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The development of adolescents' friendships and antipathies: A longitudinal multivariate network test of balance theory

J. Ashwin Rambaran[a,*], Jan Kornelis Dijkstra[a], Anke Munniksma[b], Antonius H.N. Cillessen[c]

[a] Department of Sociology and Interuniversity Center for Social Science Theory and Methodology (ICS), University of Groningen, Grote Rozenstraat 31, 9712 TG Groningen, The Netherlands
[b] Department of Education, University of Amsterdam, Nieuwe Achtergracht 127, 1018 WS Amsterdam, The Netherlands
[c] Department of Developmental Psychology and Behavioural Science Institute (BSI), Radboud University, Montessorilaan 3, 6500 HE Nijmegen, The Netherlands

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ABSTRACT

We examined the interplay between friendship (best friend) and antipathy (dislike) relationships among adolescents ($N = 480$; 11–14 years) in two US middle schools over three years (grades 6, 7, and 8). Using longitudinal multivariate network analysis (RSiena), the effects of friendships on antipathies and vice versa were tested, while structural network effects (e.g., density, reciprocity, and transitivity) and individual (age, gender, and ethnicity) and behavioral (prosocial and antisocial behavior) dispositions were controlled for. Based on (structural) balance theory, it was expected that friendships would be formed or maintained when two adolescents disliked the same person (shared enemy hypothesis), that friends would tend to agree on whom they disliked (friends' agreement hypothesis), that adolescents would tend to dislike the friends of those they disliked (reinforced animosity hypothesis), and, finally, that they would become or stay friends with dislikes of dislikes (enemy's enemy hypothesis). Support was found for the first three hypotheses, and partially for the fourth hypothesis. Results are discussed in light of adolescents' peer relationships.

Peer relationships constitute an important context for the social and emotional development of adolescents (for a review, see Furman and Rose, 2015). Research on peer relationships has increased exponentially over the past two decades, providing much insight into how relationships among children and adolescents develop over time (for a review, see Brechwald and Prinstein, 2011). Most attention has been drawn to the emergence and maintenance of positive relationships, most prominently friendships (for a review, see Veenstra et al., 2013). However, positive peer relationships only represent a selective aspect of the peer ecology. Adolescents can also be tied negatively to peers, for example, through dislike, antipathy, or enemy relationships.

Researchers have started to acknowledge the importance of these so-called antipathies in the larger peer group. For instance, Card (2010) showed in a review that about one third of children and adolescents are involved in mutual antipathies and that such relationships are associated with externalizing and internalizing problems, low academic achievement, low prosocial behavior, victimization and rejection by peers, lower positive peer regard (e.g., social preference), and the absence of friendships, emphasizing the importance of investigating antipathetic relationships during childhood and adolescence.

Although antipathies are inherently relational in nature, in only a few studies have they been treated from a social network perspective in which antipathies were examined together with positive peer relationships, revealing an interplay between the two types of relationships (Berger and Dijkstra, 2013; Casper and Card, 2010; Huitsing and Veenstra, 2012; Huitsing et al., 2012, 2014). Casper and Card (2010) showed how friendship relationships might turn into antipathetic relationships; four other studies examined the specific network configurations underlying negative and positive peer relationships among students in primary school. Using advanced methods (i.e., social network analyses), Huitsing and colleagues showed both cross-sectionally (Huitsing and Veenstra, 2012; Huitsing et al., 2012) and longitudinally (Huitsing et al., 2014) that victims with the same bullies and bullies with the same

* Corresponding author. Tel.: +31 503636290; fax: +31 503637398.
E-mail addresses: j.a.rambaran@rug.nl (J.A. Rambaran), jan.dijkstra@rug.nl (J.K. Dijkstra), a.munniksma@uva.nl (A. Munniksma), a.cillessen@psych.ru.nl (A.H.N. Cillessen).

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victims like or defend each other. Berger and Dijkstra (2013) found that friends tend to dislike the same person.

Together, the findings of these studies indicate that positive ties (e.g., friendships) and negative ties (antipathies) are interrelated. In the present study, we add to this previous work by (1) performing a more systematic examination of the interplay between positive and negative peer relationships (i.e., by examining different network configurations); (2) investigating this interplay in two relatively large middle schools covering three years (previous researchers examined them over one year of primary school); and (3) better accounting for alternative selection mechanisms (i.e., accounting for individual and behavioral characteristics that determine selection processes among individuals; see Veenstra et al., 2013).

In sum, the present study was aimed at undertaking a thorough examination of the network configurations that may underlie the way positive relationships (friendships) affect negative relationships (antipathies) in terms of formation and maintenance, and vice versa. Toward this end, the present study examined the simultaneous development of friendship and antipathy networks and their interplay using longitudinal multivariate social network analysis (Snijders et al., 2013).

1. Background

We used balance theory to understand the interplay between adolescents' friendship and antipathy networks (Heider, 1946, 1958; see also Cartwright and Harary, 1956; Davis, 1967; Davol, 1959; Newcomb, 1961). Heider's balance theory (1946, 1958) describes how relationships shape a person's sentiment (e.g., a thought, view, attitude, or feeling) about any 'situation, event, idea, or a thing' (Heider, 1946: 107). That is, the valence of a person's tie to a second person (and how the second person 'feels' about something) influences the focal person's opinion or attitude about others. Hence, Heider (1946) assigned meaning to the influence of a second person to whom the focal person is tied. The key assumption of balance theory is that people prefer balanced configurations over imbalanced ones (Doreian et al., 2005). For instance, having the same opinion about certain objects as those who you are friends with is in line with one's expectations of what a friendship should look like. This leads to configurations that are congruent as they are perceived as comfortable and stable. In contrast, people tend to avoid configurations that are imbalanced as disagreeing with friends causes strain and tension, and hence, people will change their relationship, opinion or attitude.

Heider's balance theory (1946, 1958) has been used to explain a wide range of socio-psychological phenomena (e.g., relative deprivation, political opinions, conflict management, job mobility, social comparison processes, leadership and group effectiveness, social behavior, communication; see Davis, 1963), showing that an individual's positive (or negative) attitude about a situation or issue depends on the individual's relationship with a friend and that friend's positive (or negative) attitude toward the situation or issue. Although balance theory was rooted in (social) psychology, the main principles also have been applied to sociometric triplets of three individuals who share ties to one another (Davol, 1959; Newcomb, 1961). The best-known example of such a configuration is transitivity (Davis, 1970); the tendency to call a 'friend of a friend as one's own friend.'

Balance theory research has been divided into two main groups (Hummon and Doreian, 2003): cognitive balance theory to explain individuals' cognitive reasoning (Heider, 1946, 1958), and structural balance theory to explain structurally determined social relationships (Cartwright and Harary, 1956). We place ourselves in the latter category but recognize that relationships are formed and maintained in the presence of cognitive functioning. We consider such processes by taking an actor-based social choice approach similar to that taken in recent structural balance research as outlined by Hummon and Doreian (2003), which takes the group dynamics of social balance processes into account. We assume that (1) actors have pre-existing knowledge, whether accurate or not, about each other's tie choices and preferences, (2) actors have some awareness of the wider group structure, and (3) tie choices made by actors to achieve balance are based on what they know at the time they make a choice, and that their social knowledge changes as they learn about and react to their social environment (see for a discussion Hummon and Doreian, 2003).

Although the line of balance theory research, both structural and social, is long and extensive (for reviews see Forsyth, 1990; Opp, 1984; Taylor, 1970), the theory only infrequently has been explored in dynamic contexts (e.g., Abell and Ludwig, 2009; Doreian et al., 1996; Doreian and Mrvar, 1996; Hummon and Doreian, 2003). It is important to note here that a cross-sectional design is insufficient (see Abell and Ludwig, 2009), because structural balance theory is a theory of change (Doreian et al., 2005). It assumes an interrelation and interchangeability between positive and negative relationships (Doreian and Mrvar, 1996; Hummon and Doreian, 2003). Moreover, empirical studies in which a 'complete dynamic network' approach was taken, and in which important alternative selection mechanisms (i.e., structural tendencies and selection homophily) were controlled for, are scarce (e.g., Berger and Dijkstra, 2013; Huitsing et al., 2014).

To enhance our knowledge of balance mechanisms, we examined multiple social networks (positively and negatively tied) simultaneously over time as well as their mutual dependence, while controlling for the roles of the individual (i.e., age, gender, and ethnicity) and behavioral dispositions (i.e., prosocial and antisocial behavior) of individuals in the formation and maintenance of relationships with others, using the stochastic actor-oriented model (SAOM) (Snijders et al., 2013). This allowed us to examine the main principles of balance theory, which are described below.

1.1. Hypotheses

According to structural balance theory (Cartwright and Harary, 1956; see also Heider, 1958), relationship constructs are balanced when they are characterized by three positive ties or by two negative ties and one positive, resulting in stable relationships among the three individuals in the group. Conversely, relationship constructs involving two positive ties and one negative are considered unstable and imbalanced. Based on these principles, we tested eight configurations between friendships and antipathies.

