Isolation but Diffusion?
A Structural Account of Depression Clustering among Adolescents

Jun Zhao1*, Dawn T. Robinson2*, and Chyi-In Wu3

Abstract
Depression can cause people to withdraw from friendships or be avoided by others, protecting others from exposure to that depression. Yet, researchers observe depression contagion, particularly among adolescents. We address this empirical puzzle by examining the role of gender in structuring friendship networks and the implications for isolation and the spreading of depression. Using stochastic actor-based models of friendships among 421 adolescents from mixed-gender, all-girls, and all-boys classrooms in six Taiwanese high schools, we find that networks with only girls are characterized by high reciprocity and low transitivity. This, in turn, facilitates the withdrawal of depressed girls from interactions. In contrast, networks with all boys create more opportunities for depression to spread through interconnected pathways. Our computational experiment further demonstrates that local preferences governing friendship choice influence levels of network connectivity. This, coupled with depression withdrawal and peer influence, shapes depression prevalence at the network level. These findings refine our understanding of the mechanisms through which friendships expose boys and girls unequally to health risks of depression.

Keywords
adolescents, depression, gender, homophily, social networks

Friends matter when it comes to adolescent depression (Falci and McNeely 2009; Ueno 2005). Sociological investigation of depression and friendship networks has largely established two distinct and apparently incongruous patterns. On the one hand, symptoms and stigma associated with depression cause relationships to wane, leading depressed individuals to become socially marginalized (Cornwell 2003; Joiner and Coyne 1999; Link and Phelan 2001; Schaefer, Kornienko, and Fox 2011). Logically, isolating tendencies of depression should limit the exposure of healthy individuals to their depression. On the other hand, empirical evidence on aggregated patterns consistently shows...

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that depression spreads through friendship networks (Howes, Hokanson, and Loewenstein 1985; Prinstein 2007; Rosenquist, Fowler, and Christakis, 2011; van Zalk et al. 2010a). How does depression both hinder social engagement of depressed individuals and yet contribute to larger patterns of diffusion in friendship networks?

In this article, we develop a structural account to address how network patterns affect depression isolation and socialization. We argue that depression diffusion is less likely to occur when networks are compartmentalized, whereas depression is likely to spread more widely when personal networks are interconnected (Guan and Kamo 2016). We focus on gendered networks as a context within which to examine this mechanism because prior work suggests distinct network dynamics among adolescent boys and girls, with girls tending toward greater selectivity and socializing in more compartmentalized group structures and boys tending toward socializing in more inclusive groups (Crosnoe 2000; McNelles and Connolly 1999). We propose that gender differences in key network processes promote depressive symptoms to spread among boys but leave depressed girls to become socially marginalized in their networks.

To test our theoretical arguments, we analyze friendship formation and depression change in 13 all-girls, all-boys, and mixed-gender classrooms from six Taiwanese high schools. We then supplement our empirical analyses with a “computational experiment” (Macy and Willer 2002; Adams and Schaefer 2016) where we manipulate key rules (i.e., network processes) for social interaction and track subsequent change of depression at the network level. While prior research reports gender differences in peer influence of depression (Cheadle and Goosby 2012; Giletta et al. 2012; Hoge and Steinberg 1995; Stevens and Prinstein 2005; van Zalk et al. 2010b), our study is, to the authors’ knowledge, the first to link gendered network structure to unequal health risks of depression among adolescent boys and girls.

**BACKGROUND**

**The Paradox of Depression Isolation and Diffusion**

Extant research documents multiple processes leading to the social segregation of people with greater and lesser depressive symptoms. First, depression leads to loss of interest in social activities, fatigue, and sadness (Radloff 1977). Depressive symptoms diminish engagement in social relationships and especially inhibit formation of bridging ties (Cornwell 2009), leaving depressed individuals poorly connected within their networks (Schaefer et al. 2011). Second, depressed individuals dwell on the negatives, have less energy, and display poorer coping skills, all of which reduce their attractiveness as potential friends (Coyne 1976; Joiner and Coyne 1999). Due to the emotional cost depression imposes on friendships and the stigma associated with depression, depressed people often experience social exclusion (Lucas and Phelan 2012) or friendship termination (van Zalk et al. 2010b). Worse, to the extent that depressed people internalize the stigma of mental illness, they may simply avoid social relations altogether (Link et al. 1989). Third, depression symptoms lead individuals to prefer associating with depressed others (Rosenblatt and Greenberg 1991; Schachter 1959). The social and emotional support provided from experientially similar network ties allow individuals to communicate with less effort and greater feelings of understanding (Suitor and Pillemer 2000), which may explain why people are attracted to similar others.
All three processes—social withdrawal, social exclusion, and homophilic selection—lead us to expect that as people with depressive symptoms become more socially marginalized, nondepressed people become increasingly protected from exposure to depression. Consequently, individuals with better mental health would remain available to each other as friends, resulting in observable depression clustering (McPherson, Smith-Lovin, and Cook 2001) that is due to depression containment.¹

Nonetheless, longitudinal research shows clusters of depression apparently resulting from socialization (Howes et al. 1985; Kiuru et al. 2012; Prinstein 2007; Rosenquist et al. 2011; van Zalk et al. 2010a). Of note, the socialization processes include both depression contagion, a process by which depression spreads from depressed to nondepressed individuals, and depression mitigation, a process by which nondepressed friends help to improve the well-being of depressed individuals. Researchers offer multiple mechanisms to explain these empirical findings, including co-rumination (Rose 2002; Rose, Carlson, and Waller 2007), learned social appraisal (Parkinson 2010; van Zalk et al. 2010b), and emotional contagion for both positive and negative affect (Coviello et al. 2014; Fowler and Christakis 2008; Hatfield, Cacioppo, and Rapson 1994; Kramer, Guillory, and Hancock 2014). This research provides potential explanations for why we observe depression convergence when actors are exposed. The question remains, how does large-scale depression clustering occur when social interactions with depressed individuals are inhibited in the first place?

