Prev Sci (2016) 17:903–913
DOI 10.1007/s11121-016-0678-8

Peer Influence on Academic Performance: A Social Network Analysis of Social-Emotional Intervention Effects

Dawn DeLay[1] · Linlin Zhang[1] · Laura D. Hanish[1] · Cindy F. Miller[1] · Richard A. Fabes[1] · Carol Lynn Martin[1] · Karen P. Kochel[2] · Kimberly A. Updegraff[1]

Published online: 19 July 2016

Abstract Longitudinal social network analysis (SNA) was used to examine how a social-emotional learning (SEL) intervention may be associated with peer socialization on academic performance. Fifth graders ($N = 631$; 48 % girls; 9 to 12 years) were recruited from six elementary schools. Intervention classrooms (14) received a relationship building intervention (RBI) and control classrooms (8) received elementary school as usual. At pre- and post-test, students nominated their friends, and teachers completed assessments of students' writing and math performance. The results of longitudinal SNA suggested that the RBI was associated with friend selection and peer influence within the classroom peer network. Friendship choices were significantly more diverse (i.e., less evidence of social segregation as a function of ethnicity and academic ability) in intervention compared to control classrooms, and peer influence on improved writing and math performance was observed in RBI but not control classrooms. The current findings provide initial evidence that SEL interventions may change social processes in a classroom peer network and may break down barriers of social segregation and improve academic performance.

Keywords Social networks · Peer influence · Intervention · Social-emotional learning · Academic performance

✉ Dawn DeLay
dawn.delay@asu.edu

[1] T. Denny Sanford School of Social and Family Dynamics, Arizona State University, PO Box 873701, Tempe, AZ 85287, USA

[2] University of Richmond, 28 Westhampton Way, Richmond, VA 23173, USA

Peers have a powerful influence over youth outcomes, affecting behavioral change via modeling, reinforcement, and collaborative learning (Harris 1995). Peers can influence youth toward negative outcomes (e.g., problem behavior; Dishion et al. 1996), but there is the potential for peer influence on positive dimensions (e.g., academic competencies, adaptive functioning; Blanton et al. 1999). As important as peers are to the socialization of youth, it is surprising that little is known about the extent to which youth-oriented interventions have the potential to alter peer relationship networks in ways that enhance socialization toward successful outcomes. That is, from a prevention science perspective, are interventions capable of facilitating positive peer influence? This study takes a first step toward answering this question.

A school-based social-emotional learning (SEL) intervention was used to address this question in the current study. SEL interventions are designed to target children's socially relevant behaviors and skills exhibited in the peer network, making them ideally suited for such an investigation. Targeted skills may include understanding and regulating oneself (e.g., emotional regulation), understanding others (e.g., empathetic concern), and establishing and maintaining healthy relationships (e.g., social problem solving; Collaborative for Academic Social and Emotional Learning 2012). Meta-analyses show that children who participate in an SEL program demonstrate significant gains in social and emotional skills, attitudes, behaviors, and academic performance relative to those in a control condition (Durlak et al. 2011). Additional research demonstrates the effectiveness of SEL interventions at diminishing problem behavior and promoting positive peer relationship outcomes (e.g., prosocial behaviors, cohesive relationships; Greenberg et al. 2015; Rulison et al. 2015). The SEL intervention used here was the relationship building intervention (RBI; Miller et al.

2015, 2016)—a teacher-led classroom program involving 21 activities designed to foster social, emotional, and relational skills implemented over a period of 26 weeks.

The current study tests the RBI's association with peer influence on academic outcomes—namely, writing and math performance—in fifth grade. Writing and math performance are malleable outcomes of SEL programs (Durlak et al. 2011; Zins et al. 2007), reliable indicators of overall classroom performance and long-term academic success (Borkowski 1992), and susceptible to peer influence (DeLay et al. 2015; Paulus 1999). To assess the potential impact of the RBI on peer influence, we used longitudinal social network analysis (SNA) with the RSiena program (Ripley et al. 2016). Thus, we move beyond an individual-level analysis to one of social network change. To our knowledge, this is a first attempt to use longitudinal SNA to assess the impact of an SEL intervention on peer influence over academic performance.

SEL Interventions and the Potential for Peer Influence

The proximal aim of SEL programs is to improve the social and emotional skills of children. Improving social and emotional skills is likely to strengthen the potential for positive peer influence because socially and emotionally skilled children are likely to build close social bonds that can increase the chances of positive peer influence (Hawley et al. 2002; Ladd et al. 1999). Influence is further enhanced when children are better at encoding social cues and generating prosocial problem-solving strategies (Dodge and Price 1994; Erdley and Asher 1999). Peer influence is also driven by the resolution of divergent views (Schwarz and Linchevski 2007), making peer influence probable in a diverse classroom where children interact regularly and are skilled at perspective taking to resolve conflict when differences arise. These skills have been targeted by SEL interventions and were the specific focus of the RBI.

SEL programs are more likely to lead to positive peer influence (toward enhanced academic performance) than negative peer influence (toward diminished academic performance) for several reasons. First, in inclusive classrooms, students feel supported, included, and valued by their peers. This type of social bonding and peer support is likely to engage children in their schoolwork and to provide opportunities for children to more readily engage in collaborative learning behaviors that allow for successful problem solving with peers (Greenberg et al. 2003; Pianta et al. 2007). Influence over learning also requires a specific set of collaborative skills (i.e., the ability to successfully evaluate and critique solutions) that are enhanced through prolonged positive social exchanges (Ryan and Ladd 2012). These prolonged social exchanges are more likely to occur during the positive interactions that are fostered by SEL programs, rather than during the negative interactions, which are more likely in classrooms that do not include SEL (Azmitia and Montgomery 1993). In general, an SEL intervention's aim to foster a healthy peer climate can allow students to feel secure and confident in the classroom setting so that they are able to successfully initiate peer collaborations during challenging academic tasks (Wentzel and Watkins 2002).