In the first configuration, balance is achieved when two individuals share the same negative tie with a third person (Fig. 1). In this configuration, it is likely that the first person's relationship with the second becomes or stays positive over time (e.g., *i* dislikes *h* and *j* dislikes *h*, then *i* likes *j*). This balanced state tells us that when two individuals both dislike a third person they are likely to become or stay friends. We call this the *shared enemy hypothesis*, indicating that sharing the same antipathy may result in friendship formation or maintenance; expressed proverbially, 'when my enemy is your enemy, we're (staying) friends.' This effect can be explained in two ways: an initial situation of friends disliking the same people persisted over time (friendship maintenance); alternatively, a friendship formed because two persons disliked the same person (friendship formation). The former indicates that sharing the same enemy stabilizes or strengthens friendship. The latter indicates that disliking the same person fosters the formation of friendship. In both cases, we expect that the configuration is held together by balance: the 'cost' of not gaining a new friend or losing an existing one,

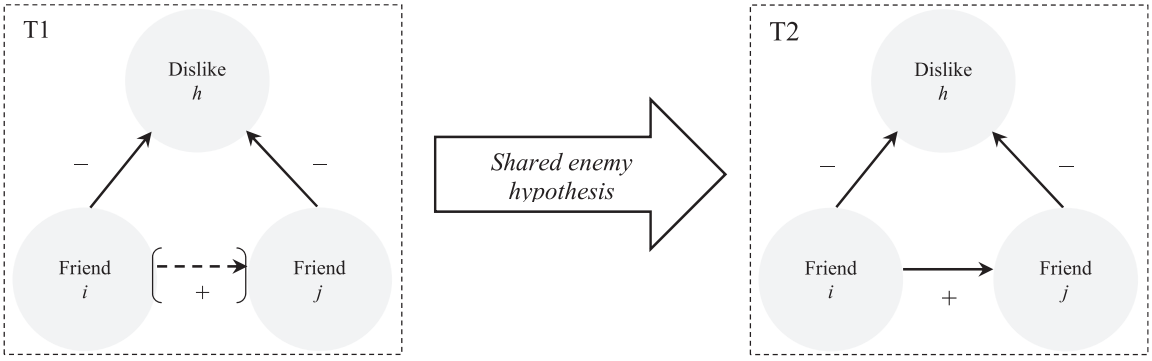


Fig. 1. Shared antipathies leads to friendship formation and maintenance (between brackets).

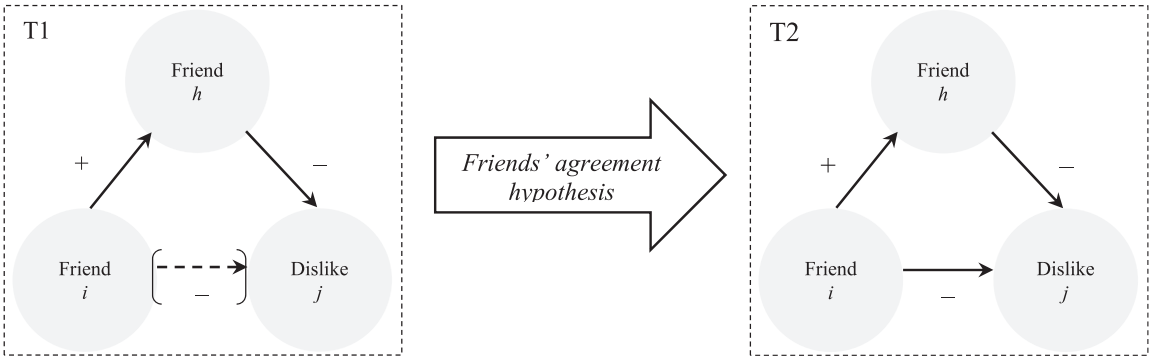


Fig. 2. Friendship leads to antipathy formation and maintenance (between brackets).

and the accompanying discomfort (imbalance), ensure that both actors dislike the same person and are friends with each other.[1]

In the second configuration, balance is achieved when the first person's relationship with a third person is positive while the third person's relationship with a second person is negative (Fig. 2). In this configuration, it is likely that the first person's relationship with the second person becomes or stays negative over time (e.g., *i* likes *h* and *h* dislikes *j*, then *i* dislikes *j*). This balanced state tells us that when a friend dislikes a person, the person will dislike the person as well. We call this the *friends' agreement hypothesis*, indicating that friends 'agree' on shared antipathies or, proverbially, 'my friend's enemy is my enemy.' This effect may be seen as an influence effect, as it indicates that people influence whom their friends dislike. This effect can be explained in two ways: adolescents may start to dislike a person whom their friends already dislike (antipathy formation); alternatively, adolescents may persist in disliking a person whom their friends dislike (antipathy maintenance). The former may operate more strongly when friendships are in the early stages of development, and adolescents may feel a stronger urge to agree (i.e., conform) with their 'perceived' or 'desired' friends in order to become 'truly' friends. The latter may operate more strongly when friendships have 'matured.' Perceived norms governing these friendships may impose strong expectancies for what is needed to stay part of the friendship group. In both instances, we expect that the configuration is held together by balance: the 'cost' of losing an existing friendship, and the accompanying discomfort (imbalance) ensures that adolescents will agree with their friends even when this means disliking another person.

In the third configuration, balance is achieved when the first person's relationship with a third person is negative while the third person's relationship with a second person is positive (Fig. 3). In this configuration, it is likely that the first person's relationship with the second person becomes or stays negative over time (e.g., *i* dislikes *h* and *h* likes *j*, then *i* dislikes *j*). This balanced state tells us that when an adolescent dislikes a person, he will dislike that person's friend as well. We call this the *reinforced animosity hypothesis*, indicating that adolescents 'disagree' with their antipathies or, proverbially, 'my enemy's friend is my enemy.' This effect may also be seen as an influence effect, as it suggests that people (start to) dislike the friends of their antipathies. This effect can be explained in two ways: adolescents may start to dislike a person whom their antipathies already like (antipathy formation); alternatively, adolescents may persist to dislike a person whom antipathies like (antipathy maintenance). The former may operate more strongly when antipathies are in the early stages of development and adolescents may feel a strong urge to disagree with them. The latter may operate more strongly when antipathies have 'matured', and the resentment for antipathies via their friends becomes prominent.

In the fourth configuration, balance is achieved when the first person's relationship with a third person is negative and the third person's relationship with a second person is negative (Fig. 4). We expect that the first person's relationship with the second person becomes or stays positive over time (e.g., *i* dislikes *h* and *h* dislikes *j*, then *i* likes *j*). This balanced state indicates that adolescents befriend the dislikes of dislikes. This was labeled as the *enemy's enemy hypothesis*, shorthand for 'my enemy's enemy is my friend.' This effect may also be seen as a configuration that strengthens one's own position against antipathies by forming or maintaining an alliance with a person who initially seems unattractive; that

[1] It is possible to test the mechanisms of maintenance and formation underlying these processes using the stochastic actor-oriented model utilized in the present study. That is, the evaluation function that captures both effects can be substituted with the 'creation' and 'endowment' (maintenance) effects. Unfortunately, the models in which both effects were analyzed did not converge, probably due to low power (too little information) to separate effects for tie creation from those of tie termination (Ripley et al., 2015).

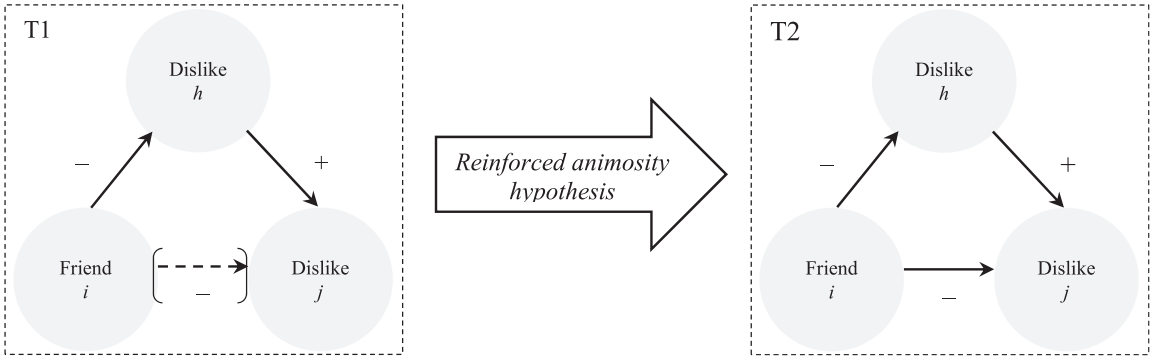


Fig. 3. Antipathy leads to antipathy formation and maintenance (between brackets).

person is disliked as well, but may be instrumental in opposing a strong adversary.

Additionally, we examined four imbalanced triadic configurations that mirror the four balanced triadic configurations described above. In the first imbalanced state two adolescents are friends with the same person but come to dislike each other over time (e.g., *i* likes *h* and *j* likes *h*, then *i* dislikes *j*; see Imbalanced Figure A in Table 1). In other words, sharing the same friends has resulted in antipathy. In the second imbalanced state adolescents 'agree' with their antipathies on whom they befriend (e.g., *i* dislikes *h* and *h* likes *j*, then *i* likes *j*; see Imbalanced Figure B in Table 1). In other words, adolescents become friends with friends of 'enemies'. In the third imbalanced state adolescents 'disagree' with their friends on whom they like (e.g., *i* likes *h* and *h* dislikes *j*, then *i* likes *j*; see Imbalanced Figure C in Table 1). In the fourth imbalanced state adolescents 'disagree' with their friends on whom they dislike (e.g., *i* likes *h* and *h* likes *j*, then *i* dislikes *j*; see Imbalanced Figure D in Table 1). These imbalanced configurations are unlikely, according to Cartwright and Harary's (1956) generalization of Heider's (1946, 1958) balance theory (see also Hummon and Doreian, 2003; Doreian and Krackhardt, 2001).

In the present study, all eight network configurations were tested, allowing us to examine the interplay between adolescents' friendships and antipathies over time. We controlled for structural network effects that are known to affect relationship formation or maintenance, such as transitivity (the tendency to form or maintain clustered groups of relationships), reciprocity (the tendency to form or maintain bilateral relationships), and outdegree (the tendency to form or maintain unilateral relationships). In addition to network tendencies, relationship formation and maintenance are also influenced by individual and behavioral dispositions (Byrne, 1971). McPherson et al. (2001) showed that similarities in gender and ethnicity are important factors for attraction (see also Moody, 2001). In terms of behaviors, similarities in prosocial and antisocial behaviors foster friendship formation and maintenance among adolescents (e.g., Logis et al., 2013; Sijtsema et al., 2010).

