2013). Each effect defines a specific network mechanism, such as friendship reciprocity, or dependence of sports affiliation on the number of friends participating in this sport. Mathematical definitions of available effects are given in Ripley et al. (2017). For the multivariate dynamics of the two networks we distinguish within-network effects, for the dependence of friendship changes on the current friendship and of sports changes on the current sports affiliations, from between-network effects, for the dependence of friendship changes on the current sports affiliations, and vice versa. The choice of effects defines the model specification. The effects included were selected based on the following criteria: (1) effects that express our hypotheses; (2) control effects that are necessary for testing the hypothesized effects; (3) effects that follow from general knowledge about the specification of actor-oriented models (Snijders et al., 2010); (4) effects that are based on theoretical ideas about the modeled processes; and (5) effects that improve the fit, added after doing a goodness-of-fit study.

The demarcation between effects specified in types (4) and (5) is not sharp because reflecting about what might have led to an unsatisfactory fit includes theoretical considerations. In the discussion below, we use the effect names as defined in the software (Ripley, Snijders et al., 2017). We give formulae only for the effects that are of major theoretical importance for the current study; formulae for other effects can be found in the cited literature. The friendship network is denoted by X and the sports affiliation network by Y , with tie variables X_{ij} and Y_{ia} , respectively.

3.6 Between-network effects of multivariate dynamics

For effects of type (1), the hypotheses are expressed by two mixed triadic effects in the form of mixed transitive closure. The first hypothesis: "Participation in the

same organized sport activities leads to friendship development and maintenance” is expressed by what the manual (Ripley et al., 2017) calls “from two-mode agreement to one-mode out-tie,” and what here represents “shared sports activities leading to friendship.” This is interpreted as individual i becoming friends with j dependent on the number of activities a they share, as shown in Figure 1(a). The effect is defined for actor i by the number of closed triangles in this figure actor i is involved in,

$$\sum_{j,a} x_{ij} y_{ia} y_{ja}$$

The second hypothesis: “Existing friendships lead adolescents to participate in the same organized sports activities” is expressed by the effect “from one-mode out-tie to two-mode agreement,” here representing “friendship leading to shared sports activities.” This is interpreted as an individual affiliating with an activity a dependent on the number of his or her friends j affiliating with that activity, as shown in Figure 1(b). The effect is defined for actor i also by

$$\sum_{j,a} x_{ij} y_{ia} y_{ja}$$

the same formula as for the first hypothesis. The difference is that the former is an effect in the evaluation function for friendship, and the second for sports affiliation. Accordingly, they are treated differently in the model and in the parameter estimation, as explained in Snijders et al. (2013).

Note for the effect of “friendship leading to shared sports activities,” we allowed our models to distinguish between starting and terminating sports participation to better interpret the effect of friendship on sport participation. Here, we specified a creation and maintenance effect. In this model, for these two effects, there is an “evaluation” as well as a “maintenance” effect (*a.k.a.*, endowment effect). This implies that the creation of ties is represented by the “evaluation” effect, and the “maintenance” effect is represented by the sum of the “evaluation” and the “maintenance” effects; see Ripley et al. (2017), Sections 2.1.2 and 12.1.4. Thus, we specified the “evaluation” and the “maintenance” effects of the cross-network effects of friendship to sports activity, that is “friendship leading to shared sports activities” and the corresponding lower-level mixed degree effect of “from one-mode activity to two-mode activity” that is described in the following section. When testing the hypothesis of the influence of friendship on sports participation, because the question posed about sports referred to participation in the past 12 months, we tested only for the creation of ties; while controlling for maintenance. Thus, only the “evaluation” effects are taken into consideration for the second hypothesis test of “friendship leading to shared sports activities” (where also the two maintenance effects are present).

Considering effects of type (2), these mixed triadic effects must be controlled for two actor-level effects, specifically, mixed degree-related effects. We specified four effects, and this is argued as follows. We see in Figure 1 that the mixed triad involved in the hypotheses includes three two-stars as sub-configurations: the mixed two-stars $i \rightarrow j, i \rightarrow a$ and $i \rightarrow j \rightarrow a$, and the two-mode two-star $i \rightarrow a, j \rightarrow a$. These have to be controlled for because without this control, a higher frequency of mixed two-stars, the signal for the two hypotheses, might also be interpreted as merely the consequence of a higher frequency of such two-stars. The two mixed two-stars are

represented by setting outdegree (expressing activity by the number of nominations made) in one network as the explanatory variable operating on the outdegree in the other network. The first mixed degree effect is from one-mode activity to two-mode activity, which models whether nominating many friends leads to increased sports participation, and this effect was added to the sports participation function. Note, that we specified the pair of a creation (evaluation) and maintenance effect as described above.

The second is from two-mode activity to one-mode activity, modeling whether participating in many sports leads to nominating many friends, and this effect was added to the friendship function. The two-mode two-star is represented by the indegree popularity effect for the two-mode network, a within-network effect, and this effect was added to the sports participation function.