Using Longitudinal Social Network Analysis to Assess Intervention Effects

Gest and colleagues (2011) first introduced the advantages of coupling an SNA approach with intervention research in *Prevention Science*. To summarize these points, a major advantage of using an SNA approach is that complex social dynamics within a classroom do not have to be reduced to aggregates of individual scores that are unable to explain *how* interventions affect social processes. For our purposes, this distinction is particularly important because of our interest in exploring whether an intervention may have been associated with changing particular social processes in the classroom, namely changing influence effects to improve academic performance after accounting for peer selection. *Selection* is the peer network process through which students choose their friends (Kandel 1978). *Influence* is the peer network process through which peer relationships change the behavioral attributes or characteristics (e.g., academic performance) of the students in the relationship (Snijders et al. 2010). Thus, adequately testing for network-level intervention effects requires simultaneously accounting for both selection and influence. This must be done using longitudinal SNA.

A failure to adopt a longitudinal SNA approach presents several challenges to the reliable assessment of peer influence. For example, when researchers fail to use longitudinal SNA, dynamic peer network features are collapsed into composite measures to be used in linear models (e.g., OLS regression; Ahn et al. 2013). This leads to a loss of information on the dynamic social process (Cascio and Schanzenbach 2007). Linear models also require subjective decisions to be made on how best to transform data to represent the social composition of the classrooms, again adding bias to estimates of influence (Yudron et al. 2014).

The alternative is for researchers to adopt a longitudinal SNA assessment of peer relationships in the classroom. Doing so addresses the limitations of linear models but can be challenging. For instance, it requires a reliable longitudinal SNA sample with (a) complete assessments of all relationships in the classroom, (b) the simultaneous assessment of individual characteristics and attributes, and (c) all assessments completed longitudinally. Thus, collecting data for use in longitudinal SNA is quite demanding. Another challenge is

that social network theory evolved largely in isolation from prevention science. Therefore, there is not yet a standard for how longitudinal SNA should be applied to assess intervention effects. The application of such an approach in the current study required innovative modifications including (a) follow-up analyses that allowed for the assessment of, not only the presence of influence but also the direction of influence (e.g., assessing influence toward improved rather than diminished academic performance) and (b) follow-up analyses that allowed for a comparison of significant differences in longitudinal SNA effects between intervention and control classrooms.

The Current Study

The current study used longitudinal SNA to assess changes over time in academic performance in RBI classrooms and control classrooms (school as usual). We examined whether the increases observed in academic performance in intervention classrooms, as compared to control classrooms, could be, in part, associated with (a) changes in peer *influence* after accounting for (b) changes in peer *selection*. Peer *influence* may be more likely to occur in intervention than control classrooms because the RBI may strengthen positive peer influence by building cohesive and inclusive classrooms that increase the likelihood students will assist their peers during academic struggle (e.g., Hartup 1996). Peer *selection* in RBI classrooms may also become more diverse over time, so that the social barriers that limit cross-gender, ethnic, and/or academic ability collaborations are removed, because teachers in intervention classrooms were instructed to regularly provide students opportunities to build connections with every member of their class. Therefore, we simultaneously assess peer selection and influence to examine the effects of each on academic performance outcomes in RBI versus control classrooms.

Method

Participants

Participants were recruited in two cohorts. The initial sample included 826 fifth graders (48 % girls) from 15 RBI intervention and 14 control classrooms. Intervention classrooms were selected based on principal and teacher willingness to implement the intervention. Control classrooms were recruited from the same school district in an effort to match on demographics (e.g., gender, ethnicity, socioeconomic status) with intervention classes. In the first cohort, 5 intervention classrooms in one school and 3 control classrooms in a different school were recruited. In the second cohort, 10 intervention classrooms in two schools (one repeating school) and 11 control classrooms in three schools were recruited. Five teachers participated in both cohorts. From the recruited sample, one intervention classroom ($n = 28$ students) and six control classrooms ($n = 167$ students) were excluded due to low participation rates that may lead to estimation bias in social network samples (less than 65 % participation; Cillessen 2009). The final sample used in the current study included 631 fifth graders (48 % girls) recruited from six elementary schools in 14 intervention classrooms (class size ranged from 24 to 30) and 8 control classrooms (class size ranged from 23 to 31). There were no significant differences in demographic (i.e., age, ethnicity, gender, socioeconomic status) or study variables between participants and non-participants.

Participants ranged from 9 to 12 years ($M = 10.51$ years, $SD = 4.54$ months) at the onset. Participants were from relatively diverse ethnic backgrounds (58.0 % White, 8.9 % Latino, 8.0 % Asian, 3.1 % Black, 1.2 % Native American, 0.2 % Pacific Islander, 18.3 % multiracial, and 2.3 % non-respondents). Most of the students were living with both parents (78.4 %). Parental education ranged from some high school to an advanced degree (mode = college graduate). Annual family income ranged from $20,000 and below to $100,000 and above (mode = $100,000 and above; 7.0 % not responding). Compared to the students in intervention classrooms, students in control classrooms had lower levels of parent education, $t(492) = 6.14$, $p < .001$, and family income, $t\ (274.23) = 6.81$, $p < .001$, but no other significant demographic differences emerged.

Procedures

Participants were assessed twice during the school year. Pre-test data were collected in the fall (August/September) prior to the onset of the RBI. Post-test data were collected in the spring (February/March) after the completion of the RBI. School principals and teachers were informed of the study and volunteered to participate. Information letters and parent consent forms were sent to the parents of the students in the participating classrooms. Written assents were collected from students who received parental consent. Consent and assent rate was 81 %. The study was approved by the university Institutional Review Board and the school district.