¹In this article we use depression clustering to describe network patterns of homogeneity and use homophilic selection to indicate individual preference for similar others.

Guan and Kamo (2016) analyzed National Longitudinal Study of Adolescent to Adult Health (Add Health) data to shed light on the mechanisms driving this paradox. They found that dense peer networks with many indirect ties provide more pathways through which depression travels and peer group norms are reinforced (Conway, Rancourt, and Prinstein 2011). These findings suggest that the key to this paradox is in the larger network structures in which friendships are embedded.

Network Structures and Depression Diffusion

When people interact, they spread ideas, emotions, and germs, and their interaction partners spread them to their own interaction partners. A fundamental insight of the social network literature is that network architecture influences diffusion speed and coverage. When social networks are highly clustered, information recirculates inside densely connected clusters, creating insider knowledge and amplifying attitudes and emotions. Content flowing through the system can get stuck in cul-de-sacs if those networks are also compartmentalized, circling only between clusters (Burt 1992). In this scenario, content spreads (and recirculates) within the friends but not across the network. This effect should be exacerbated when people have depressive symptoms. Withdrawal tendencies among depressives and the stigma of depression should further shrink the size of local friendship networks and increase compartmentalization. Consequently, depressed individuals become to a certain degree self-quarantined, reducing the likelihood of large-scale depression contagion.

On the other hand, network research shows that the presence of even a few long ties, those that bridge otherwise separated clusters, accelerates the spread of
content across the system (Granovetter 1973; Watts and Strogatz 1998). This could turn a compartmentalized network into a “small world” where novel information diffuses quickly. While long chains can be inefficient in spreading behaviors that require repeated social reinforcement (Centola and Macy 2007), bridges may not be so “weak” in the context of adolescents’ friendship networks. Given the amount of time adolescents spend with their peers, youth friendships provide opportunities for the learning and refining of socioemotional skills (Crosnoe 2000). As such, they carry the capacity to reinforce behaviors in repeated interpersonal interactions. When embedded in a friendship network with high connectivity, depression symptoms are likely to spread across social ties via the mechanisms established above: co-ruminating, emotion contagion, and so on.

**Gendered Pathway to Depression Clustering**

We examine gendered classroom networks—consisting of all girls, all boys, and mixed genders—to investigate the impact of network structure on depression isolation and socialization. We argue that gendered networks provide natural and strong variations along which network theorists predict behavior diffusion, namely, network connectivity. In particular, we focus on gendered differences in reciprocity and transitivity, two of the most important endogenous network mechanisms underlying network formation and evolution (Rivera, Soderstrom, and Uzzi 2010; Snijders et al. 2010), and make predictions about how they influence network structure and depression clustering.

Reciprocity and transitivity exert predominant influence on network evolution (Kossinets and Watts 2009; Schaefer et al. 2010). Reciprocity means individuals return social ties to those from whom they receive a tie. Transitivity, or triadic closure (Granovetter 1973), refers to the tendency to form ties with friends’ friends. Both mechanisms have deep social-psychological roots. A common explanation underlying friendship mutuality is that friendship needs reciprocation to be evaluated positively and to continue to provide/receive support, advice, and so on in future social exchanges (Emerson 1976). The canonical explanation for transitivity dates back to theories of cognitive dissonance (Heider 1946). With a Simmelian understanding of social networks (Simmel 1950), balance theory (Heider 1946) suggests that individuals seek triad closure in order to reduce psychological distress caused by intransitive networks (e.g., my friends are not friends with each other, or my friends dislike each other).

Scholars observe gender differences with respect to these network processes. Specifically, due to early childhood socialization, boys tend to establish more expansive but less intimate friendships through group activities, whereas girls often establish fewer but emotionally charged friendships through discussion and self-disclosure (Crosnoe 2000; McNelles and Connolly 1999; Perry and Pauletti 2011; Rose and Rudolph 2006). Girls’ emphasis on intimacy and closeness promotes more exclusive dyadic friendships with their peers. In contrast, boys have more dispersed networks and are more likely to be friends with their friends’ friends (Eder and Hallinan 1978; Markovits, Benenson, and Dolenszky 2001). In addition, boys and girls also differ in how they manage ties. When network intransitivity occurs, there is some evidence that girls tend to strategically resolve network imbalance by dropping intransitive ties, leading to more fragmented networks, while boys are more likely to resolve network imbalance by adding ties (Eder and Hallinan
1978; Parker and Seal 1996). Together, past research on gender and network seems to suggest the following:

**Hypothesis 1a:** Adolescent girls are more likely than adolescent boys to reciprocate ties.

**Hypothesis 1b:** Adolescent boys are more likely than adolescent girls to choose friends of friends as friends.

These network processes play a critical role in shaping network structure (Kossinets and Watts 2009; Schaefer et al. 2010). We expect girls’ greater emphasis on dyads over expansive groups to fragment all-girl networks into microcompartments. One consequence of greater fragmentation should be to reduce the likelihood of peer influence on depression. Given their loosely connected network structure, we also expect all-girls networks to facilitate the exit (withdrawal) and exile (exclusion) of depressed girls from the local groups.

**Hypothesis 2:** Adolescents in all-girls classes will be more likely to experience depression marginalization than depression socialization in their friendship networks.