3.7 *Within-network effects of internal dynamics*

Type (3) effects contain the within-network effects that are by now common for actor-oriented modeling of one-mode networks (Snijders et al., 2010) and similarly for their two-mode counterparts (Snijders et al., 2013). For the friendship network these are outdegree (reflecting the balance between creating and dropping friendship ties), reciprocity (expressing the extent to which ties are reciprocated), transitive triplets (expressing the tendency for friends of friends to become or remain friends), three-cycles (expressing the tendency of triadic closure in a cyclical direction), transitive ties (expressing the same as the transitive triplets effect but considering at least one indirect tie sufficing for the triadic closure), indegree popularity (expressing the extent to which adolescents who are nominated by more friends continue to do so, thereby reinforcing existing indegree differentials), outdegree popularity (expressing the extent to which current outdegrees contribute to the likelihood that adolescents become or remain receivers of ties), outdegree activity (expressing the extent to which adolescents who nominate more friends continue to do so, thereby reinforcing existing outdegree differentials). For the actor covariates gender, ethnicity, and academic grades, the sender and receiver were included (referred to as covariate-ego and covariate-alter, respectively). Also, for academic grades we included the effect of similarity between ego and alter, and for gender, ethnicity and class we included the effect of the same values for ego and alter. These structural and covariate-related effects have been commonly found to predict friendship network dynamics among adolescents.

Within-network effects for the two-mode network of sports participation are outdegree (expressing the balance between joining and leaving activities), outdegree activity (expressing the extent to which adolescents participating in many sports continue to do so), indegree popularity (expressing the extent to which sports with many participants continue to be popular), 4-cycles closure effect (expressing the extent to which pairs of adolescents who share one sport tend to have more sports activities in common), as well as the sender (ego) effects of the adolescent's gender, ethnicity, and academic grades (expressing the differential propensity to sports activity depending on these variables).

Type (4) consists of theoretically motivated effects. Block (2015) argued that, for the friendship network, the interaction between reciprocity and transitive triplets is

important, and a negative parameter value is expected. This led to the inclusion of the transitive reciprocated triplets effect. Another effect that may theoretically be expected is the reciprocated degree activity effect, which expresses how the tendency to send ties depends on the current number of reciprocated ties. We argue that adolescents who have many reciprocated friendships will be less motivated to create new, unreciprocated friendships, and, therefore, we expect a negative reciprocated degree effect.

For the two-mode network, we developed specifications that reflect homophily for the two-mode case, in this case, gender homophily. We expect that sports may be, to some extent, gender-specific and that adolescents tend to be attracted especially to those sports that are popular for others of the same gender. This is a version of homophily for the two-mode network. We define it by the similarity between the gender of the adolescent and the proportion, among the participants in the given sport, of others of the same gender. Recall that gender is coded as 1 for females and 0 for males. Denoting by v_i the gender of adolescent i and by p_{ia} the proportion of females among those participating in sport a (not counting i him/herself), the two-mode homophily effect is defined by

$$\sum_a y_{ia} \{ 1 - | v_i - p_{ia} | \}.$$

Note that the weight $\{ 1 - | v_i - p_{ia} | \}$ is 1 if all participants in sport a are of the same gender as i , and 0 if all are of the other gender. In the RSiena manual (Ripley et al., 2017) this is called the gender ego-in-alter distance 2 similarity, with short name “simEgoInDist2.”

The second kind of two-mode homophily effect is the four-cycle effect restricted to same-gender pairs, defined as

$$\sum_j \sum_{a \neq b} y_{ia} y_{ib} y_{ja} y_{jb} I\{v_i = v_j\}$$

where $I\{v_i = v_j\}$ is the indicator function defined as 1 if i and j have the same gender and 0 otherwise. This reflects that same-gender pairs of adolescents who share one sport tend to have more sports activities in common. By including this effect, we can distinguish it from the regular four-cycle effect (which also is included), expressing that adolescents who share one sport tend to have more sports activities in common, irrespective of gender.

Type (5) consists of those effects that have less of a theoretical justification and that were added because goodness-of-fit studies of provisional model specifications yielded results that were not totally satisfactory. These effects were, first, interactions between reciprocity and same gender, between reciprocity and same class, and between same gender and same class. Arguments for them can be given along the lines of Block and Grund (2014). Second, some specific degree-related effects were added. These were outdegree at least 1 (expressing the tendency to nominate at least one friend or to participate in at least one sport) and outdegree activity—square root version.

A table of the within-network effects of the internal dynamics and the between-network effects on multivariate dynamics as well as the corresponding RSiena names are found in the online supplemental material (Table 1(S)).

3.8 Procedure of modeling, meta-analysis, and goodness-of-fit test

We specified common multivariate dynamic models for each school from five school networks. The method of moments was used as an estimation method (Snijders et al., 2013; Snijders et al., 2007). The estimated parameters were tested by comparing the t -ratio (estimate divided by standard error) to a standard normal distribution. All of our models attained good convergence with overall maximum convergence ratio < 0.20 (Ripley et al., 2017).