RBI Procedures

The overall goal of the RBI was to promote positive peer relationships and create supportive classroom communities. The RBI consists of 21 activities across five units—Diversity and Inclusion, Empathy and Critical Thinking, Communication, Problem Solving, and Peer Relationships—over 26 weeks. Teachers were trained on the implementation of these activities in a half-day training and were provided with all materials (e.g., handouts, posters, video clips) to

support the activities. Teachers implemented a total of 21 activities in 45-min weekly sessions beginning in the fall and continuing until the spring semester. Most of the students (69 %) attended all the activities, and the average number of absences in the activities per student was less than one session ($M = .49$; $SD = .94$). Non-treatment "education-as-usual" control group was used; therefore, during the implementation period, the control students participated in regularly scheduled education activities. Using separate schools for intervention and control classrooms reduced the likelihood of contamination effects (Craven et al. 2001).

Data Collection

Primary caregivers reported on students' demographic information. Students completed sociometric and self-report questionnaires during two 1-h sessions in the classroom over 2 days at pre- and post-test. Instructions were read aloud by research assistants (RAs), and an RA was available to help students who needed assistance. Students were given small gifts for participation. Procedures were identical in intervention and control classrooms.

Measures

Friendship Nominations

At both pre- and post-test, students were asked to identify up to 8 *close friends* on a class roster. Cross-gender nominations were allowed. Non-participants did not provide nominations, but they were on the class roster and were eligible to be nominated.

Academic Performance

Academic performance was obtained using teacher-rated report card grades on writing and math performance using the scale (*0 = area of concern*, *1 = developing*, and *2 = proficient*) in each quarter of the academic year. Data in quarter 1 (pre-test) and quarter 4 (post-test) were used in the present study. *Writing performance* included 2 items (i.e., effective use of writing process, effective writing). *Math performance* included 3 items (i.e., number sense, number operations, and problem solving). The scores for these items were averaged to create continuous variable composite scores of writing and math performance.

To use academic performance ratings in RSiena, the continuous variable composite scores for writing and math performance had to be transformed into categorical variables (see Ripley et al. 2016). However, when rounding teacher-rated academic performance using a 3-point scale to the nearest categorical membership (i.e., category 1, 2, or 3), these variables were highly skewed. To normalize the data for analysis, we created 4 distinct categories (*1 = struggling*, *2 = developing*, *3 = transitioning to proficiency*, *4 = proficient*). These categories were created as follows: (a) a student was determined to be *struggling* if teachers rated at least one of his or her performance indicators as an "area of concern" and none of the performance indicators as "proficient," (b) a student was determined to be *developing* if teachers rated *all* of his or her performance indicators as "developing," (c) a student was determined to be *transitioning to proficiency* if teachers rated at least one of his or her performance indicators as "proficient" and none of the performance indicators as "struggling," and (d) a student was determined to be *proficient* if teachers rated *all* of his or her performance indicators as "proficient." After moving from the 3- to the 4-category conceptualization of academic performance, the data were no longer skewed.

Covariates

Parent reports of *parental education*, the highest level of household education on a scale ranging from 1 (some high school) to 6 (doctorate degree), were used. Parent reports on child *gender* (coded as Male = 1; Female = 0) and *ethnicity* (coded as Majority [White] = 1; Minority [Non-white] = 0) were also included. *Parental income* could not be included in the RSiena model due to statistical convergence problems.

Plan of Analysis

The first step in the analysis was to create a meta-network from the friendship nominations within the intervention and control classrooms. To do this, an $N \times N$ matrix file of all friendship nominations was created for each classroom where N is the number of students in each classroom. In these $N \times N$ matrix files, a "1" indicates that a friendship nomination was given and a "0" indicates that no friendship nomination was given. Next, the classroom $N \times N$ matrix files were combined into a single intervention network and a single control network using multi-group options for the 14 intervention classrooms and the 8 control classrooms. After the matrix files were created, we could use RSiena to connect the social process data to our dependent variables for writing and math performance and add in all control variables.

By simultaneously examining the peer network in intervention and control classrooms, we were able to assess differences between intervention and control classrooms on tendencies for how peer relationships in the classroom alter academic performance from pre- to post-test (*influence*) after accounting for how children affiliate with peers based on academic performance (*selection*). To do this, we included all students in the classroom, even if the students did not make or receive peer nominations. Missing nomination data are given less

statistical power in the social network, but their presence in the network is recognized (Ripley et al. 2016).

Structural Controls

Initially, five theoretically determined structural control parameters were included in the models (i.e., *outdegree*, *reciprocity*, *transitive triplets*, *linear tendency*, and *quadratic shape*). These structural control parameters represent fundamental tendencies in peer social networks and, as such, must be accounted for in efforts to model how social influence processes may similarly effect change in the network and behavioral outcomes (e.g., Snijders et al. 2010; see Table 1 for an explanation of each effect).

Network Controls

Both similarity (e.g., *gender similarity*) and difference (e.g., *gender ego*, *gender alter*) effects were included as network controls for gender, ethnicity, and parent education. Difference effects (e.g., *ego*, *alter)* for writing and math performance were also included as network controls (see Table 1).

Behavioral Controls

Behavioral controls were included for gender, ethnicity, and parental education. These behavioral controls were included to account for the effect of each on changes in writing and math performance across the academic year (see Table 1).

Goodness of Fit Controls

In addition to adding the theoretical structural control parameters, we engaged in tests of goodness of fit (GOF) (Ripley et al. 2016). GOF tests are recommended to reliably match one's model specification to each unique peer network under investigation. GOF tests indicated that several additional control parameters should be included in the present models. Thus, we added the *three-cycles*, *outdegree activity*, *outdegree sqrt activity*, and *outdegree truncated activity* to the RSiena model (see Table 1).