In reverse, it could be argued that dissimilarity in antisocial and prosocial behavior might steer the development of antipathies. However, little is known about how individual and behavioral characteristics affect negative ties because attention so far has mostly been devoted to positive networks (see Veenstra et al., 2013). Research has yet to determine the role of age, gender, ethnicity, and prosocial and antisocial behavior in negative networks. For instance, gender differences in antipathetic relationships are trivial, and antipathetic relationships are equally often same gender and mixed gender (Card, 2010), whereas ethnicity is a common cause of stereotyping and peer rejection (see Killen and Stangor, 2011), potentially triggering the emergence of antipathies. Finally, we take age into account as same-age peers might be more inclined to interact with each other, leading to friendships but also antipathies. Hence, these covariates seem important to control for when examining the formation and development of positive and negative tied networks.

1.2. The present study

In the present study, we tested the principles of balance theory by examining the development of adolescents' friendships and antipathies in two US middle schools ($N = 480$; 11–14 years) across three years (grades 6, 7, and 8), while controlling for structural network effects and individual (age, gender, ethnicity) and behavioral (antisocial and prosocial) dispositions in the formation and maintenance of friendships and antipathies. We expected that friendships would be formed or maintained when two adolescents disliked the same person (shared enemy hypothesis), that friends would agree on whom they (continue to) dislike (friends' agreement hypothesis), that adolescents would tend to dislike the friends of those they disliked (reinforced animosity hypothesis), and that dislikes of

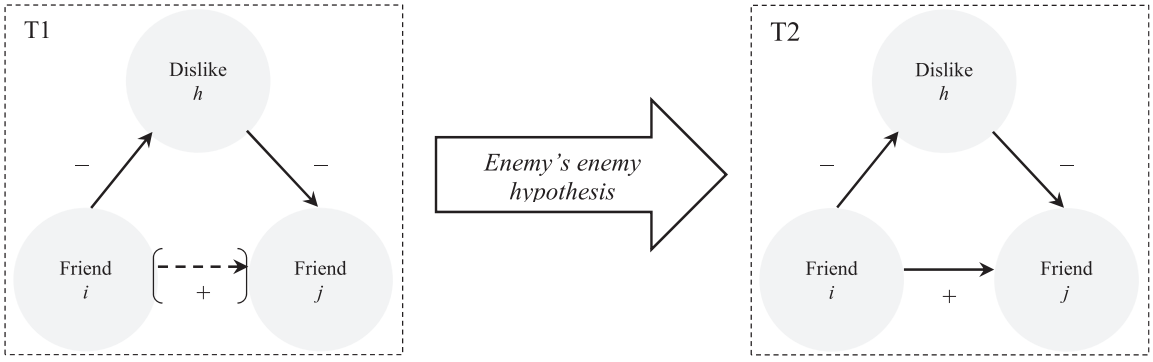
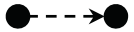
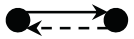
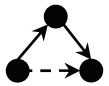
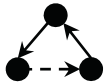
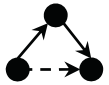
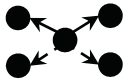
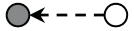
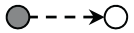
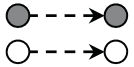
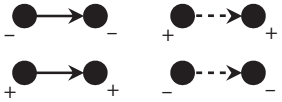
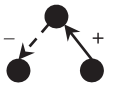
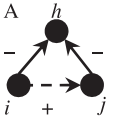
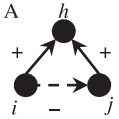
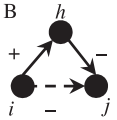
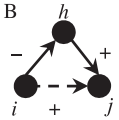
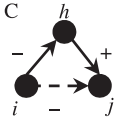
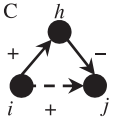
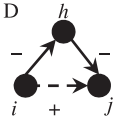
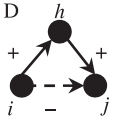
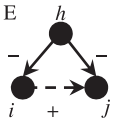
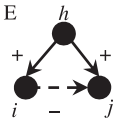
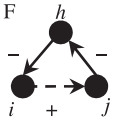
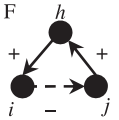


Fig. 4. Antipathy leads to friendship formation and maintenance (between brackets).

Table 1
Mathematical representation and interpretation of the effects used in the present study.

Effect used	Mathematical express.	Graphical express.	Interpretation {RSiena shortname}
Structural network effects			
Outdegree (density)	$\sum_i x_{ij}$		Actor *i* extending ties to alter *j* {density}
Reciprocity	$\sum_j x_{ij}x_{ji}$		Actor *i* reciprocating ties to alter *j* {recip}
Transitive triplets	$\sum_{j,h} x_{ij}x_{ih}x_{hj}$		Actor *i* extending ties to alter *j* to whom he is indirectly tied (via *h*) {transTrip}
Three-cycles	$\sum_{j,h} x_{ij}x_{jh}x_{hi}$		Actor *i* extending ties to alter *j* to whom he is indirectly tied (via *h*) {cycle3}
Transitive ties	$\sum_j x_{ij}\max_h(x_{ih}x_{hj})$		Actor *i* extending ties to alter *j* to whom he is directly and indirectly tied (via *h*) (one indirect tie suffices) {transTies}
Indegree-popularity	$\sum_j x_{ij}\sum_h x_{hj}$		Actors with many incoming ties attract more incoming ties {inPop}
Outdegree-activity	x_{i+}^2		Actors with many outgoing ties extend more outgoing ties {outAct}
Covariate selection effects			
Covariate alter	$\sum_j x_{ij}v_j$		Actor *i* with higher values on a covariate (v) attracts more incoming ties {altX}
Covariate ego	$v_i x_{i+}$		Actor *i* with higher values on a covariate (v) extends more outgoing ties {egoX}
Same covariate	$\sum_j x_{ij}\{v_i = v_j\}$		Actor *i* extends ties to alter *j* who has exactly the same values on a covariate {sameX}
Covariate similarity	$\sum_j x_{ij}(\mathrm{sim}_{ij}^v - \widehat{\mathrm{sim}}^v)$		Actor *i* extends ties to alter *j* who has similar values on a covariate {simX}
Between-network dyadic effects			
Main effect of friendship on antipathy (and vice versa)	$\sum_j x_{ij}w_{ij}$		Friendship (or antipathy) between *i* and *j* leads to antipathy (or friendship) between *i* and *j* {crprod}
Friendship popularity on antipathy popularity (and vice versa)	$\sum_j x_{ij}(w_{j+} - \bar{w})$		Actors who receive many friendship (or antipathy) ties attract more antipathy (or friendship) ties {inPopIntn}

Friendship popularity on antipathy activity	$\sum_j w_{ij}(x_{i+} - \bar{x})$			Actors who receive many friendship ties extend more antipathy ties {outActIntn}
Between-network triadic effects		Balanced	Imbalanced	
Shared antipathy to friendship (B) ('*shared enemy*') Shared friendship to antipathy (I)	$\sum_{j\#h} x_{ij} w_{ih} w_{jh}$			Agreement between *i* and *j* in antipathy (or friendship) toward *h* leads to friendship (or antipathy) between *i* and *j* {from}
Friendship agreement to antipathy (B) ('*friends' agreement*') Antipathy agreement to friendship (I)	$\sum_{j\#h} x_{ij} w_{ih} x_{hj}$			Friendship (or antipathy) between *i* and *h* and antipathy (or friendship) between *h* and *j* lead to antipathy (or friendship) between *i* and *j* {to}
Mixed closure of antipathy (B) ('*reinforced animosity*') Mixed closure of friendship (I)	$\sum_{j\#h} x_{ij} x_{ih} w_{hj}$			Incoming of *j* in friendship (or antipathy) from *h* and outgoing of *i* in friendship (or antipathy) toward *h* lead to friendship (or antipathy) between *i* and *j* {cl.XWX}
Closure of friendship (B) ('*enemy's enemy*') Closure of antipathy (I)	$\Sigma_{j\#h} x_{ij} w_{ih} w_{hj}$			Outgoing of *h* in antipathy (or friendship) to *j* and outgoing of *i* in antipathy (or friendship) to *h* lead to friendship (or antipathy) between *i* and *j* {closure}
Shared incoming of antipathy (B) Shared incoming of friendship (I)	$\sum_{j\#h} x_{ij} w_{hi} w_{hj}$			Shared incoming of *i* and *j* in antipathy (or friendship) from *h* leads to friendship (or antipathy) between *i* and *j* {sharedIn}
Cyclic closure of friendship (B) Cyclic closure of antipathy (I)	$\Sigma_{j\#h} x_{ij} w_{jh} w_{hi}$			Incoming of *i* from *h* and incoming of *h* from *j* in antipathy (or friendship) leads to friendship (or antipathy) between *i* and *j* {cyClosure}

Notes. The solid lines in the figures represent the initial tie configuration that was observed at the starting point of the estimation; the dotted lines in the figures represent ties that were formed or maintained after the estimation procedure was finished; B = balanced and I = imbalanced.

dislikes would turn into or remain friends (enemy's enemy hypothesis).

2. Methods

2.1. Data and sample

The participants were enrolled in a larger longitudinal study on the social and academic development of youth. The study was approved by the Internal Review Board (IRB) of the University of Connecticut. The data for the present study were collected in grades 6, 7, and 8 (age range 11–14 years) in three consecutive years (spring 1998, 1999, and 2000) in two middle schools, serving lower and lower-middle class families in a medium-sized town in the northeastern United States. Parental consent was obtained for all participating adolescents prior to testing; verbal assent was also obtained from the participants themselves. Less than 1% of the initially approached students refused to participate. From the original data pool of approximately 600 students, complete data were available for 480 students (220 students in School 1 and 260 students in School 2). Only those students who participated in all three grades and for whom both nomination and individual data were available were included in the present study (see also Dijkstra et al., 2013).[2]

The two schools were similar with regard to gender and ethnicity. Gender was evenly distributed, with slightly more boys in School 1 (53.2%) than in School 2 (49.5%). The schools were also similar in terms of ethnic/racial composition (School 1: White 71.8%, Black 18.2%, and Hispanic 10.0%; School 2: White 78.1%, Black 11.9%, Hispanic 7.7%, and Asian 2.3%).