For each parameter separately, the results of the five schools were combined in a meta-analysis (Lubbers & Snijders, 2007; Snijders & Baerveldt, 2003). Five schools is too low a sample size to give adequate information about a population of networks. Therefore the focus of the meta-analysis is on combining the five tests with a Fisher combination procedure, as documented in Ripley et al. (2017). This provides, for each parameter separately, results from combinations of left-sided as well as of right-sided tests of the null hypothesis that in all these five schools the parameter is zero. These two combinations are based on Fisher's combination of p -values (Hedges & Olkin, 1985), each using an overall one-sided significance level of $\alpha = 0.025$ to obtain a combined significance level of $\alpha = 0.05$, with four possible results: (a) no evidence for non-zero parameter values in any schools; (b) evidence for positive parameter values only (no negative ones) in some schools; (c) evidence for negative parameter values only (no positive ones) in some schools; (d) evidence for both positive and negative parameter values in some schools. Note that these conclusions refer to these five schools only, without an attempt to generalize to a population. In addition, to provide more numerical information about the average pattern represented by the five schools, results of a random-effects meta-analysis are given. This takes the form of estimates for the average effect in a presumed population of similar schools, with standard errors for this average, according to Snijders & Baerveldt (2003). These standard errors reflect the standard errors within the studies of the separate schools, combined with the uncertainty because of the between-school variability; the latter contribution may be rather large, as a consequence of the small school-level sample size of $N = 5$. The standard errors cannot be used for testing because the sample size of $N = 5$ is too low, but are given because they do roughly indicate our uncertainty about the parameter estimates.

A goodness-of-fit analysis was conducted to check and potentially improve the fit of the multivariate dynamic models. Goodness of fit was checked with the function `sienaGOF` in `RSiena` according to Lospinoso (2012), with $p > 0.05$ considered good fit. For one-mode friendship networks, goodness-of-fit checks were performed for the distributions of outdegrees, indegrees, and geodesic distances. For the two-mode networks of sports participation, we conducted goodness-of-fit checks for outdegrees and indegrees. These checks led to the model improvements noted above in Group (5); also some effects in Group (4) were found on the basis of the goodness of fit considerations.

More detailed information on the procedure for meta-analysis and goodness-of-fit analysis are described in the `RSiena` Manual (Ripley et al., 2017). For the entire analysis, we used `RSiena` Version 1.1-302 (Ripley et al., 2017), a package of the statistical system R v.3.3.2 (R Development Core Team, 2011).

3.9 Quantitative assessment of the friendship-sports association

To quantify the extent of the association between the friendship network and the sports network, we used a version of the assessment method in Section 4.6 of Steglich et al. (2010), which we adapted to the case of the co-evolution between a one-mode and a two-mode network. The procedure of Steglich et al. (2010) is for co-evolution studies of networks and behavior, and quantifies the mechanisms that contribute to the network-behavior autocorrelation. In the case of co-evolution of a one-mode and a two-mode network, the quantitative comparison uses a measure for the association between the one-mode and the two-mode network, and has the purpose to determine how much of the association of the networks observed at Wave 2 is determined by, respectively, the observed association at Wave 1, the endogenous dynamics of both networks taken independently, the effect of “shared sports activities leading to friendship,” the effect of “friendship leading to shared sports activities,” and the combination of these two effects. The procedure is explained below.

The first input is a measure of the association between the one-mode and the two-mode networks. We measure this by a centered version of the Jaccard similarity coefficient (Batagelj & Bren, 1995; Snijders et al., 2010) between the one-mode network and a one-mode projection of the two-mode network. The Jaccard similarity coefficient between a network $X = (x_{ij})$ and a network $Z = (z_{ij})$ is defined as the number of ordered pairs (i, j) that are tied in both networks, divided by the number of pairs tied in at least one of the networks:

$$J = \frac{\sum_{ij} x_{ij} z_{ij}}{\sum_{ij} (x_{ij} + z_{ij} - x_{ij} z_{ij})}.$$

For the quantitative comparison, we need a measure that is 0 when there is no association. Therefore, we replace the numerator of J by its deviation from the value that would be expected under no association between X and Z . This leads to the centered version of J defined by

$$J_c = \frac{\sum_{ij} x_{ij} z_{ij} - \left\{ \left(\sum_{ij} x_{ij} \right) \left(\sum_{ij} z_{ij} \right) / \{n(n-1)\} \right\}}{\sum_{ij} (x_{ij} + z_{ij} - x_{ij} z_{ij})}.$$

We apply this coefficient in the quantitative comparison as a measure of the association between friendship and sports by calculating the one-mode projection for the network Z . There is a tie in Z between two adolescents if and only if they have at least one sport in common.

The second input is the specification of the several versions of the dynamic model. These are the following five specifications of an actor-oriented model, in accordance with Steglich et al. (2010, Section 4.6):

1. The trend model includes only the degree effects for both networks and represents the influence of the observations at Wave 1 with a random trend.
2. The control model assumes that the friendship and the sports networks develop independently but otherwise with all of the complexities that are specified in the dynamic within-network model.
3. The selection-only model represents only “shared sports activities leading to friendship.” This is a hybrid model for which the specification and parameter

values of the friendship model are taken from the full model; this is the model that was finally estimated and presented in Table 3 or more precisely in the Supplementary Information for all five schools separately, whereas, for the sports participation model, the control model is taken. This model assumes that friendship depends on sports but that sports participation does not depend on friendship, counterfactually expressed by the hybrid model.