Selection Effects

To reliably estimate peer influence on writing and math performance, we must first account for selection effects (Kandel 1978). Therefore, we included selection for *similarity on writing performance* and selection for *similarity on math performance*. The *writing* or *math performance similarity* parameters describe the tendency for children to select peers who are similar to themselves in levels of

Table 1 Explanation of RSiena control parameters included in the analysis

Structural controls

- *Outdegree* (indicates conscious friendship choices, conscious choice (−))
- *Reciprocity* (indicates the social tendency for friendships to be mutual, tendency for mutuality (+))
- *Transitive triplets* (indicates the social tendency for friends of friends to become friends, transitive tendencies (+))
- *Writing linear tendency* (indicates classroom tendencies on writing performance, higher performing (+))
- *Writing quadratic shape* (indicates student dispersion on writing performance within the classroom, student dispersion (+))
- *Math linear tendency* (indicates classroom tendencies on math performance, higher performing (+))
- *Math quadratic shape* (indicates student dispersion on math performance within the classroom, student dispersion (+))

Network controls

- *Gender ego* (tendency for gender differences in nominations made, boys nominate more friends than girls (+))
- *Gender alter* (tendency for gender differences in nominations received, boys receive more friend nominations than girls (+))
- *Gender similarity* (tendency for nominating same-gender friends, tendency for same-gender friends (+))
- *Ethnicity ego* (tendency for ethnic differences in nominations made, majority nominate more friends than minority (+))
- *Ethnicity alter* (tendency for ethnic differences in nominations received, majority receive more friend nominations than minority (+))
- *Ethnicity similarity* (tendency for nominating same-ethnic friends, tendency for same-ethnic friends (+))
- *Parent education ego* (tendency for parent education differences in nominations made, higher parent educated nominate more friends than lower parent educated (+))
- *Parent education alter* (tendency for parent education differences in nominations received, higher parent educated receive more friend nominations than lower parent educated (+))
- *Parent education similarity* (tendency for nominating similar-parent educated friends, tendency for similar-parent educated friends (+))
- *Writing performance ego* (tendency for writing performance differences in nominations made, higher performers nominate more friends than lower performers (+))
- *Writing performance alter* (tendency for writing performance differences in nominations received, higher performers receive more friend nominations than lower performers (+))
- *Math performance ego* (tendency for math performance differences in nominations made, higher performers nominate more friends (+))
- *Math performance alter* (tendency for math performance differences in nominations received, higher performers receive more friend nominations (+))

Behavioral controls

- *Effect from gender on writing* (tendency for gender differences in changes in writing performance, boys change more in writing performance than girls (+))
- *Effect from ethnicity on writing* (tendency for ethnic differences in changes in writing performance, majority change more in writing performance than minority (+))

Table 1 (continued)

Effect from parent education on writing (tendency for parent education differences in changes in writing performance, higher parent educated change more in writing performance than lower parent educated (+))
Effect from gender on math (tendency for gender differences in changes in math performance, boys change more in math performance than girls (+))
Effect from ethnicity on math (tendency for ethnic differences in changes in math performance, majority change more in math performance than minority (+))
Effect from parent education on math (tendency for parent education differences in changes in math performance, higher parent educated change more in math performance than lower parent educated (+))
Goodness of fit (GOF) controls
Three-cycles (estimate included to improve model fit in the transitivity distribution)
Outdegree activity (estimate included to improve model fit in the degree distribution)
Outdegree activity sqrt (estimate included to improve model fit in the degree distribution)
Outdegree trunc (estimate included to improve model fit in the degree distribution)

writing or math performance (e.g., a positive effect for *writing or math performance similarity* means that children select friends with similar levels of writing or math performance, respectively; a negative writing or math performance similarity effect means that children select friends with dissimilar levels of writing or math performance). Thus, the interpretation of writing or math performance similarity mirrors the interpretation of the similarity effects for control parameters.

Influence Effects

The parameters of primary interest in the current investigation are *peer influence on writing performance* and *peer influence on math performance*. We compared this effect between intervention and control classrooms. We modeled peer influence as the impact of friends' academic performance (the average across friends) on change over time in a child's academic performance. The *math performance average alter* parameter was used to account for peer influence on math performance and the *writing performance average alter* parameter was used to account for peer influence on writing performance. A positive peer influence on the writing or math performance parameter indicates that children change their level of writing or math performance to increase or decrease toward the average level of writing or math performance of their friends. A negative peer influence on writing or math performance parameter indicates that children change their level of writing or math performance to become less similar to the average level of writing or math performance of their friends.

Follow-up Analyses

After modeling influence tendencies, we compared peer selection and influence effects in intervention and control classrooms. To do this, we first conducted follow-up analyses to investigate the direction of peer influence on writing and math performance in intervention and control classrooms. This was done to determine if influence was toward improved or diminished academic performance in writing and math. These follow-up analyses were calculated to determine *who is most likely to influence whom* as a function of relative levels of writing and math performance. In this way, we could illustrate that when influence occurs in intervention classrooms, it is from higher to lower performers, or toward heightened academic performance in writing and mathematics. To calculate these follow-up estimates, we followed recommendations outlined in section 13.4 of the RSiena manual (Ripley et al. 2016). Thus, the formula for these analyses can be presented as

$$F_i^{\mathbf{beh}} = \beta_{\mathbf{trend}}\left(z_i - \overline{z}\right) + \beta_{\mathbf{quadratic}}\left(z_i - \overline{z}\right)^2 + \beta_{\mathbf{av.alter}}\left(z_i - \overline{z}\right)\left(z_{(i)} - \overline{z}\right),$$

where variables are internally centered as required by RSiena and linear (β_{trend}) and quadratic ($\beta_{\text{quadratic}}$) behavioral trends in the network's academic performance levels are accounted for. Finally, the strength of the peer influence effect ($\beta_{\text{av.alter}}$) between the influential peer ($z_{(i)}$) and the influenced peer (z_i) at all academic performance levels was assessed. Results are described in the "Follow-up Analyses" subsection of the "Results."