In contrast, networks that exhibit stronger transitivity are expected to become more interconnected, imposing constraints on depression withdrawal strategies. An ironic consequence of an integrated network is to expose less depressed individuals to the influence of their depressed peers and vice versa. We hypothesize the following:

**Hypothesis 3:** Adolescent boys in all-boys classes will be more likely to experience depression socialization than depression marginalization in their friendship networks.

Our predictions are consistent with past research that finds peer influence of depression among adolescent boys but not girls (Hogue and Steinberg 1995; Cheadle and Goosby 2012). Notably, research also shows the opposite gender findings (Giletta et al. 2012; Stevens and Prinstein 2005; van Zalk et al. 2010b). For example, studies examining adolescents’ same-gender “very best” friend find that girls are more susceptible than boys to their friends’ depression (Giletta et al. 2012; Stevens and Prinstein 2005). However, this finding holds only among dyads who remain best friends over the course of study. We suspect that among enduring best friends, girls’ tendency to provide emotional support and self-disclosure increases their likelihood to influence and be influenced by their friends (Rose 2002; Rudolph 2002). When considering both enduring and dissolving friendships, we expect those embedded in highly interconnected, less fragile networks to be more vulnerable to peer influence.

**METHODS**

**Data**

The data came from a large-scale school-based longitudinal survey examining health behaviors among Taiwanese adolescents (Ko, Buskens, and Wu 2014). Single-sex schooling plays a critical role in the secondary education system in Taiwan. While primary schools put boys and girls together in the same classroom, high schools opt for gender-segregated classrooms in order to cultivate a more academically oriented climate. In Taipei, while only 9 out of 64 high schools are single-sex schools, many of the remaining coeducational schools have a mixture of same-gender and mixed-gender classrooms. Depending on students’ academic performance, personal preference, and so on, boys and girls in coed schools are placed in gender-segregated or integrated classrooms. A stratified (i.e., selective
The total number of classes retained in the sample as 13. For additional details about the data, see Ko et al. (2014). Non-response analyses indicate that respondents (n = 421) and nonrespondents (n = 45) were not significantly different in gender (t = −.648, p = .52), level of experienced stressful life events (t = −1.11, p = .91), and academic performance (t = −.752, p = .45). However, respondents who initially reported higher levels of depression (t = −1.83, p = .03), nominated fewer friends (t = 2.25, p = .01), and were less popular among peers (t = 1.74, p = .04) were more likely to drop out of the follow-up survey. Those patterns hold especially true for girls. Girls with fewer depressive symptoms are relatively overrepresented in the longitudinal sample (t = −1.53, p = .06). Hence, our estimates of the effect of depression on friendship formation are likely to be conservative for girls (highly depressed girls had already withdrawn from the study). Given these attrition patterns violate the missing-at-random assumption (Stork and Richards 1992), we restricted our final analytic sample to the 421 adolescents who contributed full data in both waves.

**Measures**

**Friendships.** Students were told to “list the names of your good friends within the class. There are no limits on how many friends you can nominate.” Each network is formally represented by an adjacency matrix with 1 representing directed ties and 0 representing relationship absence.

**Depression.** Students completed the Center for Epidemiological Studies Depression scale (CES-D; Radloff 1977). The scale consists of 20 items describing depressive symptoms during the previous week. Items are rated on a scale ranging from 0 to 3.
from 0 (less than one day) to 3 (five to six days), with a total score ranging between 0 and 60. Cronbach’s alphas were high at both waves (Time 1, \( \alpha = .89 \); Time 2, \( \alpha = .91 \); \( r = .59, p < .01 \)). Additional analyses confirmed that our depression scale has a similar factor structure found in the prior literature (Fountoulakis et al. 2001) and individual items that produced gender-biased responses (Stommel et al. 1993) had no impact on our results.\(^3\)

Four depression levels were created using cutoffs suggested in the literature. Adolescents with a CES-D score below 16 were coded as nondepressed. Those with a score between 16 and 21 were classified as having “low risks of depression.” A score between 22 and 28 was classified as “subclinically depressed” and a score greater than 29 as “clinically depressed.” These cutoffs have demonstrated diagnostic and predictive validity in relation to clinical depression studies (Yang et al. 2004). Compared to prior studies (van Zalk et al. 2010b), our sample has a slightly higher level of depression prevalence within the clinical range (12 percent vs. 15 percent).

**Covariates.** We included a set of covariates that influence both depression and networks. We measured stressful life events (Conger et al. 1993) by asking whether students had experienced each of the 43 stressful events during the past 12 months, such as suspension from school and parents’ divorce (for the full list of events, see Appendix A, available with the online version of the article). Respondents also reported their academic rank on the most recent exam at Time 1, ranging from 1 (bottom 10 percent) to 10 (top 10 percent).

Finally, we included respondent’s gender in mixed-gender classrooms (0 = female; 1 = male, 51%).

**Model Overview**

We perform stochastic actor-based (SAB) modeling to examine the coevolutionary processes of friendship networks and depression. A nontechnical account of the SAB model follows. For technical details, we refer readers to Snijders (2001) and Steglich, Snijders, and Pearson (2010).

The SAB model estimates peer influence on behavior as well as the processes producing friendship ties between actors. It assumes that network change occurs through a series of microsteps; at a given moment, one randomly selected actor is given the opportunity to modify their ties, change their behaviors, or make no changes if they are already in an optimal position. Within the SAB models, these decisions are probabilistically governed by the effects we included in the parameter vector. The model captures mutual dependence between social relations and individual behaviors in the sense that behaviors influence friendship formation/dissolution and are influenced by one’s friendships.