4. The influence-only model represents only “friendship leading to shared sports activities.” This also is a hybrid model for which the specification and parameter values of the sports participation model are taken from the finally estimated full model, and the control model is used for the friendship dynamics. This is the converse and analogue of the selection-only model.
5. The full model is the final model presented in this paper.

For these five models and for each of the schools, the network dynamics are simulated. The trajectories start at the observations for Wave 1 and stop when the time of Wave 2 is reached. Then the average of the centered version of Jaccard coefficient is calculated for 1,000 independent repetitions of this simulation. For school k , we denote these five centered Jaccard coefficients by J_k^t , J_k^c , J_k^s , J_k^i , and J_k^f . Because, we are using a centered measure for which the baseline value is 0, we can then distinguish the following separate proportional contributions:

- proportional contribution of the past situation and random trend: J_k^t/J_k^f ;
- proportional contribution of endogenous within-network dynamics: $(J_k^c - J_k^t)/J_k^f$;
- proportional contribution of “shared sports activities leading to friendship” on top of endogenous within-network dynamics: $(J_k^s - J_k^c)/J_k^f$;
- proportional contribution of “friendship leading to shared sports activities” on top of endogenous within-network dynamics: $(J_k^i - J_k^c)/J_k^f$;
- proportional contribution of “shared sports activities leading to friendship” on top of endogenous within-network dynamics and “friendship leading to shared sports activities”: $(J_k^f - J_k^i)/J_k^f$;
- proportional contribution of “friendship leading to shared sports activities” on top of endogenous within-network dynamics and “shared sports activities leading to friendship”: $(J_k^f - J_k^s)/J_k^f$.

This shows that the contribution of the two mechanisms may be different, depending on whether the mechanism is assessed on top of only the within-network dynamics or on top of the within-network dynamics together with the other mechanism. If controlling for the other mechanism leads to a larger contribution, we say that there is synergy; if it is less, we say that there is *overlap* between the two mechanisms. Proceeding in this way, we obtain the following proportional contributions:

1. Trend: J_k^t/J_k^f .
2. Control (within-network): $(J_k^c - J_k^t)/J_k^f$.
3. Selection, i.e., “shared sports activities leading to friendship”: $\min\{(J_k^s - J_k^c)/J_k^f, (J_k^i - J_k^c)/J_k^f\}$.
4. Influence, i.e., “friendship leading to shared sports activities”: $\min\{(J_k^i - J_k^c)/J_k^f, (J_k^s - J_k^c)/J_k^f\}$.

Table 1. Baseline descriptive statistics by school: Percentages and averages (standard deviations) for students ($N = 1,776$).

	School 1	School 2	School 3	School 4	School 5
N	446	381	275	365	309
Sex (female)	52%	46%	54%	46%	53%
Ethnicity (Hispanic)	55%	67%	79%	42%	81%
Academic grades	2.7 (0.9)	2.4 (0.9)	2.5 (0.8)	2.7 (0.9)	2.6 (0.9)

Note. Academic grades were coded as 1 (Mostly D's or F's) to 4 (Mostly A's).

Table 2. Average degrees of friendship and sports participated and Jaccard coefficients by network for each school.

	School 1	School 2	School 3	School 4	School 5
Average degree of friendship					
t_1	5.8	4.8	4.3	5.4	6.6
t_2	4.8	5.3	3.9	5.4	6.2
Jaccard coefficient	0.25	0.26	0.27	0.31	0.25
Average degree of sports participated					
t_1	1.4	0.9	1.0	1.1	1.2
t_2	1.1	0.9	1.0	1.0	1.1
Jaccard coefficient	0.40	0.36	0.38	0.37	0.44

The remainder is an ambiguous part.

If $J_k^f + J_k^c > J_k^i + J_k^s$, there is a synergy of $\{(J_k^f + J_k^c) - (J_k^i + J_k^s)\}/J_k^f$.

If $J_k^f + J_k^c \leq J_k^i + J_k^s$, there is an overlap of $\{(J_k^i + J_k^s) - (J_k^f + J_k^c)\}/J_k^f$.

Note that, in the various partial models, the Friendship-Sports association was represented by the total of evaluation and maintenance effects for both “friendship leading to shared sports activities” and “from one-mode activity to two-mode activity.”

4 Results

4.1 Descriptive statistics

Table 1 displays baseline descriptive statistics (percentage and means with standard deviations in parentheses) by school for the total sample. Approximately 50% were female, 42% to 81% were Hispanic or Latino, and mean academic grades ranged from 2.4 to 2.7 (between mostly Bs and Cs to mostly Bs).

Table 2 displays average degree and Jaccard Coefficients, measuring network stability, by network for each school at both time points. Average degree (numbers of friends named) was between 3.9 and 6.6 across schools, which is not unusual for friendship networks. The average degree (numbers of sports participated in) was 1.0 across schools, and the percentage of students who did not participate in any sport was 40%, 58%, 51%, 46%, and 47% for the five schools. The Jaccard coefficient values (Batagelj & Bren, 1995; Snijders et al., 2010) were approximately 0.3 for friendship networks and 0.4 for sports participation. This indicates somewhat higher stability for the affiliation network compared to the friendship network.