Finally, for selection and influence effects in intervention and control classrooms, we offer an illustration of testing for significant differences in SEL effects between intervention and control classrooms. Although a similar approach has been used (Rambaran et al. 2015), we made slight modifications to this original approach based on current recommendations from section 8.5 of the RSiena manual (Ripley et al. 2016). In the current approach, we compare the strength of network effects by calculating the difference of the effect estimates (provided by RSiena) divided by the pooled standard error of the effect estimates.

Results

Preliminary Analyses

Descriptive statistics of classroom peer networks are presented in Table 2. On average, students in the RBI classrooms nominated more than five friends and students in control

Table 2 Descriptive and change statistics of peers in intervention and control classrooms

	Intervention		Control	
	Pre-test	Post-test	Pre-test	Post-test
Network descriptives				
Friendship nominations	5.41	5.41	5.00	4.82
Number of network ties	2180	2175	1131	1088
Behavioral descriptives				
Mean levels of writing performance	2.65	3.42	2.58	3.33
Mean levels of math performance	2.87	3.22	2.80	3.04
Network change	Pre-test to post-test		Pre-test to post-test	
Children joining the classroom	10		7	
Children leaving the classroom	16		9	
Stability of friendships (Jaccard index)	.43		.44	
Behavioral change	Pre-test to post-test		Pre-test to post-test	
Writing performance temporal autocorrelation	.34**		.42**	
Math performance temporal autocorrelation	.52**		.69**	

$N = 404$ participants from 14 intervention classrooms. $N = 228$ participants from 8 control classrooms

*$p < .05$; **$p < .01$

classrooms nominated slightly less than five friends across time. The total number of friendship ties in RBI classrooms was somewhat higher and remained more stable from pre- to post-test when compared to control classrooms. Nevertheless, RSiena accounts for differences in network size. In RBI classrooms, 10 students joined and 16 students left the classroom from pre- to post-test. In control classrooms, 7 students joined and 9 students left the classroom from pre- to post-test. Friendship ties were adequately stable from pre-test to post-test in both RBI (43 %) and control (44 %) classrooms, which indicates that it is appropriate to use RSiena with these data (Snijders et al. 2010). Writing and math performance were also adequately stable ($rs = .34$ to .69, $ps < .01$, respectively). All descriptive information was within an acceptable range for analysis.

Peer Influence Effects on Writing and Math Performance

Below, we describe the characteristics of the classroom peer network across the fifth grade academic year in RBI and control classrooms (see Table 3). First, we present *only* the statistically significant structural, network, and behavioral control effects and describe the goodness of fit (GOF) estimates. Next, we present selection and influence effects for writing and math performance. For statistically significant influence effects, we present the results of follow-up analyses to determine the direction of peer influence (i.e., toward improved or diminished writing and math performance). Because we are adopting a longitudinal SNA approach, the reported estimates refer to change across time from pre-test to post-test; thus, initial differences between the RBI and control classrooms are accounted for in the analysis of change.

Structural Controls

As expected, the *outdegree* parameter was negative (Snijders et al. 2010), indicating that children showed selectivity in friendship nominations in both RBI and control classrooms. Friendship nominations were significantly ($p < .05$) more likely to be reciprocal (*reciprocity*) in RBI classrooms (reciprocity estimate above 1) than in control classrooms (reciprocity estimate below 1). In both types of classrooms, there was a tendency for friends of friends to be nominated as friends (*transitive triplets*). In RBI classrooms only, there was a significant and positive *linear tendency* in writing performance, indicating that on average, students in RBI classrooms tended to perform at levels above the midpoint on the writing performance scale. For math performance, there was a significant and positive *linear tendency* for both RBI and control classrooms, indicating that, on average, students in RBI and control classrooms tended to perform at levels above the midpoint on the math scale.

Network Controls

There was some evidence that girls tended to make more nominations than boys in control classrooms (*gender ego*). Boys tended to receive more nominations than girls in both RBI and control classrooms (*gender alter*). Also, in both types of classrooms, the inclusion of study control variables indicated that students were more likely to nominate same- than other-gender friends (*gender similarity*). There was a tendency for students in control classrooms to nominate friends of the same ethnicity (*ethnicity similarity*; i.e., majority students tended to nominate majority students rather than minority students; $p < .05$). Thus, concerning the friendships that formed from pre-test (prior to

Table 3 Peer selection and influence processes on the basis of writing and math performance for intervention and control classrooms

	Intervention		Control	
	Est.	SE	Est.	SE
Influence effects				
Writing performance average alter	1.63*	0.70	1.98	2.59
Math performance average alter	0.97**	0.39	0.83	0.48
Selection effects				
Writing performance similarity	1.04	0.91	0.30	0.56
Math performance similarity	−0.02	0.22	0.73*	0.32
Structural controls				
Outdegree	−1.56**	0.52	−1.70*	0.77
Reciprocity	1.26**	0.07	0.91**	0.10
Transitive triplets	0.31**	0.02	0.30**	0.02
Writing linear tendency	2.15**	0.54	3.65	3.24
Writing quadratic shape	0.03	0.29	0.69	0.77
Math linear tendency	0.73**	0.11	0.52*	0.21
Math quadratic shape	−0.11	0.11	0.17	0.13
Network controls				
Gender ego	−0.09	0.06	−0.16*	0.08
Gender alter	0.11*	0.05	0.15*	0.07
Gender similarity	0.50**	0.06	0.53**	0.07
Ethnicity ego	0.04	0.06	0.05	0.08
Ethnicity alter	0.05	0.05	−0.01	0.08
Ethnicity similarity	−0.10	0.06	0.27**	0.08
Parent education ego	−0.08**	0.03	−0.01	0.04
Parent education alter	−0.02	0.03	−0.05	0.04
Parent education similarity	0.17	0.15	−0.18	0.25
Writing performance ego	−0.15	0.09	0.09	0.09
Writing performance alter	0.18	0.10	0.29**	0.11
Math performance ego	0.03	0.05	−0.04	0.05
Math performance alter	0.08	0.05	0.10*	0.05
Behavioral controls				
Effect from gender on writing	−0.76	0.40	−0.40	0.95
Effect from ethnicity on writing	0.36	0.31	−0.78	1.23
Effect from parent education on writing	0.69	0.38	1.11	1.25
Effect from gender on math	−0.16	0.15	0.27	0.27
Effect from ethnicity on math	0.23	0.15	0.03	0.24
Effect from parent education on math	0.34**	0.10	−0.05	0.13
Goodness of fit (GOF) controls				
Three-cycles	−0.31**	0.03	−0.31**	0.04
Outdegree activity	−0.20**	0.06	−0.25**	0.05
Outdegree activity sqrt	1.50**	0.30	0.78*	0.31
Outdegree trunc	−1.25**	0.23	−1.48**	0.36