2.2. Procedure

All testing took place in the spring during 90-min English classes and was administered by trained graduate and undergraduate research assistants. In most cases, the classroom teacher remained in the room during testing. Students not participating in the study were instructed to do homework or read. Prior to testing, all confidentiality procedures were explained. Students were told that the data would be entered and stored using code numbers instead of names, that only the researchers would see the data, that participation was voluntary, and that they could leave blank any questions they did not wish to answer.

Participants completed a sociometric measure each year, consisting of a booklet in which they reported their choices. Each page of the booklet contained one sociometric question followed by the names of the students in the grade who had permission to participate, sorted alphabetically by first name and preceded by a code number. Participants were asked to read each question, think about the students who best fit the description, and then circle their code numbers. Nominations were unlimited; students could choose as many or as few grade-mates as they wished for each question, including same- and other-gender peers, but not themselves. Students without permission were not on the roster and could not be nominated.

[2] Network analysis is sensitive to missing network and missing actor data (cf. Huisman and Steglich, 2008). RSiena can take into account up to 20% of missing data (Ripley et al., 2015). In the present study, there was substantial missing data in both schools during both time intervals (i.e., 1998–1999 and 1999–2000) (School 1, 16% and 24%; School 2, 10% and 16%, respectively). Hence, no nomination data were available for these students. In order to avoid potential model convergence problems, we included only students who participated in all three waves. Additional analysis with the full network including missing data showed, however, largely similar results for both schools. With regard to the between-networks effects, the 'shared antipathy to friendship' effect in School 1 was positive but no longer significant (results available upon request).

2.3. Measures

Friendships. Students were asked to nominate the peers whom they perceived as their 'best friends' in their grade. Friendship nominations were coded 1 and non-nominations were coded 0, resulting in friendship networks consisting of directed nominations for each grade.

Antipathies were measured by asking students to nominate the peers whom they 'liked the least' in their grade. Similar to friendship networks, antipathy nominations were coded 1 and non-nominations were coded 0, and these were used to construct antipathy networks with directed antipathy nominations.

Prosocial behavior. Students were asked to nominate the peers who 'cooperate, share, and help others.' Peer nominations for each student were summed. For analytical purposes, total scores were transformed into proportion scores by dividing them by the number of participating grade-mates, resulting in a continuous measure ranging from 0 to 1 (T1: mean = 0.548, SD = 0.279; T2: mean = 0.514, SD = 0.287; T3: mean = 0.498, SD = 0.289).

Antisocial behavior. Students were asked to nominate the peers who 'start fights, say mean things, and tease others.' Similar to prosocial behavior, nominations were summed and transformed into proportion scores, resulting in a continuous measure ranging from 0 to 1 (T1: mean = 0.476, SD = 0.275; T2: mean = 0.485, SD = 0.286; T3: mean = 0.498, SD = 0.288).

2.4. Attrition analyses

Students who did not participate in all waves were compared with students who did participate in all waves on friendships and antipathies in the three grades. There were no significant differences in School 2. In School 1, participants who dropped out of the study had fewer friendships in grade 6, $t(265) = -2.46$, $p < .05$, and fewer antipathies in grade 7, $t(196) = -2.70$, $p < .01$. There were no significant differences in friendships in grades 7 and 8, or in antipathies in grades 6 and 8.

2.5. Analytic strategy

Analyses were conducted using longitudinal social network modeling (RSiena; 'Simulation Investigation for Empirical Network Analysis'), which allowed for examination of the development of adolescents' friendship and antipathy networks simultaneously over time (Snijders et al., 2013; Ripley et al., 2015), while taking students' age, gender, ethnicity, and prosocial and antisocial behavior into account.

2.6. Estimation procedure

RSiena simulates data between two time points by interpreting the observed social networks as the cumulating result of unobserved sequences of changes based on decisions made by individuals in the network (Veenstra and Steglich, 2012). RSiena models the unobserved change processes via 'microsteps.' At each step, individuals can choose to maintain, dissolve, or create ties to other individuals in the network. The dependencies at the beginning of an observed network are taken as the starting point. From there, RSiena models each subsequent step through repeated imputation of microsteps via the Robbins–Monro stochastic approximation. This method also allows for the estimation of structural and individual effects on changes in the network over time. The reliability of the estimates in the estimation process is assessed using good convergence statistics (t-ratios close to zero; for details, see Ripley et al., 2015). For a technical explanation of and an introduction to the coevolution multivariate network analysis model, we refer to Snijders et al. (2013).

Multivariate analysis in RSiena yields three types of parameters: rate parameters for each type of network (i.e., friendship and antipathy), selection parameters for each type of network, and between-networks parameters (reflecting the interplay between the two networks). Below, we briefly discuss the effects that were included in our models. The choice of these parameters was based on a combination of three requirements: (1) to include structures that are theoretically relevant, (2) to capture adequately the structures in our networks (i.e., lower-order, second-order, and higher-order network structures), and (3) to keep the model parsimonious. The final two requirements were assessed using fit statistics and model convergence. A mathematical representation of the included effects is presented in Table 1.

2.7. Lower-order effects

Lower-order network parameters were included to capture the basic tendencies of actors to form and maintain relationships in the networks. For example, actors in friendship networks generally have a tendency to form and maintain ties; this is captured by the *density* parameter. Friendship networks are further characterized by high levels of *reciprocity*, or the tendency of actors to reciprocate friendships. There is reason to believe that these processes are similar in antipathy networks (see Card, 2010). Unlike antipathy networks, friendship networks are often transitive. Therefore, we included three transitivity effects in the friendship networks: transitive triplets, three-cycles, and transitive ties. The *transitive triplets* effect reflects the tendency that 'friends of friends become friends' (transitive closure), whereas three-cycles effect reflects the tendency toward anti-hierarchy. The *transitive ties* effect was also included in the antipathy network, and represents the tendency to be tied both directly and indirectly (Steglich et al., 2010). In addition to these effects, we included two degree-related effects to differentiate between actors who received or gave many (or few) ties in the networks. The *indegree-popularity* (or *indegree-antipathy*) effect reflects the tendency of actors who receive many nominations to receive more nominations over time, whereas the *outdegree-activity* effect reflects the tendency of actors who give many nominations to give more nominations over time.

When examining higher-order effects, that is, effects in our model assessing balanced configurations, it is necessary to control for second-order effects. We included two such effects that controlled for the main effects of friendship on antipathy and vice versa, which gave the likelihood that an outgoing friendship tie would result in an antipathy tie at subsequent time points and vice versa. Additionally, we controlled for three other dyadic between-networks effects that controlled for the spread of the networks with regard to outgoing and incoming ties. The choice of these effects was based on score-type tests (see Schweinberger, 2012). We considered whether actors who received many friendship nominations received more antipathy nominations over time (*friendship indegree to antipathy indegree* effect) and vice versa (*antipathy indegree to friendship indegree* effect); and whether actors who received many friendship nominations gave more antipathy nominations over time (*friendship indegree to antipathy outdegree* effect). These effects seemed highly unlikely and, therefore, were expected to be negative.

2.8. Between-networks effects

Modeling two networks simultaneously allows one to test between-networks effects; that is, the dependency of one type of network on another type (see Snijders et al., 2013). Eight between-networks effects were included for each network (i.e., friendship and antipathy) to test for these network dependencies: four balanced effects and four counterpart imbalanced effects (Table 1). The *shared antipathy to friendship* effect indicates the likelihood that 'agreeing' upon shared antipathies will result in the formation of a new or the maintenance of an existing friendship tie (Fig. 1); this was used to test the shared enemy hypothesis. The *friendship agreement to antipathy* effect indicates to what extent an existing friendship tie results in the formation of a new or the maintenance of an existing antipathy tie (Fig. 2); this was used to test the friends' agreement hypothesis. The *mixed closure of antipathy* effect indicates the formation or maintenance of antipathies with friends of dislikes (Fig. 3); this was used to test the reinforced animosity hypothesis. The *closure of friendship* effect indicates whether people form or maintain friendships with dislikes of those they dislike (Fig. 4); this was used to test the enemy's enemy hypothesis. Balance theory predicts that these triadic configurations will have positive parameters indicating balance between the three individuals involved.

With regard to the four counterpart imbalanced effects (see Table 1), balance theory predicts that these triadic configurations are unlikely and will have negative parameters indicating imbalance between the three individuals involved. The *shared friendship to antipathy* effect reflects the probability that sharing a friendship relationship will lead to the creation or maintenance of antipathy between two individuals (Imbalanced Figure A in Table 1). The *antipathy agreement to friendship* effect indicates the likelihood that having an antipathy relationship will result in the same friendship relationship (Imbalanced Figure B in Table 1). The *mixed closure of friendship* effect indicates to what extent individuals form or maintain a friendship tie with dislikes of friends (Imbalanced Figure C in Table 1). The *closure of antipathy* effect indicates to what extent individuals form or maintain an antipathy tie with friends of friends (Imbalanced Figure D in Table 1).

2.9. Covariate selection effects

We controlled for individual (i.e., age, gender, and ethnicity) and behavioral dispositions (i.e., prosocial and antisocial behavior), by including selection effects for each of these covariates. These selection effects are dynamic and thus change over time, while the covariates may change or remain constant. We included three selection dynamics effects (*alter* effect, *ego* effect, and *same* or *similarity* effect). The same/similarity effects are dyadic in nature, meaning that they capture the effects of covariates on tie formation or maintenance between an adolescent (ego) and his or her peer (alter) ('homophily' effect); the alter and ego effects are individual in nature, meaning that they capture the effects of covariates on nominations received ('popularity' effect) or nominations given ('activity' effect), respectively.