Each SAB model consists of two functions: a network function and a behavior function. The network function first and foremost examines endogenous network effects on tie formation. We included several commonly examined network effects in each model (see details in Results) but focused on reciprocity and transitivity based on our earlier arguments. The network function also models the probability of a tie between a dyad by examining the ego, alter, and attribute similarity effects on tie presence. For instance, the ego effect of depression measures whether depressed egos nominate fewer friends (a negative coefficient) than their less

\(^3\)Two items, “I had crying spells” and “I talked less than usual,” generated gender-specific responses among girls and boys, who otherwise exhibit the same general levels of depressive symptomatology. Results were similar when we removed the two items.
depressed counterparts, an indication of social disengagement, whereas the alter effect of depression measures whether depressed alters are less likely (when negative) to be nominated as a friend, a proxy of social rejection. A positive similarity effect suggests that ties occur more often between actors with similar depression scores, indicating homophilic selection.

The behavior function predicts the determinants of ego’s changes in depression. Of primary interest is the average similarity effect of depression, which estimates the likelihood that adolescents report a depression level that brings them closer to the average depression level of their friends (i.e., behavior convergence through depression diffusion or mitigation).

**Analytic Plan for the Empirical Data**

Depression-induced social marginalization and influence-based depression socialization may emerge from different social processes, but the outcome in each case is increased depression clustering. Thus, we first examined whether our networks exhibit signs of depression homogeneity. We then evaluated and compared network processes across gendered networks by estimating a series of SAB models using the RSiena package (Version 1.2-12) (Ripley et al. 2018). We specified identical SAB models for 13 individual classes and performed separate meta-analyses for single-gender and mixed-gender networks (Snijders and Baerveldt 2003).

**RESULTS**

Table 1 shows means and standard deviations of the study variables. The mean depression level ranges from 1.94 to 2.11 (i.e., “at risk of depression”) at various time points and for different classroom types. Numbers of nomination ranged from 0 to 10 at each wave. On average, adolescents in all-girls classrooms nominated 3.87 ($SD = 1.83$) and 3.37 ($SD = 1.85$) friends at Time 1 and Time 2, respectively. The corresponding numbers are 3.11 ($SD = 2.47$) and 3.43 ($SD = 2.47$) for adolescents in all-boys classrooms. See Appendix B in the online supplement for correlation matrices by classroom types.

Appendix Table 1 shows network and depression changes between the two waves by class. On average, students nominated three to four friends per wave, though the number of friends nominated dropped over time. The Jaccard value measures network stability. This score is high when networks have little turnover (1 = no changes at all) and is low when too much change of relationships has happened between observations (0 = complete turnover of networks). All scores were above 0.20, suggesting sufficient network changes to be modeled (Snijders et al. 2010).

Two patterns are also worth noting in Appendix Table 1. First, among adolescents in all-girls classrooms, those who experienced decreases in their ego network size also reported higher levels of depression at Time 1 ($M = 2.25$, $SD = 1.10$). In contrast, among boys in all-boys classrooms, it is the group with stable networks that reported the highest level of Time 1 depression ($M = 2.44$, $SD = 1.21$). Second, the proportion of students who experienced mental health improvement is slightly higher among all-girls classes (23.5%) than among all-boys classes (21.8%). Both findings align with our proposition that as depressed girls become less socially connected with their friends, the rest of the network will be more protected from depression exposure and may experience a higher rate of depression recovering.

**Evidence for Depression Clustering**

As an initial assessment of network depression homogeneity, we calculated
Pearson correlations between ego’s depressive symptoms and the average depressive symptoms of ego’s friends at two time points. The focal respondents’ depressive symptoms were mildly but statistically significantly associated with their friends’ average levels of depressive symptoms at Time 2 but not Time 1: the higher the ego’s depressive scores, the higher the average scores of their alters ($r_{t1} = .07, p = .27; r_{t2} = .25, p = .01$).

The finding that friendships were not initially sorted along the depression dimension is expected, as we anticipate depression-based homophily to emerge after students spend time with newly acquired classmates. By Time 2, boys and girls were modestly and statistically significantly more likely to be friends with similar others than dissimilar others when it comes to depressive symptoms.

Figure 1 plots two of the friendship networks across waves, one from an all-girls classroom and one from an all-boys classroom. The color of the circles indicates the student’s depression status: the darker the color, the more depressed the individual. Both of these classrooms show the overall tendency toward an increase in depression between Time 1 and Time 2 and a tendency for depression to be socially clustered. One difference visible in these two classrooms is for depressed girls to become relatively more isolated and for depressed boys to remain more connected, with slightly more apparent diffusion of depression among their friends. It is difficult to disentangle the relationships between network features, like reciprocity and transitivity, and dynamics, like depression change and clustering, from visual inspection of these networks. So, we turn now to our SAB model for that purpose.