$N = 404$ participants from 14 intervention classrooms. $N = 228$ participants from 8 control classrooms. Gender: male = 1, female = 0. Ethnicity: majority (White) = 1, minority (Non-white) = 0. Parent education: ranged from high school = 1 to doctorate degree = 6. Statistical significance of the mean parameter estimates is obtained by an approximate *t* ratio of the estimate divided by its standard error (*SE*)

*$p < .05$; **$p < .01$

the onset of the RBI activities) to post-test (after the completion of the RBI activities), students in the control classrooms tended to segregate friendships by ethnicity, whereas students in the intervention classrooms did not.

Behavioral Controls

In RBI classrooms, there was a tendency for students with higher parental education levels (*effect from parent education*) to change in math performance more than students with lower parental education levels, and this was significantly different from control classrooms ($p < .05$).

Goodness of Fit controls

The *three-cycles* parameter that was added to improve model fit for the transitivity distribution was significant in RBI and control classrooms. All three outdegree parameters (i.e. *outdegree activity*, *outdegree activity sqrt*, and *outdegree truncated activity*) that were added to improve model fit for the outdegree distribution were significant in RBI and control classrooms.

Selection Effects

In RBI classrooms, there were no significant selection effects (*writing performance similarity*, *math performance similarity*). In contrast, in control classrooms, friendships were more likely to form with those who were similar on levels of math performance than with those who were dissimilar on levels of math performance (*math performance similarity*), an indication of social segregation as a function of math performance.

Influence Effects

Finally, after accounting for each of these structural, network, and behavioral control parameters and selection effects, there was evidence of significant peer influence on both writing (*writing performance average alter influence*) and math (*math performance average alter influence*) performance in intervention classrooms only (see Table 3). That is, in the RBI but not in the control classrooms, children moved toward the average level of their friends' academic performance from pre- to post-test. The pattern of significance in peer influence estimates provides preliminary evidence that peer influence on improved learning may be possible in RBI classrooms

Follow-up Analyses

Follow-up analyses were conducted to illustrate the direction of influence on writing and math performance in RBI classrooms. Friends were likely to be influential over children with similar levels of writing performance (odds of influence = 3.65 for highest performers; 2.09 for lowest performers), but higher performers were also likely to influence lower performers toward improved writing performance (odds of influence = 2.07 for highest performers on moderate performers and 1.23 for moderate performers on struggling performers). There was no evidence of influence toward diminished writing performance.

Friends were likely to be influential over children with similar levels of math performance (odds of influence = 1.50 for highest performers; 2.09 for lowest performers), but higher performers were also likely to influence lower performers toward improved math performance (odds of influence = 0.56 for highest performers on moderate performers and 1.18 for moderate performers on struggling performers). There was minimal evidence of influence toward diminished math performance, so that the lowest performers were not influential, but moderate performers had some minimal influence over higher performers (odds of influence = 0.11). These results indicate that when influence occurred in intervention classrooms, it was typically toward improvements in writing and math performance.

Discussion

The effect of the relationship building intervention (RBI; Miller et al. 2015) on peer influence toward improved academic performance was tested using an innovative application of longitudinal SNA. We expected the RBI to contribute to the social climate of the classroom. The current study addressed this potential while also providing the first demonstration of how such changes in the *classroom peer network* may change academic performance outcomes by encouraging positive peer influence. Thus, findings suggest that SEL intervention effects might stem, in part, from positive peer influence over writing and math performance.

One benefit of adopting a longitudinal SNA approach to assess the effects of SEL programming is that scholars can investigate the intervention's impact on peer *influence* after simultaneously accounting for the possible impact of the intervention on peer *selection*. There are a number of ways that the RBI implemented in the present study might exert changes in peer influence. By improving social skills, students may form closer relationships with other students. We know that students are more likely to be influenced by close (i.e., more intimate) peer relationship partners than by casual peer affiliates (Hartup 1996) and by peers who are more prosocial (Erdley and Asher 1999). Thus, the aim of the RBI to improve social relationships seems to have created a more socially skilled group of students, allowing for a greater likelihood of peer influence over improved academic performance. Finally, the RBI may have allowed teachers more time to provide instructions to other students in the classroom.

Greater selection of other-ethnic friends (i.e., greater likelihood for majority selecting minority youth and vice versa) and a greater likelihood for friendships to form between children with differing performance abilities were found in the RBI classrooms but not control classrooms. In contrast, control classrooms were marked by restrictive selection with a

greater likelihood for selection of same-ethnic friends and for friendships to form between children with similar math and writing abilities. The lack of restricted selection found in the RBI classes suggests that the RBI may have improved intergroup contact among diverse peers. According to Allport's ideas about Intergroup Contact Theory (Allport 1954; Pettigrew et al. 2011), when in-group and out-group members are brought together toward a common goal, it encourages improved attitudes and positive feelings toward other-group members. If the RBI created more ethnically diverse social interactions, this may have improved academic outcomes by improving the classroom climate and increasing opportunities for collaborative learning as ethnically diverse peers began to work together (Milem et al. 2005).