4.2 Results of fitting multivariate dynamic model

The common multivariate dynamic models were fitted for each school separately, and the corresponding meta-analysis results across the five schools are presented in Table 3. School-wide results are reported only for schools with significant effects at the $\alpha = 0.05$ level, and the complete results are available in the online supplemental material (Table 2(S)). In the following, we report the results of the two main tested between-network effects, followed by the within-network effects.

4.3 Between-network effects of multivariate dynamics

Interdependencies at the triad level. The results of the testing of our study hypotheses indicate that the mean mixed triadic effects of sports agreement leading to friendship (as illustrated in Figure 1(a): shared sports activities leading to friendship) was significant ($\hat{\mu}_\theta^{WLS} = 0.236$, (b); significant for S1–S5). Adolescents tended to become friends with those who participated in the same sports. These results support Hypothesis 1 (Participation in the same organized sport activities leads to friendship development and maintenance).

The dynamics worked in the opposite direction as well. Mean mixed triadic effects of friendship leading to sports agreement (as illustrated in Figure 1(b): friendship leading to shared sports activities) were significant for the evaluation effect ($\hat{\mu}_\theta^{WLS} = 0.473$, (b); significant for S1, S4, S5) and for the maintenance effect ($\hat{\mu}_\theta^{WLS} = 0.992$, (b); significant for S1, S3). Adolescents tended to participate in the same sport in which their friends participated. As the evaluation effect was significant (representing the creation of ties), these results support Hypothesis 2 (Existing friendships lead adolescents to participate in the same organized sports activities).

In summary, the social mechanisms of multivariate dynamic interdependencies between friendship and sports participation are bi-directional over time.

4.4 Within-network effects of internal dynamics

For friendship dynamics, most structural parameters had significant mean effects (Table 3). The negative outdegree coefficients reflect the sparseness of all the networks typical for nomination and two-mode data. There were positive effects of reciprocity ($\hat{\mu}_\theta^{WLS} = 2.831$, (b); significant for S1–S5), transitive triplets ($\hat{\mu}_\theta^{WLS} = 0.381$, (b); significant for S1–S5), three-cycles ($\hat{\mu}_\theta^{WLS} = 0.143$, (b); significant for S1, S2, and S4), transitive ties ($\hat{\mu}_\theta^{WLS} = 0.553$, (b); significant for S1–S5), and a negative effect of reciprocity degree-related activity ($\hat{\mu}_\theta^{WLS} = -0.085$, (c); significant for S1–S5), transitive reciprocated triplets ($\hat{\mu}_\theta^{WLS} = -0.362$, (c); significant for S1, S2, S4, and S5). Tendencies toward differentiated popularity were indicated by the positive parameter of indegree popularity ($\hat{\mu}_\theta^{WLS} = 0.020$, (b); significant for S1, S2, S3, and S5), which indicates the Matthew effect: Popular students become or stay more popular. A negative effect of outdegree popularity ($\hat{\mu}_\theta^{WLS} = -0.072$, (c); significant for S1–S5) indicates the tendency of expansive adolescents (those who nominate many friends) to be less popular (less likely to be nominated as friends). A positive effect of outdegree activity ($\hat{\mu}_\theta^{WLS} = 0.041$, (b); significant for S2) indicates the tendency of expansive adolescents to continue to be expansive (by nominating many friends). A negative effect of outdegree at least 1 ($\hat{\mu}_\theta^{WLS} = -1.557$, (c); significant

Table 3. Meta-analysis results of multivariate dynamic models: Mean within-network and between-network effect sizes of coefficients ($\hat{\mu}_\theta^{WLS}$), their standard errors (SE), and significance based on Fisher's combination of one-sided tests of within-network effects of internal dynamics (school $N = 5$).