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**Table 1. Means and Standard Deviations of All Study Variables ($N = 421$)**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Range</th>
<th>All girls</th>
<th>All boys</th>
<th>Mixed gender</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{Depression}_{t1}$</td>
<td>1–4</td>
<td>2.05</td>
<td>1.94</td>
<td>2.16</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1.12)</td>
<td>(1.13)</td>
<td>(1.16)</td>
</tr>
<tr>
<td>$\text{Depression}_{t2}$</td>
<td>1–4</td>
<td>2.11</td>
<td>1.99</td>
<td>2.07</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1.14)</td>
<td>(1.12)</td>
<td>(1.12)</td>
</tr>
<tr>
<td>$\text{SLE}_{t1}$</td>
<td>0–22</td>
<td>3.58</td>
<td>3.39</td>
<td>3.61</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(3.14)</td>
<td>(2.87)</td>
<td>(3.59)</td>
</tr>
<tr>
<td>$\text{Academic}_{t1}$</td>
<td>1–10</td>
<td>4.39</td>
<td>4.45</td>
<td>4.28</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(2.35)</td>
<td>(2.29)</td>
<td>(2.30)</td>
</tr>
<tr>
<td>$\text{Incoming ties}_{t1}$</td>
<td>0–10</td>
<td>3.87</td>
<td>3.13</td>
<td>3.62</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1.93)</td>
<td>(2.33)</td>
<td>(2.06)</td>
</tr>
<tr>
<td>$\text{Incoming ties}_{t2}$</td>
<td>0–8</td>
<td>3.37</td>
<td>3.44</td>
<td>3.16</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1.72)</td>
<td>(2.72)</td>
<td>(2.15)</td>
</tr>
<tr>
<td>$\text{Outgoing ties}_{t1}$</td>
<td>0–8</td>
<td>3.87</td>
<td>3.11</td>
<td>3.62</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1.83)</td>
<td>(2.47)</td>
<td>(2.24)</td>
</tr>
<tr>
<td>$\text{Outgoing ties}_{t2}$</td>
<td>0–8</td>
<td>3.37</td>
<td>3.43</td>
<td>3.16</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1.85)</td>
<td>(2.47)</td>
<td>(2.00)</td>
</tr>
<tr>
<td>Male</td>
<td>0–1</td>
<td>.00</td>
<td>1.00</td>
<td>.48</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(.00)</td>
<td>(.00)</td>
<td>(.50)</td>
</tr>
<tr>
<td>$n$</td>
<td>107</td>
<td>119</td>
<td>195</td>
<td></td>
</tr>
</tbody>
</table>

Note: $t1 = \text{Time 1}; t2 = \text{Time 2}; \text{SLE} = \text{stressful life event}.$

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4We also performed exponential random graph models (ERGMs) to detect depression clustering and found similar results. See Appendix C in the online supplement for further explanation and tabular results from ERGMs.
Table 2 shows results from multigroup meta-analysis of SAB models for single-gender and mixed-gender classes. Interpretation of the coefficients is similar to those obtained in logistic regression, that is, in terms of the likelihood of tie presence. Measures of model fit are reported at the bottom of Table 2, indicating good convergence for reporting results (i.e., all convergence ratios for individual parameters \(t_{\text{max}}\) are smaller than .10; overall maximum convergence ratios \(t_{\text{conv, max}}\) are also smaller than .25) (Ripley et al. 2018). Appendix D in the online supplement reports the goodness of fit for all models.

We started with the baseline model, where we evaluated the magnitude of endogenous network effects in single-gender networks. Gender norms tend to be more salient in single-gender than in mixed-gender social environments (Drury et al. 2013; Wong, Shi, and Chen 2018). Hence, we expect differences in reciprocity and transitivity to be pronounced in gender-segregated contexts.

As can be seen from Model 1 and Model 2 in Table 2, structural network effects played prominent roles in the formation of friendship ties. The negative outdegree parameters suggest that adolescents were less inclined to extend friendships to random classmates. Instead, they reciprocated an incoming friendship tie by sending an outgoing tie to the same person (reciprocity) and made friends with friends of friends (geometrically weighted edgewise shared partner)\(^5\). To put these numbers into perspective, among girls, the odds of making a reciprocated tie are 7.39 times (\(\exp^{2.00} = 7.39\)) the odds of making a nonreciprocated tie, all else being equal, whereas the likelihood of two friends having a common friend is only about 2.72 times higher than when these two are not tied (\(\exp^{1.00} = 2.72\)). The corresponding odds for boys are 5.75 (\(\exp^{1.75}\)) and 5.64 (\(\exp^{1.73}\)), respectively.

Results also suggest that while popular egos attract no more friendship nominations over time (indegree popularity), already gregarious actors refrained from further expanding their nominations (outdegree activity).

To assess gender differences in reciprocity (Hypothesis 1a) and transitivity (Hypothesis 1b), we pooled all single-gender classes together and examined whether gender significantly interacted with either parameter (results available upon request). Boys were significantly less likely than girls to reciprocate friendship ties and were more likely than girls to choose friends of friends as friends \((b_{\text{male}*\text{reciprocity}} = -.58, b_{\text{male}*\text{gwesp}} = .25, p < .05)\). Hypotheses 1a and 1b were both supported.

One consequence of gendered network processes with regard to reciprocity and

\(^5\)The geometrically weighted edgewise shared partner provides a summary measure of the tendency for two actors (who are friends) to have partners in common.
Table 2. Meta-analysis Results from SAB Models for All-Girls, All-Boys, and Mixed-Gender Classes