2.10. Model building and model fit

The coevolution of friendship and antipathy networks was analyzed for each school separately in three steps.[3] In Step 1, we score-type tested (see Schweinberger, 2012) whether our networks

[3] A model selection criterion has not yet been developed (Snijders et al., 2010). Currently, the best way is to use ad hoc stepwise modeling procedures combining forward selection (where effects are added) with backwards selection (where effects are deleted). The steps can be based on significance tests (Schweinberger, 2012) for the various effects that may be included in the model. In principle, forward selection is technically easier than backward selection because the latter is more time consuming and may lead to instability of the estimation algorithm (see for more details about this procedure Snijders et al., 2010). The inclusion of additional effects can be guided by assessing the fit of the model with respect to auxiliary statistics of networks, which are not explicitly fit by a particular effect, but are nonetheless important features of the network to be represented by the probability model (cf. Ripley et al., 2015).

adhered to the expected structure of networks: that is, that relationships were formed in dyads (reciprocity) that were embedded in triadic structures (transitivity) within the larger network (see for model specification issues Veenstra and Steglich, 2012; see also Snijders et al., 2010). As mentioned previously, we did not include the transitive triplets effect in the antipathy networks, but included the transitive ties effect as well as the indegree-antipathy effect. Inclusion of these structural network effects significantly improved model fit (Schweinberger, 2012) (χ^2 = 34,228.4 and 46,748.0, *df*'s = 6, *p*'s < .001, School 1 and 2, respectively). In Step 2, we added individual gender, and ethnicity and prosocial and antisocial behaviors to test whether they accounted for the formation and maintenance of friendships and antipathies. This appeared to be the case as model fit increased significantly (individual variables: χ^2 = 959.0 and 1243.1; behavioral variables: χ^2 = 202.7 and 443.6; *df*'s = 12; *p*'s < .001; School 1 and 2, respectively). In Step 3, between-networks effects were added to test whether friendships and antipathies interacted and affected each other. Again, model fit increased significantly (χ^2 = 66.6 and 69.1, *df*'s = 6, *p*'s < .001, School 1 and 2, respectively), allowing us to test the main principles of balance theory. For the sake of brevity, we present the results from the full model only (i.e., the model that includes all effect parameters described), because the estimates from the previous models were not (or only marginally) affected by the inclusion (i.e., estimation) of additional effects.

After this model-building procedure, we assessed model fit using Goodness of Fit (GoF) tests with auxiliary statistics (Lospinoso, 2012; Schweinberger, 2012). Four auxiliary GoF statistics were assessed: outdegree distribution, indegree distribution, geodesic distribution, and triadic census. Basically, each test compares the observed values at the ends of the periods with the simulated values for the ends of the periods. The differences are assessed by combining the auxiliary statistics using Mahalanobis distance (for more details see Ripley et al., 2015). Analyses of the initially specified model showed unsatisfactory fit on the auxiliary statistics. Hence, we decided to estimate a more comprehensive model and added several other parameters (here we added also age as predictor; see Table 1 for a complete list of the included effects), but were mainly successful in improving the indegree distribution.[4]

3. Results

3.1. Network characteristics

Description of the network and individual variables are presented in Table 2. On average, participants nominated 6–10 friends or antipathies (see average degrees in Table 2). The majority of students nominated at least one friend (77.7–85.5%) or disliked one peer (82.7–94.1%). Density (proportion of nominations given) was also similar for friendship (2.7–4.6%) and antipathy (2.3–4.6%). The proportion of reciprocated nominations was higher for friendship (30.4–41.1%) than for antipathy (8.3–10.5%). Same-gender nominations were also higher for friendship (78.2–83.6%) than for antipathy (52.3–67.7%), whereas same-ethnicity nominations were similar (friendship: 67.4–79.6%; antipathy: 64.8–70.0%). Over 50% of friendship nominations were same gender or same ethnicity.

Geary's *C* network autocorrelation coefficient was used to indicate the degree to which friends or antipathies display similarity in traits or behaviors (Steglich et al., 2010). We opted for Geary's *C* (1954), and not Moran's *I* (1948), because the former is distance-based and suits our grade-based data better. That is, we assessed how correlated two actors are when they have a sociometric distance of 1 (i.e., being direct 'neighbors' – the usual Geary measure). Correlations were moderate to high in the friendship networks and low (particularly for prosocial and antisocial behavior) to moderate in the antipathy networks. These differences between the friendship and antipathy networks appeared to be significant for each correlation including the same covariate, meaning that similarity was more prominent in the friendship networks than in the antipathy networks.[5]

The Jaccard index indicated moderate stability in friendship ties between time points (around 15–20%), but low stability in antipathy ties (around 6–10%).[6] This means that students changed antipathies more frequently than friendships from one time point to the next. Although the Jaccard index was relatively low in the present study, this had no consequences for the analyses as all models showed good convergence statistics.

3.2. Structural network effects

Results of the RSiena analyses are presented in Table 3. Participants were likely to be selective in their nominations (negative outdegree effects) and to reciprocate nominations received (positive reciprocity effects). Further, participants tended to nominate friends of friends as friends (positive transitive triplets effects), and to be both directly and indirectly tied to others in the networks (positive transitive ties effects). The positive transitive triplets effects in combination with the negative three-cycles effects indicate the existence of local hierarchies (with some adolescents receiving more friendship nominations than others within the same triplet). Participants who received many nominations attracted more nominations in the antipathy networks (positive in-degree-antipathy effect in School 1) but fewer nominations in the friendship networks (negative in-degree-popularity effects). However, those who gave many friendship nominations were more likely to give additional friendship nominations over time (positive outdegree-activity effects).

3.3. Covariate selection effects

We discuss only the main findings for the selection effects. Friendships and antipathies were more likely between participants

[4] Using score-type tests (see Schweinberger, 2012), we also tested and found other intransitive structural parameters that would contribute both theoretically and empirically to our study (e.g., structural equivalence). Regrettably, these parameters could not be modeled; this may have something to do with the size of the networks. Large networks tend to have more ties, and this is even more the case when an unlimited nomination procedure is used. Furthermore, the antipathy networks had many tie changes. This puts a constraint on the estimation algorithm, which has to go through a range of change steps in order to come close to the observed data, which become more difficult to reach. As a consequence, the model does not converge optimally. Additionally, multicollinearity may also play a role in model convergence when many of these effects capture the same selection patterns.

[5] We calculated differences between two correlations by performing *z*-score tests (see Cohen et al., 2003: 45–49), where correlations are transformed into *z*-scores (using Fisher's *r*-to-*z* transformation: $z' = 1/2\ln[(1+r)/(1-r)]$ (assuming equal variance across groups) and the test statistic is derived using the following formula: $= z'1 - z'2/\sqrt{[1/(n1-3)+1/(n2-3)]}$. *Z* statistics above 1.96 are significant at the two-tailed $\alpha = 0.05$ significance criterion for the normal distribution (results available upon request). Note that Geary's *C* autocorrelation can reach values that are larger than 1. In that case, the transformation does not work. This was the case for some of the correlations for the behavioral covariates in the antipathy networks (see Table 1).

[6] Without a good fraction of stability in the data, an initial measurement of the network is uninformative for the evolution process toward the next measurement, and the two measurements points might better be analyzed separately (Veenstra and Steglich, 2012). Jaccard indexes around 20% are still acceptable for relatively large sized positive networks (around 200 nodes) (Veenstra et al., 2013). However, no guideline is available for similarly sized negative tied networks. Although selection processes are determined by changes in network ties, relative low stability will likely result in relatively low estimates.

Table 2
Descriptive statistics of the friendship and antipathy networks per and between grades and schools.

	Friendship networks						Antipathy networks					
	School 1 (N = 220)			School 2 (N = 260)			School 1 (N = 220)			School 2 (N = 260)		
	Grade 6	Grade 7	Grade 8	Grade 6	Grade 7	Grade 8	Grade 6	Grade 7	Grade 8	Grade 6	Grade 7	Grade 8
Network density indicators:												
Density[a]	4.6%	3.4%	4.1%	2.9%	2.7%	2.9%	3.8%	3.5%	3.4%	3.9%	2.5%	2.3%
Number of ties	2225	1635	1964	1956	1797	1946	1827	1705	1657	2649	1660	1516
At least one tie	85.5%	77.7%	79.5%	90.0%	82.3%	91.8%	94.1%	82.7%	91.8%	84.6%	81.5%	84.2%
Average degree	10.11	7.43	8.93	7.52	6.91	7.49	8.31	7.75	7.53	10.19	6.39	5.83
SD outdegree	8.30	7.94	10.21	8.38	7.24	7.55	12.23	10.48	11.63	13.06	8.80	7.14
SD indegree	6.46	4.74	5.42	4.86	4.48	4.61	6.27	6.16	6.69	6.63	5.48	5.70
Dyad counts and indicators												
Asymmetrical ties	2622	1982	2464	2724	2270	2344	3306	3126	3034	4742	3016	2716
Mutual ties	914	644	732	594	662	774	174	142	140	278	152	158
At least one mutual tie	89.5%	78.6%	80.5%	73.5%	75.0%	84.6%	43.6%	33.2%	37.3%	51.2%	30.8%	31.9%
Reciprocity[b]	41.1%	39.4%	37.3%	30.4%	36.8%	39.8%	9.5%	8.3%	8.4%	10.5%	9.2%	10.4%
Same gender	83.6%	81.3%	78.2%	79.6%	79.8%	79.2%	52.3%	60.5%	60.4%	53.6%	61.5%	67.7%
Same ethnicity	71.6%	79.6%	75.7%	67.4%	72.1%	78.3%	64.8%	65.6%	69.3%	68.4%	70.2%	72.0%
Network autocorrelation												
Geary's *C* gender	0.327	0.374	0.437	0.408	0.403	0.414	0.953	0.790	0.791	0.925	0.768	0.643
Geary's *C* ethnicity	0.539	0.373	0.429	0.768	0.638	0.504	0.804	0.753	0.699	0.828	0.803	0.754
Geary's *C* prosocial	0.663	0.569	0.638	0.698	0.664	0.617	1.045	0.949	1.007	0.978	0.887	0.820
Geary's *C* antisocial	0.671	0.602	0.595	0.705	0.641	0.736	1.065	1.090	1.120	1.069	1.151	1.051

	Grade 6–7	Grade 7–8	Grade 6–7	Grade 7–8	Grade 6–7	Grade 7–8	Grade 6–7	Grade 7–8
Hamming distance[c]	2670	2321	2915	2621	3106	2802	3767	2700
Jaccard index[d]	18.2%	21.6%	12.6%	17.6%	6.4%	9.1%	6.7%	8.1%

[a] Density was calculated as N of ties divided by the total number of ties.
[b] Reciprocity was calculated as $2M/(2M+A)$, where M = mutual ties and A = asymmetric ties.
[c] Hamming distance is the number of tie changes.
[d] Jaccard index is the fraction of stable ties relative to all new, lost, and stable ties. Sample contains complete data of all respondents.

of the same gender or same ethnicity (positive same-gender and same-ethnicity effects).[7] These effects appeared to be stronger in the friendship networks than in the antipathy networks.[8] Male and older participants were less likely to give nominations in the negative networks (negative gender ego and age ego effects for antipathies); the same tendency was observed for ethnic minority students.