Diverse relationships may also foster positive influence as children with varying skill levels begin to work together. Empirical evidence shows that upward academic comparisons between classroom peers can improve academic performance (Blanton et al. 1999), suggesting that academic advances may occur when higher-achieving students are willing to provide support to lower-achieving peers. It seems reasonable that the increased diversification of peer relationships in RBI classrooms may have led higher achievers to be more willing, or facilitated opportunities, to work with lower-achieving peers. In general, building positive and more supportive relationships may have resulted in comfortable and cooperative learning exchanges between both ethnically and academically diverse peers in the intervention classrooms.

Another contribution of the current study is that it provides a demonstration of why coupling longitudinal SNA with intervention data is critical to intervention science efforts. To further illustrate this point, we advanced two innovative follow-up analyses to assess the direction and strength of influence in the RBI compared to control classrooms. This allowed for an illustration of how applying longitudinal SNA to intervention data offers the potential to enhance our understanding of how interventions impact social relationships to change outcomes.

Limitations

Despite the intriguing results, some caution is needed in generalizing from the present findings. The RBI was tested only in fifth-grade classrooms. We do not know if the same patterns would hold for children in other grades. Also, we illustrated that positive influence occurred for children in RBI classes and not for children in the control classes, but we were unable to identify the exact mechanisms driving the effect. The investigation used a matched classroom design, which may have suffered from selection bias. Specifically, it is possible that only teachers who were open to the ideas proposed in the intervention participated in the study and it is a lack of teacher buy-in that resulted in low participation rates in control classrooms. Thus, only the most motivated control classrooms were able to be included in analyses, which may have diminished the robustness of some of the effect differences between intervention and control classrooms. Although some of these biases were controlled using longitudinal SNA, a randomized control trial is needed to move toward causal inference. Additional attention should be directed to variations in peer influence across classrooms to identify specific classroom factors (e.g., teaching practices) that may contribute to such variation. Questions also remain about how best to evaluate intervention effects using RSiena; thus, we view the current investigation as a first step in illustrating how this may be done.

Conclusions

The current findings suggest that SEL programming (such as the RBI) may be effective, in part, because it changes the nature of social relationships *within* SEL classrooms in ways that foster positive peer influence. Moving beyond assessments of aggregate level change will allow us to better understand the dynamic nature of intervention effects on social relationships. By adopting a longitudinal SNA approach, scholars can better assess the impact of SEL interventions on social relationships. The current study offered an initial demonstration of how this might be done. Greater methodological (e.g., longitudinal SNA) and design (e.g., randomized control trials) precision in understanding *how* SEL interventions affect classroom social relationships will present a critical step forward for prevention science.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

Informed Consent Informed consent was obtained from all individual participants included in the study.

Funding This research was supported by the T. Denny Sanford School of Social and Family Dynamics.

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

References

Ahn, H. J., Rodkin, P. C., & Gest, S. (2013). Teacher-student agreement on "bullies and kids they pick on" in elementary school classrooms: Gender and grade differences. *Theory Into Practice, 52*, 257–263. doi:10.1080/00405841.2013.829728.

Allport, G. W. (1954). *The nature of prejudice*. Reading, MA: AddisonWesley.

Azmitia, M., & Montgomery, R. (1993). Friendship, transactive dialogues, and the development of scientific reasoning. *Social Development, 2*, 202–221. doi:10.1111/j.1467-9507.1993.tb00014.x.

Blanton, H., Buunk, B., Gibbons, F., & Kuyper, H. (1999). When better-than-others compare upward: Choice of comparison and comparative evaluation as independent predictors of academic performance. *Journal of Personality and Social Psychology, 76*, 420–430. doi:10.1037/0022-3514.76.3.420.

Borkowski, J. G. (1992). Metacognitive theory: A framework for teaching literacy, writing, and math skills. *Journal of Learning Disabilities, 25*, 253–257. doi:10.1177/002221949202500406.

Cascio, E., & Schanzenbach, D. W. (2007). *First in the class? Age and the education production function* (Working Paper No. w13663). National Bureau of Economic Research.

Cillessen, A. H. N. (2009). Sociometric methods. In K. H. Rubin, W. M. Bukowski, & B. Laursen (Eds.), *Handbook of peer interactions, relationships, and groups* (pp. 82–99). New York, NY: Guilford.

Collaborative for Academic Social and Emotional Learning. (2012). *2013 CASEL Guide: Effective social and emotional learning programs-preschool and elementary school edition*. Retrieved from http://www.casel.org/preschool-and-elementary-edition-casel-guide.

Craven, R. G., Marsh, H. W., Debus, R. L., & Jayasinghe, U. (2001). Diffusion effects: Control group contamination threats to the validity of teacher-administered interventions. *Journal of Educational Psychology, 93*, 639–645. doi:10.1037/0022-0663.93.3.639.

DeLay, D., Laursen, B., Kiuru, N., Poikkeus, A. M., Aunola, K., & Nurmi, J. E. (2015). Stable same-sex friendships with higher achieving partners promote mathematical reasoning in lower achieving primary school children. *British Journal of Developmental Psychology, 33*, 519–532. doi:10.1111/bjdp.12117.

Dishion, T. J., Spracklen, K. M., Andrews, D. W., & Patterson, G. R. (1996). Deviancy training in male adolescent friendships. *Behavior Therapy, 27*, 373–390. doi:10.1016/S0005-7894(96)80023-2.

Dodge, K. A., & Price, J. M. (1994). On the relation between social information processing and socially competent behavior in early school-aged children. *Child Development, 65*, 1385–1397. doi:10.2307/1131505.