<table>
<thead>
<tr>
<th>Variable</th>
<th>All girls (Model 1)</th>
<th>All boys (Model 2)</th>
<th>All girls (Model 3)</th>
<th>All boys (Model 4)</th>
<th>Mixed gender (Model 5)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Network function</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Outdegree</td>
<td>-.70† (.37)</td>
<td>-1.00*** (.27)</td>
<td>-.57 (.41)</td>
<td>-.99*** (.26)</td>
<td>-.95*** (.26)</td>
</tr>
<tr>
<td>Reciprocity</td>
<td>2.00*** (.16)</td>
<td>1.75*** (.15)</td>
<td>1.99*** (.15)</td>
<td>1.77*** (.16)</td>
<td>1.70*** (.14)</td>
</tr>
<tr>
<td>Transitivity (gwesp)</td>
<td>1.00*** (.20)</td>
<td>1.73*** (.15)</td>
<td>1.02*** (.23)</td>
<td>1.71*** (.17)</td>
<td>1.42*** (.14)</td>
</tr>
<tr>
<td>3-cycles</td>
<td>.11 (.14)</td>
<td>-.28*** (.07)</td>
<td>.12 (.14)</td>
<td>-.28*** (.07)</td>
<td>-.06 (.07)</td>
</tr>
<tr>
<td>Indegree popularity (sqrt)</td>
<td>-.56*** (.15)</td>
<td>-.30* (.10)</td>
<td>-.54* (.10)</td>
<td>-.33** (.07)</td>
<td>-41*** (.07)</td>
</tr>
<tr>
<td>Outdegree activity (sqrt)</td>
<td>-.20* (.10)</td>
<td>-.27*** (.11)</td>
<td>-.28* (.11)</td>
<td>-.27*** (.07)</td>
<td>-.29*** (.07)</td>
</tr>
<tr>
<td><strong>Depression</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alter (rejection)</td>
<td>.02 (.10)</td>
<td>-.03 (.07)</td>
<td>.07 (.07)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ego (withdrawal)</td>
<td>-.19* (.10)</td>
<td>.01 (.08)</td>
<td>-.02 (.06)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Similarity (homophilous choice)</td>
<td>-.07 (.37)</td>
<td>.26 (.34)</td>
<td>.15 (.25)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Male</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alter</td>
<td>-.30*** (.10)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ego</td>
<td>.19* (.10)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Similarity</td>
<td>.55*** (.09)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male × Depression Ego</td>
<td>.20† (.11)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Behavior function</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Linear shape</td>
<td>-.26* (.12)</td>
<td>-.12 (.15)</td>
<td>-.47*** (.10)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quadratic shape</td>
<td>.25 (.15)</td>
<td>.45*** (.16)</td>
<td>.16 (.13)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average similarity (peer influence)</td>
<td>.90 (1.39)</td>
<td>3.94* (1.98)</td>
<td>-.69 (1.41)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td></td>
<td>-.20 (.22)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male × Average Similarity</td>
<td></td>
<td>.44 (1.88)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Model fit</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All t ratio</td>
<td>&lt;.10 &lt;.10 &lt;.10 &lt;.10</td>
<td>&lt;.10 &lt;.10 &lt;.10 &lt;.10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall maximum convergence ratio</td>
<td>.16 .18 .16 .22</td>
<td>.22 .21</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>107 119 107 119 195</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: See Appendix E for full tabular results with control variables. Findings remain substantively the same when including those variables. SAB = stochastic actor based; gwesp = geometrically weighted edgewise shared partner; sqrt = square root.

† p < .10. *p < .05. **p < .01. ***p < .001 (two-tailed test).
transitivity is to expose girls and boys to different health risks as networks evolve into more fragmented or interconnected webs of peers. When network structures both shape and are shaped by adolescents’ depression, we expect depressed girls to become socially isolated or marginalized and the rest of the networks to be protected from peer influence of depression. We also predict that symptoms of depression will spread among boys.

Gendered Pathways toward Depression Clustering

To investigate gendered pathways toward depression clustering, we simultaneously estimated social selection and peer influence based on adolescents’ attributes while including endogenous structural forces for each network. We present models estimated with only key theoretical variables here. Results are substantively the same with or without control variables (see Appendix E in the online supplement for full results). Models 3 and 4 in Table 2 present results from the same-gender classrooms. Results from the network function are displayed at the top panel; findings from the behavior functions are in the lower part of Table 2.

Model 3 in Table 2 details the dynamics of friendship formation and depression changes among all-girls classrooms. The key finding in Model 3 is the negative and significant depression ego effect ($b = -0.19$, $p < .05$). Compared with a non-depressed girl, the odds of a depressed girl having friendship ties is 18% lower ($\exp^{-0.19} = 0.83$). Analysis further suggests that girls with higher levels of depression tend to create fewer new ties. It appears that depressed girls disengage from social relations by forgoing opportunities for social connections.

Moving to the results from the behavior function, we see the two shape terms indicate an average depression decrease ($b_{\text{linear}} = -0.26$, $p < .05$) and a tendency to push the initially nondepressed individuals to increase their depressive symptoms ($b_{\text{quadratic}} = 0.25$, ns). Importantly, the effect of average similarity of depression is not significant ($b = 0.90$, ns), providing no evidence of convergence of depression among girls. Together, results from Model 3 support Hypothesis 2, that adolescent girls are more likely to experience social marginalization (via depression withdrawal) rather than depression socialization.

In contrast, Model 4 shows no evidence of individual-level depression effects on boys’ friendships. Instead, the behavior function reveals that adolescent boys gravitated toward the average depression levels of their peers, resulting in a convergence of reported depression levels ($b = 3.94$, $p < .05$). Peer influence on depression rather than depression withdrawal

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6Classical mediation analysis (Baron and Kenny 1986) testing whether reciprocity and transitivity mediate the relationship between gender and depression isolation/socialization is not viable within the stochastic actor-based (SAB) framework. SAB models apply a generalized linear framework with continuous modeling. This means the interpretation of a reduced main effect depends on the link function transforming objective function values into actual choice probabilities and the joint distribution of all the variables needed for such a transformation. In terms of net effects on choice probabilities, a reduced main effect could still correspond to an increased choice probability, one of the peculiarities of generalized linear models. Furthermore, from a pure model-fitting perspective, an SAB model without structural effects is often poorly specified and the results are not reliable.

7The endowment function evaluates the network resulting from maintaining a tie ($b = 2.05$, $p < .01$), whereas the creation function evaluates the network from adding a tie ($b = -2.60$, $p < .01$). When combined, it suggested that depressed girls tend to create fewer new ties but also maintain the ties they do have.
or exclusion characterizes all-boys classrooms, supporting Hypothesis 3.