Similarity in prosocial and antisocial behavior also were likely to result in friendship, but mixed results were found in the antipathy networks: positive but marginal effects in School 1 (positive similarity effects) and a negative effect in School 2 (only for antisocial behavior; negative similarity effect). Again, significant differences were found between friendship and antipathy networks (except for antisocial similarity in School 1). Finally, prosocial behavior likely resulted in giving fewer antipathy nominations (negative prosocial ego effects), whereas antisocial behavior resulted in receiving more antipathy nominations (positive antisocial alter effects).

3.4. Between-networks effects

We tested the shared enemy, friends' agreement, reinforced animosity, and enemy's enemy hypotheses by looking at four balanced between-networks effects (see Table 3). In support of the shared enemy hypothesis, the *shared antipathy to friendship* effects were significant and positive: when two adolescents disliked the same person they tended to become or stay friends ($Est._{School\ 1} = .166$, $p < .05$; $Est._{School\ 2} = .141$, $p < .001$). In support of the friends' agreement hypothesis, the *friendship agreement to antipathy* effects were significant and positive ($Est._{School\ 1} = .126$; $Est._{School\ 2} = .147$, p's $< .001$): adolescents tended to dislike the peers who were disliked by their friends. The reinforced animosity hypothesis was also supported; the *mixed closure of antipathy* effects were significant and positive ($Est._{School\ 1} = .212$; $Est._{School\ 2} = .237$, p's $< .001$): adolescents tended to dislike the friends of those they disliked. Finally, in partial support of the enemy's enemy hypothesis, the *closure of friendship* effect was significant and positive in School 2 (Est. = .149, $p < .001$): adolescents in this school tended to befriend the dislikes of dislikes; this did not occur in School 1 (Est. = −.074, *ns.*). These estimates were significantly different between the two schools ($z = 2.80$, $p = .005$).

The matching imbalanced between-networks effects (see Table 3) were expected to be unlikely, as indicated by a negative parameter. As shown by the (non-)significant and negative *antipathy agreement to friendship* effects ($Est._{School\ 1} = -.395$, *ns.*; $Est._{School\ 2} = -.280$, $p < .05$), adolescents did not become or stay friends with friends of 'enemies.' That is, adolescents did not 'agree' with their antipathies on whom to befriend. Mixed results were obtained for the *shared friendship to antipathy* effect: no effect in School 1 (Est. = −.060, *ns.*), but a positive effect in School 2 (Est. = .134, $p < .001$). In contrast to our expectation, this latter effect suggests that sharing a friendship relationship will result in the formation or maintenance of an antipathy relationship. These

[7] The parameter estimates can be transformed to odds ratios by taking the exponential function of the estimates (=exp.(βk)) (Ripley et al., 2015), which was done to facilitate interpretation of the estimation results (reported in Table 3). For example, participants were on average four to five times more likely to nominate as friends peers who also nominated them as a friend in school (reciprocity), compared with peers who did not nominate them as a friend, all else being equal (OR = 4.24, 95% CI [3.76, 4.78] and OR = 5.58, 95% CI [5.04, 6.17]).

[8] We tested for differences between parameter estimates using z score tests, assuming equal variance across groups (with estimates $\hat{\beta}a$ and $\hat{\beta}b$ and standard errors $s.e_a$ and $s.e_b$, respectively), with the following formula $\hat{\beta}a - \hat{\beta}b / \sqrt{[1-(s.e^2a + 1-(s.e^2b)]}$, which under the null-hypothesis of equal parameters has an approximately standard normal distribution (see Ripley et al., 2015). Z statistics above 1.96 are significant at the two-tailed $\alpha = 0.05$ significance criterion (results available upon request).

Table 3
Results of the SIENA multivariate network analysis: estimates of between-network effects for friendship and antipathy controlled for structural network effects, and individual and behavioral dispositions.

	School 1 (N = 220)					School 2 (N = 260)				
	Est.	(SE)	p	OR	95% CI	Est.	(SE)	p	OR	95% CI
Friendship network:										
Structural network effects:										
Outdegree (density)	−2.961	(0.087)	***	0.05	[0.04–0.06]	−2.905	(0.057)	***	0.05	[0.05–0.06]
Reciprocity	1.444	(0.061)	***	4.24	[3.76–4.78]	1.719	(0.052)	***	5.58	[5.04–6.17]
Transitive triplets	0.221	(0.011)	***	1.25	[1.22–1.27]	0.318	(0.013)	***	1.37	[1.34–1.41]
Three-cycles	−0.278	(0.023)	***	0.76	[0.72–0.79]	−0.371	(0.025)	***	0.69	[0.66–0.73]
Transitive ties	0.764	(0.043)	***	2.15	[1.97–2.34]	0.729	(0.036)	***	2.07	[1.93–2.23]
Indegree-popularity	−0.047	(0.007)	***	0.95	[0.94–0.97]	−0.058	(0.006)	***	0.94	[0.93–0.96]
Outdegree-activity	0.005	(0.001)	***	1.01	[1.00–1.01]	0.003	(0.001)	***	1.00	[1.00–1.00]
Individual effects:										
Gender[a] alter	−0.031	(0.062)		0.97	[0.86–1.10]	0.104	(0.037)	**	1.11	[1.03–1.19]
Gender[a] ego	−0.040	(0.030)		0.96	[0.91–1.02]	0.013	(0.029)		1.01	[0.96–1.07]
Same gender[a]	0.414	(0.034)	***	1.51	[1.42–1.62]	0.378	(0.026)	***	1.46	[1.39–1.54]
Ethnicity[b] alter	−0.172	(0.142)		0.84	[0.64–1.11]	0.118	(0.043)	***	1.13	[1.04–1.22]
Ethnicity[b] ego	0.085	(0.037)	*	1.09	[1.01–1.17]	−0.021	(0.031)		0.98	[0.92–1.04]
Same ethnicity[b]	0.449	(0.033)	***	1.57	[1.47–1.67]	0.346	(0.030)	***	1.41	[1.33–1.50]
Age[c] alter	0.273	(0.068)	***	1.31	[1.15–1.50]	0.074	(0.054)		1.08	[0.97–1.20]
Age[c] ego	0.090	(0.045)	*	1.09	[1.00–1.19]	−0.071	(0.039)	†	0.93	[0.86–1.01]
Age[c] similarity	0.039	(0.057)		1.04	[0.93–1.16]	0.108	(0.050)	*	1.11	[1.01–1.23]
Behavior effects:										
Prosocial[d] alter	0.545	(0.105)	***	1.72	[1.40–2.12]	0.764	(0.079)	***	2.15	[1.84–2.50]
Prosocial[d] ego	−0.074	(0.061)		0.93	[0.82–1.05]	−0.145	(0.049)	**	0.87	[0.79–0.95]
Prosocial[d] similarity	0.456	(0.074)	***	1.58	[1.37–1.82]	0.423	(0.056)	***	1.53	[1.37–1.71]
Antisocial[d] alter	1.122	(0.441)	*	3.07	[1.29–7.29]	0.513	(0.113)	**	1.67	[1.34–2.08]
Antisocial[d] ego	0.002	(0.055)		1.00	[0.90–1.12]	0.062	(0.044)		1.06	[0.98–1.16]
Antisocial[d] similarity	0.163	(0.055)	**	1.18	[1.06–1.31]	0.254	(0.051)	***	1.29	[1.17–1.42]
Between-networks effects:										
Antipathy to friendship[e]	−5.000	(fixed)				−5.000	(fixed)			
Friendship indegree to antipathy indegree	−0.051	(0.032)		0.95	[0.89–1.01]	−0.031	(0.008)	**	0.97	[0.95–0.99]
Shared antipathy to friendship (B)	0.166	(0.079)	*	1.18	[1.01–1.38]	0.141	(0.032)	***	1.15	[1.08–1.23]
Antipathy agreement to friendship (I)	−0.395	(0.270)		0.67	[0.40–1.14]	−0.280	(0.113)	*	0.76	[0.61–0.94]
Mixed closure of friendship[f] (I)	0.051	(0.034)		1.05	[0.98–1.05]	0.021	(0.059)		1.02	[0.91–1.15]
Closure of friendship[f] (B)	−0.074	(0.060)		0.93	[0.83–1.05]	0.149	(0.052)	***	1.16	[1.05–1.28]
Antipathy network:										
Structural network effects:										
Outdegree (density)	−2.530	(0.037)	***	0.08	[0.07–0.09]	−2.650	(0.035)	***	0.07	[0.07–0.08]
Reciprocity	0.231	(0.058)	***	1.26	[1.13–1.41]	0.481	(0.053)	***	1.62	[1.46–1.80]
Transitive ties	0.613	(0.034)	***	1.85	[1.73–1.97]	0.519	(0.030)	***	1.68	[1.58–1.78]
Indegree-antipathy	0.006	(0.003)	*	1.01	[1.00–1.01]	0.004	(0.003)		1.00	[1.00–1.01]
Individual effects:										
Gender[a] alter	−0.083	(0.035)	*	0.92	[0.86–0.99]	0.032	(0.028)		1.03	[0.98–1.09]
Gender[a] ego	−0.154	(0.022)	***	0.86	[0.82–0.90]	−0.223	(0.026)	***	0.80	[0.76–0.84]
Same gender[a]	0.247	(0.022)	***	1.28	[1.23–1.34]	0.294	(0.021)	***	1.34	[1.29–1.40]
Ethnicity[b] alter	0.054	(0.037)		1.06	[0.98–1.13]	0.035	(0.033)		1.04	[0.97–1.10]
Ethnicity[b] ego	−0.134	(0.028)	***	0.87	[0.83–0.92]	−0.122	(0.034)	***	0.88	[0.83–0.95]
Same ethnicity[b]	0.243	(0.029)	***	1.27	[1.20–1.35]	0.138	(0.033)	***	1.15	[1.08–1.22]
Age[c] alter	−0.005	(0.048)		0.99	[0.91–1.09]	0.128	(0.035)	***	1.14	[1.06–1.22]
Age[c] ego	−0.081	(0.035)	*	0.92	[0.86–0.99]	−0.254	(0.036)	***	0.78	[0.72–0.83]
Age[c] similarity	−0.034	(0.043)		0.97	[0.89–1.05]	0.052	(0.044)		1.05	[0.97–1.15]
Behavior effects:										
Prosocial[d] alter	−0.322	(0.222)		0.72	[0.47–1.12]	0.169	(0.090)	†	1.18	[0.99–1.41]
Prosocial[d] ego	−0.149	(0.040)	***	0.86	[0.80–0.93]	−0.346	(0.045)	***	0.71	[0.65–0.77]
Prosocial[d] similarity	0.121	(0.052)	*	1.13	[1.02–1.25]	−0.034	(0.045)		0.97	[0.88–1.06]
Antisocial[d] alter	0.348	(0.092)	***	1.42	[1.18–1.70]	0.559	(0.064)	***	1.75	[1.54–1.98]
Antisocial[d] ego	0.003	(0.041)		1.00	[0.92–1.09]	0.143	(0.040)	***	1.15	[1.07–1.25]
Antisocial[d] similarity	0.076	(0.046)		1.08	[0.99–1.18]	−0.154	(0.043)	***	0.86	[0.79–0.93]
Between-networks effects:										
Friendship to antipathy[e]	−5.000	(fixed)				−5.000	(fixed)			
Friendship indegree to antipathy indegree	0.032	(0.022)		1.03	[0.99–1.08]	−0.019	(0.010)	†	0.98	[0.96–1.00]
Friendship outdegree to antipathy indegree	−0.013	(0.008)	†	0.99	[0.97–1.00]	0.002	(0.004)		1.00	[0.99–1.01]
Shared friendship to antipathy (I)	−0.060	(0.052)		0.94	[0.85–1.04]	0.134	(0.029)	***	1.14	[1.08–1.21]
Friendship agreement to antipathy (B)	0.126	(0.024)	***	1.13	[1.08–1.19]	0.147	(0.031)	***	1.16	[1.09–1.23]
Mixed closure of antipathy[f] (B)	0.212	(0.009)	***	1.24	[1.22–1.26]	0.237	(0.017)	***	1.27	[1.23–1.31]
Closure of antipathy[f] (I)	0.020	(0.035)		1.02	[0.95–1.09]	0.236	(0.037)	***	1.27	[1.18–1.36]