Dependent networks	Friendship	Sports participation
Effects	$\hat{\mu}_\theta^{WLS}$ (SE)	$\hat{\mu}_\theta^{WLS}$ (SE)
Within-network effects of multivariate dynamics		
Rate	18.051 (1.502)*	2.431 (0.183)*
Outdegree (density)	-3.058 (0.265) [†]	-3.006 (0.643) [†]
Reciprocity	2.831 (0.053)*	
Reciprocal degree-related activity	-0.085 (0.006) [†]	
Transitive triplets (friends of friends tend to become or remain friends)	0.381 (0.029)*	
Transitive reciprocated triplets (reciprocated friendship tends to close the two path)	-0.362 (0.044) [†]	
Transitive ties (the same as the <i>transitive triplets</i> effect but considering at least one indirect tie sufficing for the triadic closure)	0.553 (0.052)*	
Three-cycles (triadic closure in a cyclical direction)	0.143 (0.024)*	
Four-cycles		0.014 (0.024)
Four-cycles from same gender (two-mode homophily)		-0.006 (0.035)
Indegree popularity	0.020 (0.004)*	0.012 (0.007)*
Gender ego-in-alter distance 2 similarity		1.470 (0.201)*
Outdegree popularity	-0.072 (0.003) [†]	
Outdegree activity	0.041 (0.015)*	0.081 (0.072)*
Square root of outdegree activity	-0.095 (0.122)	
Outdegree ≥ 1	-1.557 (0.378) [†]	-1.623 (0.305) [†]
Gender alter (F)	0.007 (0.023)	
Gender ego (F)	0.034 (0.018)	-0.110 (0.176)
Same gender	0.387 (0.026)*	
Hispanic alter	-0.048 (0.018)	
Hispanic ego	0.006 (0.067)*	-0.246 (0.113) [†]
Same Hispanic	0.155 (0.046)*	
Grade alter	-0.006 (0.014)	
Grade ego	-0.007 (0.021)	0.167 (0.078)*
Grade similarity	0.375 (0.041)*	
Same class	0.561 (0.058)*	
Reciprocity $\times$ same gender	-0.283 (0.051) [†]	
Reciprocity $\times$ same class	-0.306 (0.041) [†]	
Same gender $\times$ same class	-0.035 (0.056)	
Between-network effects of multivariate dynamics:		
Actor level outdegrees		
Friendship $\rightarrow$ sports activity (evaluation effect)		-1.064 (0.772) [†]
Friendship $\rightarrow$ sports activity (maintenance effect)		1.439 (1.246)*
Sports activity $\rightarrow$ friendship	-0.112 (0.032) [†]	
<i>Mixed triads</i>		
Sports agreement leading to friendship ("Shared sports activities leading to friendship," as illustrated in Figure 1(a))	0.236 (0.021)*	

Table 3. Continued

Dependent networks	Friendship	Sports participation
Friendship leading to sports agreement ("Friendship leading to shared sports activities," as illustrated in Figure 1(b)) (evaluation effect)		0.473 (0.289)*
Friendship maintains sports agreement (Friendship maintains shared sports activities) (maintenance effect)		0.992 (0.325)*

Note. Significance level was set at $\alpha = 0.025$ for Fisher's combination test, based on the combinations of right-sided and the left-sided p -values: * $p_r \leq 0.025$, $p_l > 0.025$: evidence for some positive parameter values but no evidence for any negative parameter values; and $^{\dagger}p_r > 0.025$, $p_l \leq 0.025$: evidence for some negative parameter values but no evidence for any positive parameter values; * and † = statistically significant.

for S1, S2, and S3) indicates a tendency of some students to mention no friendship ties at all.

There also were homophilous tendencies: Adolescents of the same gender nominated each other more than did those of a different gender ($\hat{\mu}_\theta^{WLS} = 0.387$, (b); significant for S1–S5). The same was true for Hispanic students ($\hat{\mu}_\theta^{WLS} = 0.155$, (b); significant for S1, S3, S4, and S5) and for adolescents with similar academic grades ($\hat{\mu}_\theta^{WLS} = 0.375$, (b); significant for S1–S5), in the same class ($\hat{\mu}_\theta^{WLS} = 0.561$, (b); significant for S1–S5). There was a positive ego-covariate effect for Hispanic adolescents ($\hat{\mu}_\theta^{WLS} = 0.006$, (b); significant for S3 and S4). There were negative effects for interaction terms between reciprocity and same gender ($\hat{\mu}_\theta^{WLS} = -0.283$, (c); significant for S1 and S5), and reciprocity and same class ($\hat{\mu}_\theta^{WLS} = -0.306$, (c); significant for S3 and S4).

For the internal dynamics of sports participation, the effect of outdegree at least 1 was negative and significant, indicating a tendency of some students not to participate in any sports ($\hat{\mu}_\theta^{WLS} = -1.623$, (c); significant for S2, S3, S5). There was tendency for Hispanic adolescents to participate in fewer sports ($\hat{\mu}_\theta^{WLS} = -0.246$, (c); significant only for S5 for Hispanic ego), while adolescents with higher grades participated in more sports ($\hat{\mu}_\theta^{WLS} = 0.167$, (b); significant for S4, and S5 for Grade ego).

The two-mode homophily effect of gender ego-in-alter distance 2 similarity was significant ($\hat{\mu}_\theta^{WLS} = 1.470$, (b); significant for S1–S5). However, the other two-mode homophily effect of 4-cycles from the same gender closure was not significant, not supporting the tendency of adolescents who share one sport with another of the same gender to participate in more sports with this person. As a side note, the effect of general 4-cycles effect was also not significant, indicating no evidence that sharing a sport with a person from the other gender leads to sharing more sports with this person.

4.5 Other between-network effects of multivariate dynamics

Interdependencies at the actor level. Mean effects of actor level outdegree dependencies were negative and significant for sports activity $\rightarrow$ friendship ($\hat{\mu}_\theta^{WLS} = -0.112$,

(c); significant for S1, S2, S3, and S5). Adolescents who participated in more sports tended to nominate fewer friends over time. The dynamics worked in the opposite direction as well. Mean effects of actor level outdegree dependencies were negative and significant for friendship $\rightarrow$ sports activity for the evaluation effect ($\hat{\mu}_\theta^{WLS} = -1.064$, (c); significant only for S4), and for the endowment effect ($\hat{\mu}_\theta^{WLS} = 1.439$, (b); significant only for S4). Adolescents who nominated more friends tended to participate in fewer sports over time.