Findings from all-boys networks naturally raise the question, is depression convergence driven by contagion of depression or diffusion of well-being? In an attempt to answer this question, we followed prior work and generated the ego-alter influence table using coefficients obtained in Model 4 (Ripley et al. 2018).

Table 3 shows predicted likelihood under multiple scenarios that manipulate (1) ego’s current depression level (columns) and the average depression level of ego’s friends (rows). Each row corresponds to a given average depression level of ego’s friends. Comparing the different values in the row shows the relative “attractiveness” of the different values of ego’s own behavior. The maximum in each row is at the diagonal, suggesting that ego “prefers” to have the same behavior as their friends. However, the difference in the bottom row is larger than in the top row, indicating that in the case where the friends who are not depressed at all (row 1), the pressure toward imitating their behavior is less strong than in the case where all friends are depressed (row 4). It appears that friends in all-boys networks exert stronger influence in depression contagion rather than depression mitigation. It is important to note that this evidence is only suggestive, and we interpret those results with caution.

Mixed-Gender Classes and Depression Homophily

Model 5 in Table 3 details SAB results from mixed-gender classrooms. Structural effects continue to exert significant influence on network formation. Gender emerged as an important dimension along which adolescents chose friends (gender similarity, \( b = .55, p < .01 \)). With regard to depression isolation, while the interaction effect in the network function (Male Ego × Depression Ego) is in the expected direction (i.e., depressed girls are less likely than depressed boys to make friends), it only approached statistical significance (\( b = .20, p = .06 \)). We did not find evidence of peer influence of depression in mixed-gender classes. It might be that girls in these settings continue to prefer reciprocity over transitivity. As a result, networks are less interconnected. Withdrawal from networks is still plausible for depressed girls, but influence-based socialization is disrupted among boys and girls.

Simulation Experiment

Our analyses uncovered gendered network processes and gendered pathways toward depression clustering. A logical conclusion from these findings is that given depression isolation, actors in girls-like networks will be more protected from depression exposure, and that given peer influence, actors in boys-like networks will converge more toward the depression of their friends. The extent to which depression withdrawal, peer influence, and network structure influence

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### Table 3. Ego-Alter Influence Table for All-Boys Networks

<table>
<thead>
<tr>
<th>Alter (zi)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.18</td>
<td>.22</td>
<td>−.81</td>
<td>−.90</td>
</tr>
<tr>
<td>2</td>
<td>.79</td>
<td>1.61</td>
<td>.58</td>
<td>.49</td>
</tr>
<tr>
<td>3</td>
<td>−.59</td>
<td>.22</td>
<td>1.97</td>
<td>1.87</td>
</tr>
<tr>
<td>4</td>
<td>−1.99</td>
<td>−1.16</td>
<td>.58</td>
<td>3.26</td>
</tr>
</tbody>
</table>

Note: Estimates from Model 4, Table 2. Predicted likelihood or “attractiveness” under multiple scenarios that manipulate ego’s current depression level (columns) and the average depression level of ego’s friends (rows).

---

8We followed Haas and Schaefer (2014) and included the evaluation function and the endowment function of depression similarity in the behavior function. Neither coefficient was significant (evaluation, \( b = 26.65 \); endowment, \( b = −36.24, \text{ns} \)).
group-level depression is hard to isolate with our small sample of empirical networks. So, we developed a set of empirically grounded SAB simulations (adams and Schaefer 2016) to more carefully examine how friendship and depression mutually evolve in classroom networks structured like our boys’ and girls’ classrooms. In the interest of space, we summarize main findings from the simulation study here and refer readers to the online supplement (Appendix F) for details about the study design and procedures.

We simulated 900 networks in 18 conditions in a 2 (network features: girls’ style [high reciprocity, moderate transitivity]; boys’ style [moderate reciprocity, high transitivity]) by 3 (level of depression ego withdrawal: high, moderate, low) by 3 (strength of peer influence in depression: high, moderate, low) factorial design. Based on empirically grounded estimates, we then simulated two waves of network and behavior (i.e., depression) data using SAB models. We examined the resulting network fragmentation and depression prevalence across different scenarios. In summary, our simulation results showed that over time, (1) girls-like networks become more fragmented than boys-like networks, (2) increasing levels of depression ego withdrawal (like we saw among girls) dampen the increase of depression in networks with both girls-like and boys-like network features, and (3) compared to interconnected networks, fragmented networks interrupt the spread of depression, protecting the healthiest actors, as depressed actors withdraw from their networks.

DISCUSSION

How can depression simultaneously contract social interaction and contribute to larger patterns of depression contagion in networks (Hatfield et al. 1994; Howes et al. 1985; Rosenquist et al. 2011; Schaefer et al. 2011)? To address this empirical puzzle, we developed a structural argument about network conditions under which depression-based withdrawal and socialization could occur. We chose gendered networks as a context within which to examine this mechanism. Drawing on theories of depression, networks, and gender, we argue and find support that social relations built upon gendered network processes serve as catalysts for girls’ depression withdrawal and as conduits for boys’ depression (or well-being) diffusion. Our computational experiment further demonstrates that local preferences governing friendship choice influence levels of network connectivity. Network structures, coupled with depression withdrawal and peer influence, shape depression prevalence at the network level.