Notes. Rate of change effects were also included but omitted from the table; Significance tests performed by dividing the estimates by their standard errors resulting in t-values which are approximately normally distributed under the null hypothesis (Ripley et al., 2015).

[a] Gender was coded 1 = male (49.5–53.2%), 0 = female (46.8–50.5%).

[b] Ethnicity was coded 1 = ethnic minority (Black: 11.9–18.2%; Hispanic: 7.7–10%: Asian: 2.3%, only in School 2), 0 = ethnic majority (White: 71.8–78.1%).

[c] Peer nominations for prosocial and antisocial behavior were transformed into proportion scores by dividing them by the number of participating grade mates, resulting in a continuous measure ranging from 0 to 1.

[d] Age was transformed into proportion scores by subtracting date of birth from an index point, and dividing the number of months by the number of participating grade mates, resulting in a continuous measure ranging from 0 to 1.

[e] We fixed this parameter because it did not converge well. The model without the fixed parameters yielded similar results (results available upon request).

[f] This parameter was estimated in a separate model to avoid convergence problems; All parameters in the models were estimated with the evaluation function. Positive parameter estimates express the tendency to both form and maintain relationships over time; B = balanced and I = imbalanced.

† $p < .10$ (two-tailed tests).

* $p < .05$ (two-tailed tests).

** $p < .01$ (two-tailed tests).

*** $p < .001$ (two-tailed tests).

estimates were significantly different between the two schools ($z = 3.26$, $p = .001$). Further, as shown by the non-significant *mixed closure of friendship* effects, adolescents did not become or stay friends with the 'enemies' of friends. Finally, mixed findings were observed for the *closure of antipathy* effect: no effect in School 1 (Est. = .020, *ns.*), but a positive effect in School 2 (Est. = .236, $p < .001$). These estimates were significantly different between the two schools ($z = 4.23$, $p < .001$). In contrast to our expectation, this latter effect suggests that adolescents dislike the friends of friends.

3.5. Supplementary analysis

Theoretically speaking, reversing any arrow's direction would create an equally possible case for applying balance theory reasoning. As such, we performed additional analyses (results available upon request). The balanced configuration in Fig. 1 was statistically not significant in the opposite direction (Table 1, Balanced Figure E), showing that friendship between two adolescents was unlikely when they were both disliked by the same person. A precisely similar balanced configuration of Figs. 2–4 was not available in the opposite direction, but a configuration in which both direction *and* sign were switched was available (Table 1, Balanced Figure F). This effect was, however, also statistically not significant. This indicates that friendship between two adolescents was unlikely when one of them disliked a person and the other was disliked by that same person, which may be explained by lack of social knowledge for these ties (Hummon and Doreian, 2003).

Because the models showed no optimal fit on the auxiliary statistics, except for the in-degree distribution, we performed additional analyses to find out whether this was caused by actors who had many outgoing ties. Note that we allowed students to nominate as many (or as few) best friends and antipathies as they wished within their entire grade. This study design may have resulted in some students nominating a large number of best friends or antipathies, which might make it harder to fit the networks. To deal with this issue, we considered all ties of actors with extreme outdegrees (arbitrary cut-off point set at >25) as missing (friends: 3.2–7.3% and 2.7–5.4%; antipathies: 5–7.3% and 2.7–8.8%; School 1 and 2, respectively). A similar procedure was carried out in other RSiena studies (Light et al., 2013; Rambaran et al., 2015). Although model fit was still not optimal, the main findings were largely similar to those of the model without restrictions (except for the balanced effect for School 1 represented in Figure A in Table 1, which was positive but no longer significant), indicating that our main findings did not depend greatly on actors with high numbers of outgoing nominations best friend and/or antipathy nominations.

4. Discussion

In this study, we examined the interplay between friendships and antipathies in a sample of adolescents in two US middle schools over three years. Based on balance theory, it was expected that friendships would be formed or maintained when two adolescents disliked the same person (shared enemy hypothesis), that friends would tend to agree on whom they disliked (friends' agreement hypothesis), that adolescents would dislike the friends of their enemies (reinforced animosity hypothesis), and, finally, that they would become or stay friends with dislikes of dislikes (enemy's enemy hypothesis). Support was found for the first three hypotheses, and partially for the fourth hypothesis.

4.1. Sharing a common enemy promotes friendship

The finding that two adolescents become friends when they dislike the same person suggests that sharing a 'common enemy' promotes friendship; this may have to do with 'bonding by sharing negative attitudes about others' (Bosson et al., 2006). People who learn that they and a person to whom they were not related have a mutual dislike of a target person may feel closer to each other than people who learn that they share a liking for the target. This is in line with research findings that have shown that gossip about third parties persons may increase friendship formation in dyads at work (Ellwardt et al., 2012), and that bullying the same person may increase liking (Huitsing et al., 2012) or defending in elementary school (Huitsing and Veenstra, 2012; Huitsing et al., 2014). Collectively, these findings clarify how shared negative relationships with or perceptions about others can shape positive relationships such as friendships or liking.

4.2. Friends and antipathies agree on whom they dislike and like

The finding that adolescent friends and antipathies agree on whom they dislike or like is consistent with previous findings among early-adolescents students (e.g., Berger and Dijkstra, 2013), and indicates that the opinions or attitudes of friends and antipathies for others affect how adolescents evaluate these others and form or maintain (positive or negative) relationships with them. It is possible that friends and antipathies 'influence' whom adolescents dislike and like. This influence may be imposed explicitly upon adolescents that is guided and sanctioned via group norms; additionally, it may also be (simultaneously) operating in a more subtle and indirect way via the intrinsic need or preference of adolescents to become or remain part of a cohesive peer group. In peer relationship research, social influence reflects the tendency of individuals to become or to stay similar to friends in behaviors or attitudes (Brechwald and Prinstein, 2011). In this perspective, the characteristics of peers to whom one is related (positively or negatively) in a network can explain changes in individual attributes (Robins et al., 2001b). However, in the case of selection, individual characteristics such as attitudes about others may also shape (i.e., influence) relational ties (Robins et al., 2001a). The present findings show this for the opinions or attitudes of adolescents' friends and antipathies about other network members, in which selection processes are still viewed as 'actors consciously or unconsciously structuring their networks on the basis of other actors' attributes' (Leenders, 1997). In this view, friends and antipathies not only influence adolescents' behaviors but also their actual relationships.