4.6 GOF results

As for one-mode friendship networks, two schools (S1 and S3) had good fit for the distributions of outdegrees, and all five schools had good fit for the distribution of indegrees. For the geodesic distances, goodness-of-fit results were poor. With regard to the two-mode networks of sports participation, three schools (S2, S3, and S5) had good fit for the distribution of outdegrees, and all five schools had good fit for the distribution of indegrees.

4.7 Results of quantitative assessment of the friendship-sports association

The results of the average centered Jaccard coefficient for the full model were close to the observed coefficient for all schools, indicating that the fit of our full model in this respect is acceptable for all schools. The average centered Jaccard measures for the full model ranged between 0.02 and 0.03; these low values are reasonable because friendship is a much more specific relation, with a much smaller density, than is sharing the same sports. The proportional contributions of trend, control (within-network dynamics), influence, selection, and the remainder did not differ strongly between schools. These are given in the online supplementary materials (Tables 3S and 4S). In all schools, there was synergy between selection and influence: The estimated contribution of each mechanism selection and friendship increased when the other mechanism was accounted for. Figure 2 presents a pie chart of the average contributions over the five schools.

The contribution of influence, i.e., “friendship leading to shared sports activities,” was estimated as 0.52, much larger than the contribution of selection, i.e., “shared sports activities leading to friendship,” which was 0.12. The trend (which includes the effect of the situation at the first wave) accounted for 0.20 and control (within-network dynamics), for 0.13. The estimated proportion for synergy was 0.03. Thus, it can be concluded that, for these schools, the effect of friendship on sharing sports is more important than the effect of sharing sports on friendship in explaining the association between sports and friendship.

5 Discussion

Adolescents' friendships are structured within the social context of joint activities, of which an important part is organized by the school as extracurricular activities. The group dynamics that link shared activities to friendship have not, however, been explicated in prior network studies. This study investigated the co-evolution of the relational patterns of friendship and participation in organized sports, i.e., how

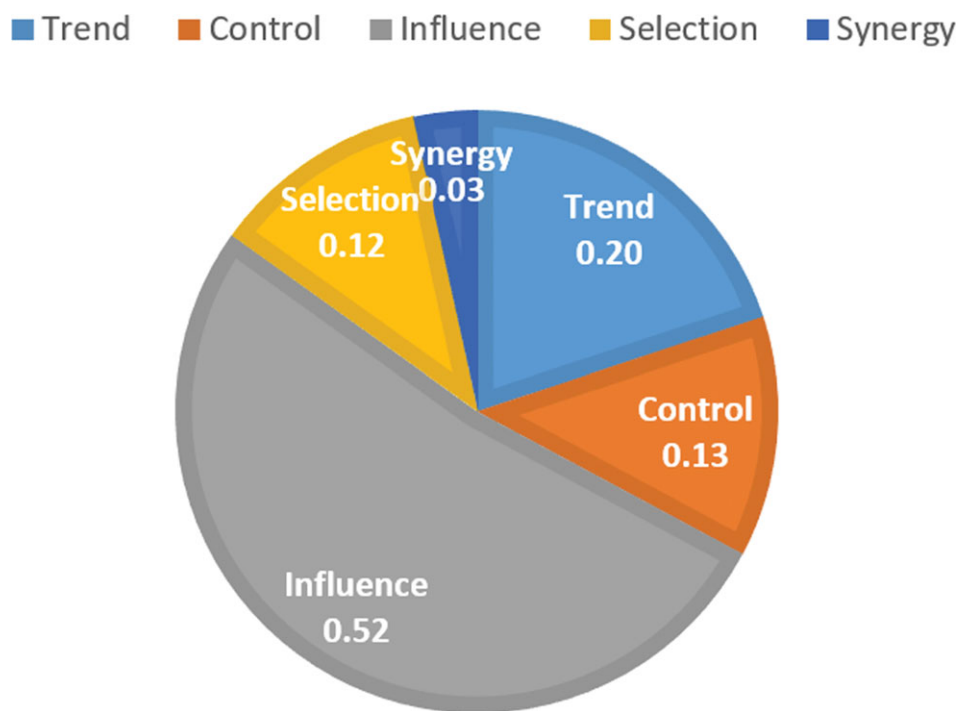


Fig. 2. Pie-charts of the average contributions over the five schools.

adolescents' friendships, on the one hand, and their joint affiliations with organized sports activities (social context), on the other, impact each other.

Our study provided strong support for the social mechanisms of “shared sports activities leading to friendship” (adolescents' participation in sports may promote the formation and maintenance of friendships) and of “friendship leading to shared sports activities” (existing friendships influence participation in the sports shared with their friends), thereby confirming our two hypotheses. These results indicate that friendship formation seems to be promoted by organized sports activities such that adolescents become friends with their co-participants, or more generally with those who are active in the same sports; adolescents also choose to participate in sport activities in which their friends are participating. This study also indicated that the process of “influence from friends on sport participation” is more important than the process of “friend selection due to shared sport context” in accounting for adolescents being friends with their co-participants.