Our findings have both theoretical and practical implications. From a theoretical perspective, social integration has been traditionally conceptualized as a primary force that promotes solidarity (Durkheim [1897] 1921). There is also a large literature on the positive impact of social support and social integration on mental health (Pescosolido 2006; Thoits 2011). However, a body of health and social psychological literature has started to challenge this assumption by suggesting that network structures and the social processes condition the role of social relations in enticing unhealthy behaviors (Abrutyn, Mueller, and Osborne 2019). We join other network researchers (e.g., Guan and Kamo 2016; Haynie 2001; Mueller and Abrutyn 2015) and argue in this article that social ties can be toxic when relationships carry undesirable traits and that behaviors spread through greater connectivity but are contained through marginalization and fragmentation.

Our findings that girls with more depressive symptoms are socially disengaged are...
consistent with prior work that shows depression withdrawal rather than peer rejection or homophilic preference is in operation to affect friendship selection (Schaefer et al. 2011). Our study takes a step further by examining the unintended consequence of depression withdrawal: a quarantine condition where the rest of the groups are protected from exposure. With fewer connections to others, depressed girls’ social marginalization “benefits” the group as a whole. At the individual level, however, depression isolation impedes access to social support and integration to those who need it. Potentially more alarming is the fact that network effects, such as being socially isolated or having intransitive friendships, played an unusually important role in adolescent female suicidality (Bearman and Moody 2004). Given these severe consequences, selective targeting of more socially disengaged girls for interventions is highly warranted.

The story for boys is different. Prior research shows that boys are influenced by their friends’ depressive symptoms and suicide attempts (Cheadle and Goosby 2012; Hogue and Steinberg 1995; Liu 2006). Our empirical and simulation results further suggest that the convergence of depressive symptoms among boys is likely a result of both depression and well-being diffusion. Perhaps, friendships fostered by shared activities lead to cohesive network structures. This, in turn, creates strong group norms that make individuals more vulnerable to behaviors pervasive in the groups.

Of note are some of the ways in which the patterns described here differ superficially from findings from adolescent suicide literature. Using data from Add Health, researchers find adolescents are more vulnerable than boys to friends’ and family’s suicide suggestions (Abrutyn and Mueller 2014; Mueller and Abrutyn 2015). It is plausible that differences in survey instruments (i.e., “good friends” in our study vs. “best friends” in Add Health) and modeling techniques have contributed to inconsistencies in our findings. With the “good friends” name generator and the aggregated peer influence measure in the SAB models, we are investigating whether adolescents gravitated toward the average depression level of all friends nominated. Thus, peer influence in our study captures group culture, whereas in suicide studies with Add Health data, it can be conceptualized as a strong dose from at least one best friend (Add Health measures friend suicide attempt by asking adolescents, “Have any of your (best) friends tried to kill themselves during the past 12 months?” and by asking adolescents’ best friends, “During the past 12 months, how many times did you actually attempt suicide?”). Relatedly, Abrutyn and Mueller (2014) link ego’s report of a best friend’s suicide attempt with their reports of their own suicide thoughts and fail to find a link between alters’ suicide attempts that were not reported by the respondents and respondents’ own ideation (Mueller and Abrutyn 2015). Our analyses link alters’ own depression reports with egos’ own depression reports, making it closer to other studies we reviewed that found greater contagion among boys than among girls. Finally, the cultural context in these Taiwanese classrooms may differ from that of the Add Health data in ways that account for these apparent differences. For example, we note that the period of time that we are studying in these classrooms is one of intense academic competition leading to considerable stress. It may well be that this competition is more keenly experienced by boys than girls and leads to a heightened sensitivity to friends’ depression/well-being among boys compared to girls.

We want to end by noting some limitations of our approach. To begin, although our argument is about how structures of
networks facilitate or constrain depression withdrawal and diffusion (and our empirical findings lend support to this argument), an alternative explanation focusing on gendered responses to depressive symptoms is also plausible. Previous studies show that depressed girls display greater propensity to self-quarantine than depressed boys and relationships among boys are more robust in the face of depressive symptoms (Pachucki et al. 2015). It is impossible to distinguish fully the gendered account from our structural account with current data. A future study where researchers compare network behaviors of depressed boys and girls embedded in the same network structure would be fruitful. An important task going forward is to examine the extent to which each mechanism contributes to the gendered pathway toward depression clustering.

Our analysis also provides little insight into the nature and motives of depression convergence. Transmission of depression could be the product of peers’ creation of a shared environment, which in turn facilitates similar emotional reactions to the same experiences. Or it may be that adolescents accommodate to their friends’ style of emotionally responding to events. It is possible that depressed boys are discouraged/prohibited from expressing weak emotions (e.g., sadness) given the gendered stereotype on emotionality (Shields 2002). Any observed depression mitigation might be the result of emotion policing among boys. Detailed behavioral observations using laboratory or ethnographic methodologies may be necessary to uncover these processual mechanisms.

Finally, our simulation approach differs from previous SAB simulation studies (e.g., Adams and Scheafer 2016) in that we relied on a set of simulated, rather than empirically observed, networks as the baseline condition. While this approach has the advantages of fixing associations between depression prevalence and other factors (e.g., popularity) constant and providing the optimal balance of generality, realism, fit, and precision (Ip et al. 2013; Squazzoni 2012), it is plausible that unobserved/unspecified associations between depression and other contextual characteristics may affect the processes we investigate. Future studies should explore alternative strategies for setting initial conditions that rely on different assumptions.

The processes uncovered in this article likely apply to other social systems that are structurally distinct—with one group operating in more compartmentalized networks and the other group operating within more inclusive, stable networks. Future scholarship should also adopt a framework that treats friendships as dynamic in nature and applies methodologies that are sensitive to the various processes that give rise to opposite mental health outcomes depending on network structure.

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SUPPLEMENTAL MATERIAL

Supplemental material for this article is available online.
REFERENCES


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