Durlak, J. A., Weissberg, R. P., Dymnicki, A. B., Taylor, R. D., & Schellinger, K. B. (2011). The impact of enhancing students' social and emotional learning: A meta-analysis of school-based universal interventions. *Child Development, 82*, 405–432. doi:10.1111/j.1467-8624.2010.01564.x.

Erdley, C. A., & Asher, S. R. (1999). A social goals perspective on children's social competence. *Journal of Emotional and Behavioral Disorders, 7*, 156–167. doi:10.1177/106342669900700304.

Gest, S. D., Osgood, D. W., Feinberg, M. E., Bierman, K. L., & Moody, J. (2011). Strengthening prevention program theories and evaluations: Contributions from social network analysis. *Prevention Science, 12*, 349–360. doi:10.1007%2Fs11121-011-0229-2.

Greenberg, M. T., Feinberg, M. E., Johnson, L. E., Perkins, D. F., Welsh, J. A., & Spoth, R. L. (2015). Factors that predict financial sustainability of community coalitions: Five years of findings from the prosper partnership project. *Prevention Science, 16*, 158–167. doi:10.1007/s11121-014-0483-1.

Greenberg, M. T., Weissberg, R. P., O'Brien, M. U., Zins, J. E., Fredericks, L., Resnik, H., & Elias, M. J. (2003). Enhancing school-based prevention and youth development through coordinated social, emotional, and academic learning. *American Psychologist, 58*, 466–474. doi:10.1037/0003-066X.58.6-7.466.

Harris, J. R. (1995). Where is the child's environment? A group socialization theory of development. *Psychological Review, 102*, 458–489. doi:10.1037/0033-295X.102.3.458.

Hartup, W. W. (1996). The company they keep: Friendships and their developmental significance. *Child Development, 67*, 1–13. doi:10.2307/1131681.

Hawley, P. H., Little, T. D., & Pasupathi, M. (2002). Winning friends and influencing peers: Strategies of peer influence in late childhood. *International Journal of Behavioral Development, 26*, 466–474. doi:10.1080/01650250143000427.

Kandel, D. B. (1978). Homophily, selection, and socialization in adolescent friendships. *American Journal of Sociology, 84*, 427–436. doi:10.1086/226792.

Ladd, G. W., Birch, S. H., & Buhs, E. S. (1999). Children's social and scholastic lives in kindergarten: Related spheres of influence? *Child Development, 70*, 1373–1400. doi:10.1111/1467-8624.00101.

Milem, J. F., Chang, M. J., & Antonio, A. L. (2005). *Making diversity work on campus: A research-based perspective*. Washington, DC: Association American Colleges and Universities.

Miller, C., Kochel, K. P., Updegraff, K., Fabes, R. A., Hanish, L. D., & Martin, C. L. (2015). *The relationship building intervention program: Fifth-grade*. Tempe, AZ: Arizona State University. Unpublished manual.

Miller, C. F., Kochel, K. P., Wheeler, L. A., Updegraff, K. A., Fabes, R. A., Martin, C. L., & Hanish, L. D. (2016). The efficacy of a relationship building intervention in 5th grade. *Journal of School Psychology* (in press).

Paulus, T. M. (1999). The effect of peer and teacher feedback on student writing. *Journal of Second Language Writing, 8*, 265–289. doi:10.1016/S1060-3743(99)80117-9.

Pettigrew, T. F., Tropp, L. R., Wagner, U., & Christ, O. (2011). Recent advances in intergroup contact theory. *International Journal of Intercultural Relations, 35*, 271–280. doi:10.1016/j.ijintrel.2011.03.001.

Pianta, R. C., Belsky, J., Houts, R., & Morrison, F. (2007). Opportunities to learn in America's elementary classrooms. *Science (New York, N.Y.), 315*, 1795–1796. doi:10.1126/science.1139719.

Rambaran, J. A., Dijkstra, J. K., Munniksma, A., & Cillessen, A. H. N. (2015). The development of adolescents' friendships and antipathies: A longitudinal multivariate network test of balance theory. *Social Networks, 43*, 162–176. doi:10.1016/j.socnet.2015.05.003.

Ripley, R., Snijders, T. A. B., Boda, Z., Voros, A., & Preciado, P. (2016). *Manual for RSiena (version Feb 25, 2016)*. Oxford: University of Oxford, Department of Statistics, Nuffield College. http://www.stats.ox.ac.uk/siena/.

Rulison, K. L., Gest, S. D., & Osgood, D. W. (2015). Adolescent peer networks and the potential for the diffusion of intervention effects. *Prevention Science, 16*, 133–144. doi:10.1007%2Fs11121-014-0465-3.

Ryan, A. M., & Ladd, G. W. (Eds.). (2012). *Peer relationships and adjustment at school*. Charlotte, NC: Information Age Publishing, Inc.

Schwarz, B. B., & Linchevski, L. (2007). The role of task design and argumentation in cognitive development during peer interaction: The case of proportional reasoning. *Learning and Instruction, 17*, 510–531. doi:10.1016/j.learninstruc.2007.09.009.

Snijders, T. A. B., van de Bunt, G. G., & Steglich, C. E. G. (2010). Introduction to scholastic actor-based models for network dynamics. *Social Networks, 32*, 44–60. doi:10.1016/j.socnet.2009.02.004.

Wentzel, K. R., & Watkins, D. (2002). Peer relationships and collaborative learning as contexts for academic enablers. *School Psychology Review, 31*, 366–377.

Yudron, M., Jones, S. M., & Raver, C. C. (2014). Implications of different methods for specifying classroom composition of externalizing behavior and its relationship to social-emotional outcomes. *Early Childhood Research Quarterly, 29*, 682–691. doi:10.1016/j.ecresq.2014.07.007.

Zins, J. E., Bloodworth, M. R., Weissberg, R. P., & Walberg, H. J. (2007). The scientific base linking social and emotional learning to school success. *Journal of Educational and Psychological Consultation, 17*, 191–210. doi:10.1080/10474410701413145.