4.3. Sharing the same friend may result in antipathy

We obtained mixed results for the 'shared friendship to antipathy' and the 'closure of antipathy' effects. Doreian and Krackhardt (2001) already observed inconsistent findings for these imbalanced triadic configurations. Contrary to the prediction from balance theory, two individuals who shared a mutual friend ended up disliking each other (in School 2). Although this may at first seem counterintuitive, it may have nothing to do with balance, but with individual attributes of the shared friend (Doreian and Krackhardt, 2001). Competition for status can result in conflict and decreased feelings of intimacy with others (Ojanen et al., 2013). Given that the achievement of status in the peer group is important in adolescence (Corsaro and Eder, 1990; Ojanen et al., 2005), competition for attention of (or for intimacy with) a popular friend might result in disliking his/her friend (Doreian and Krackhardt, 2001). In that case, adolescents may be more likely to accept an unbalanced state in order to obtain status (or a friendship). Future studies should examine the role of social positions and status (popularity) in the formation and maintenance of antipathetic relationships (see Berger and Dijkstra, 2013) and the conditions under which adolescents accept unbalanced states in their network (Burt, 1976).

4.4. Negative triads: balanced or not?

There is one triadic configuration for which no consensus exists among balance researchers as to whether or not it is balanced: transitivity in negatively tied networks. On the one hand, the formation and maintenance of all negative ties may cause high levels of tension and conflict between the three actors involved. Hence, the network is likely to fall apart due to imbalance, although the formation of stable social groups is not necessarily conflict free (Hummon and Doreian, 2003). On the other hand, in the case of directed networks, there is some uncertainty about whether all actors 'know' about each other's feelings and thoughts about others. These are not necessarily observable, and, therefore, may not be noticed by others. Hence, the network stays together due to a misperception of balance. In the present study, we observed positive parameter estimates for the transitive ties effects, which indicates that an all negative triadic configuration is viable. However, this network effect may be exacerbated because one indirect tie suffices for network closure. More research is needed to identify the conditions under which the configuration is likely to exist and desist. Although the examination of this network configuration is interesting in itself, the focus of the present study was on the examination of network configurations that arise from the interplay between friendships and antipathies, and are related to balance.

4.5. Considering the direction of relationships

Heider's balance theory (1946, 1958) was formulated for non-directed networks, whereas our data set was directed. As such, there seems to be a mismatch between theory and data in terms of the directedness of the networks. However, we believe that our choice of directed networks is justified and in line with recent structural balance research. According to Hummon and Doreian (2003: 27), an "approach based only on Heider's ideas misses the structural implications of the distribution of signed choices because it ignores the wider structure generated by them (and) an approach based only on the ideas of Cartwright and Harary ignores the affective mechanisms in the minds of actors." Our approach combined the ideas from both perspectives (considering tie preferences as affective components), but even so the model remained restricted through incompleteness of actors and the amount of social knowledge they possess, which also varies between them. The findings from the supplementary analysis seem to support our choice for directed networks: from an actor's perspective, outgoing ties appeared to be more important for balanced configurations than incoming ties.

4.6. Attribute selection and homophily in friendship and antipathy networks

Considerable work has demonstrated that adolescents develop largely in segregated social worlds (see e.g., Maccoby, 1998; Moody, 2001). In line with this finding, we found that adolescent friendships were formed or maintained on the basis of similarity in gender and ethnicity. Although it is beyond the scope of this study, it has been suggested that boys play a more active role in establishing and maintaining the separation of the sexes in order to maintain their gender status (Maccoby, 1998), and that majority group members actively avoid members of a minority group in order to maintain their majority group status (Allport, 1954). However, such processes might also be driven by shared interests rather than shared traits (Stark and Flache, 2012).

Interestingly, we also found same-gender and same-ethnicity effects in antipathy networks. One explanation is that, because friendships are primarily formed on the basis of similarity, frequent interaction between similar peers could, in time, produce tension and conflict (Ojanen et al., 2013), increasing the chances of negative relationships (antipathies) developing between similar peers. Moreover, if interaction takes place mainly among same-gender and same-ethnicity peers, they form a frame of reference and, as a consequence, are more easily considered as friends as well as antipathies. This suggests that social interaction (positive and negative) really takes place within similar groups.

Lastly, prosocial and antisocial behavior are important behaviors that are strongly related to adaptation in the adolescent peer context (see e.g., Logis et al., 2013; Molano et al., 2013; Sijtsema et al., 2010), and, as such, they are important for the development of positive and negative relationships with peers. In the present study, adolescents similar in prosocial and antisocial behavior became friends with each other (i.e., homophilous selection), and adolescents high on prosocial and antisocial behavior received more friendship nominations of peers (i.e., they were highly popular in terms of friendship affiliation). At the same time, in the antipathy networks prosocial and antisocial behavior contributed also to antipathy formation and maintenance, albeit differently for both behaviors: antisocial youth were more likely to receive dislike nominations from others, whereas prosocial youth were less likely to give dislike nominations to others. It seems that both behaviors follow similar patterns in the formation and maintenance of friendship relationships, but different patterns in the formation and maintenance of antipathetic relationships.

4.7. Structural differences between friendship and antipathy networks

The prevalence of mutual antipathetic relationships was similar to that found in previous studies: about one third of students had an antipathetic relationship (see Card, 2010). However, the proportion of reciprocal nominations (conditional on the number of assymetrical nominations in the networks) in the present study was lower for antipathy than for friendship (see Table 2), and antipathies were twice as low compared with the proportion found in other recent network studies examining the same underlying patterns among students in primary school (e.g., Berger and Dijkstra, 2013; Huitsing et al., 2012). There may be technical and substantial reasons for this. Probably the most important reason for the overall low involvement in antipathies is that nominations were grade-wise (with no limitations) instead of within-classroom, as in most other studies. Additionally, in most studies the number of nominations given is generally much lower for negative questions (e.g., "Who do you like the least?") than for positive questions (e.g., "Who do you like the most?"). The combination of lower frequencies and a larger reference group might have resulted in fewer chances of mutual 'hits.' A substantial reason might be that, in a larger grade network, it is easier to avoid 'enemies' whereas, in smaller classrooms, the students become more easily irritated and frustrated with each other as a result of frequent interpersonal contact. Such processes can be explained through mechanisms of proxemics (e.g., lack of personal space and defending one's own territory; see Hall, 1966).

4.8. Limitations, strengths, and directions for future research

The findings of this study should be interpreted in light of its limitations. Balance theory may not provide a complete representation of reality. Individuals who are located in a specific type of triadic configuration may also affect individuals located in a different type of triadic configuration to whom they are only weakly or intermediately tied (Granovetter, 1973). In this way, the (im)balanced effects that were assumed to be autonomous may well be interrelated, affecting each other's outcomes over time.

Further, the extent to which individuals are influenced by others could depend on the strength of relationships (Cheng et al.,

2013). We did not examine relative relationship strength, while imbalance, for example, may also occur if a person likes a second person relatively more than that second person likes him (Newcomb, 1961). Researchers might consider these possibilities when examining balanced configurations.

Balanced triads may also be more likely when all members are similar in traits or behaviors that are important for group affiliation (Cairns and Cairns, 1994) or when traits or behaviors are related to status. A well-known example of how traits or behaviors affect balanced outcomes is that of celebrity endorsement affecting consumers' attitudes toward products (e.g., Mowen and Brown, 1981). The idea is that people tend to favor consumer products that are associated with a high-status celebrity in order to increase their own perceived status ('basking in reflected glory'). Considering that adolescents are more likely to adjust (conform) their behavior (and ties) to the behaviors of high-status peers in direct interactions or via perceived affiliation with such peers (e.g., Dijkstra and Gest, 2015; Rambaran et al., 2013, 2015), such processes may be translated to balanced tie configurations as well.

Lastly, although our findings provide support for balance mechanisms that help explain triadic interdependence in interpersonal relations (see for a discussion Kelley and Thibaut, 1978), they are limited to our sample of two US middle schools. Related to that is our focus on grade-mates. Although this final limitation is typical in research on school-based peer relationships, a more complete examination would benefit from moving beyond the own grade (e.g., mixed grade) or school context (e.g., neighborhoods or organizations). However, although larger networks provide more insight, they also complicate model fit.

Despite these drawbacks, the strengths of the present study were the examination of friendships as well as antipathies, and the examination of their interplay. Adding to previous (longitudinal) studies among multivariate networks of children and adolescents, these were examined at the grade level rather than the classroom level (Berger and Dijkstra, 2013; Huitsing and Veenstra, 2012; Huitsing et al., 2012; with the exception of Huitsing et al., 2014), capturing a large proportion of adolescents' peer networks. The robustness of our findings is supported by the observation that the results regarding our hypotheses did not differ between the two schools, nor did they differ much depending on our control variables.

The present findings show that the use of multivariate networks in combination with the predictions of balance theory (Heider, 1946, 1958; Cartwright and Harary, 1956) can be fruitful for our understanding of the formation and maintenance of positive and negative relationships among adolescents. This study provides an important contribution to the study of friendships and antipathies by adding complexity to the way we think about and analyze relationships between adolescent peers, revealing the dynamic interplay of friendships and antipathies. Friendships emerged when two adolescents both disliked the same person, friends agreed on whom they disliked, and adolescents disliked the friends of their antipathies and befriended the dislikes of dislikes. In this study we 'triangulated' friendships and antipathies by considering how feelings about a third individual bring two other persons 'together' (friendship) or make them 'separate' (antipathy).

Future researchers, particularly investigating behaviors that are inherently relational such as bullying, may benefit from incorporating mechanisms of triadic interdependence. For example, recent studies investigating network and behavior dynamics in adolescence show traces of friendship influences among victims or bully–victims (Sentse et al., 2013; Sijtsema et al., 2013). Yet, examinations of the dynamic interplay between positive and negative networks are scarce and limited to childhood (Huitsing et al., 2014). Moreover, as the role of peers becomes more prominent in adolescence, bullying and its known correlates (e.g., moral disengagement, status, and aggression) spread via influence processes in friendship networks (e.g., Caravita et al., 2014; Dijkstra et al., 2013; Sijtsema et al., 2010, 2014). The present indicated findings indicate that this also may be correlated with a negative (antipathy) network in which adolescents participate. By more comprehensively mapping the adolescent peer ecology, we may be better able to reduce negative peer relationships and promote positive peer relationships among adolescents.

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