Several existing network-behavior co-evolution studies on network autocorrelation in substance use among adolescents have reported a stronger process of peer selection (i.e., behavior-based friendship selection) compared to the process of peer influence (i.e., friendship-influenced substance use), especially for reciprocated friends (Mercken et al., 2009a; Mercken et al., 2010). A tentative explanation of these contrasting results would be that sport activities might be more important for the adolescents than smoking or drinking, and that it is more important for adolescents to try and make their friends participate in the same sports, to strengthen their friendship and have some fun together, than to achieve the

same level of alcohol and/or tobacco consumption. Sport activities may provide a stronger social context than substance use in itself. It should be noted that previous network studies that take into account broader social contexts have demonstrated that social processes of selection and influence are governed by social structural conditions under which an individual makes a choice in social relations (Cheadle & Schwadel, 2012; Cheadle et al., 2013; de Klepper et al., 2010; Martin-Storey et al., 2015).

Both extracurricular organized sports and friendships provide adolescents with the multifunctional satisfaction of physical and social needs, producing subjective well-being. Revisiting our earlier reference to the theory of SPF, sports teams are paradigmatically a different type of group than the ones based on friendships (Lindenberg, 2015), as members in friendship groups are different functionally (linked by common sentiment rather than common goals), cognitively (linked by personal identity rather than collective identity), and structurally (linked by cohesion rather than place). As a consequence, adolescents may seek or attract friendships among a pool of potential friends within the particular “local position” (Frank et al., 2008) (in our case in the context of sports activities), and seeking to differentiate themselves from others (Frank et al., 2013; Frank et al., 2008; Giordano, 2003). Conversely, friendships may shape social contexts by influencing which sports they participate in with friends. Our study indicates that adolescents may try to assimilate into the social context of sports activities of their existing friends, more strongly than trying to develop friendships because of a shared social context, perhaps because the former often precedes the latter and is able to generate more multifunctionality via participating sports with friends.

The interdependence between shared sports activities and friendships may have implications for school-based network interventions (Valente, 2010; 2012). Coaches, for example, may need to acknowledge that their teams are creating new friendship networks which can form the basis of risk-taking behavior away from the sport. Team captains may have stronger influences on teammates’ behavior both on and off the field. Network interventions that recruit popular students to be change agents may need to acknowledge that these students are likely to be most effective when acting as role models for their friends with whom they share sport activities. These data show a weak tendency for students to recruit their friends onto their teams which may be an effect that coaches would like enhance to get more players on their teams and for the overall well-being of the student body.

Our results have some limitations. First, statistically speaking the results were obtained only for the five schools being studied. However, the significance was strong and the results are in line with existing theory and common sense, so that we think our main finding will hold more generally. Second, the timing of sports participation is not precise and may more appropriately estimate the effect of co-participation on friendship than vice versa. As our survey asked about sports participation during the past 12 months, it is not certain when co-participation may have occurred. For instance, friendship may have waned if co-participation occurred several months ago. Third, whether our findings indicate a primarily dyadic process, or if there is some interaction with transitive closure with a special role for groups of friends sharing the same sport, is unknown. This mechanism could be an interesting

area of future research. Lastly, the goodness of fit left a lot to be desired, especially for the distribution of geodesic distances. This may have to do with the large school size (the networks had 275–446 students), and it would be good to develop new models that have a better fit for large networks.

6 Conclusion

This study charts new territory in explicating the dynamics of friendship relations linked to their social context of organized extracurricular sports activities. From a social network perspective, studying the dynamics of peer networks based just on friendship networks misses the potentially important role of joint activities. Our investigation of friendship dynamics that incorporates the social context of sport activities provides a new, yet plausible, elaboration of a more holistic view of how peer relations evolve.

We have taken the actor-oriented dynamic model beyond an assessment of network dynamics based solely on friendships to a multivariate dynamic model. Social mechanisms that explain the multivariate nature of the dynamics of peer associations may be complex, as shown by our study. As an illustration of this complexity, it may be noted that the quite basic hypotheses of shared sports activities leading to friendships, and friendship leading to shared sport activities, are represented in the multivariate dynamic model by mixed triadic effects, and require controlling for mixed degree effects. By dissecting friendship into its constituent contextual elements, our study found strong evidence that friendship builds on shared sport activities, and in turn leads to shared sport activities.

Future research could extend these results to other activities, group identities, and different age groups to investigate whether this affiliation/friendship hypothesis persists in other contexts. In terms of development, it would be interesting to see whether the relative importance of influence versus selection varies over time or whether influence is the consistently stronger force, as we discovered for these 10th graders. That both selection and influence exist further underscores the importance of understanding how adolescent social context creates varied opportunities for both friendship development and activity participation.

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Conflicts of interest

All authors have nothing to disclose.

Supplementary materials

To view supplementary material for this article, please visit <http://dx.doi.org/10.1017/nws.2018.11>.

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