Do friends matter for adolescent depression? A longitudinal social network analysis

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Abstract

Background: Research efforts tend to focus on inherited and environmental familial factors for adolescent depression, but recent evidence suggests that peer relations may also play a role. Longitudinal studies are needed to confirm this and extend our understanding of ways that friends affect each other's depression symptoms. This study investigated assimilation and contagion as potential processes through which adolescent friends affect each other's depression and examined whether these processes were moderated by gender and friends' popularity. The effect of impulsivity on depression was also investigated, and moderation by gender was tested. **Methods:** We performed longitudinal social network analyses on 1114 ninth grade students from seven secondary schools in London, United Kingdom. Participants were assessed four times, every 6-month starting at age 14. Past six-month depression was assessed using self-reports on the Brief Symptoms Inventory's Depression subscale and categorized into four levels. **Results:** Consistent with an assimilation process, adolescents' depressive symptoms were likely to increase or decrease over time so as to become more similar to their friends'. For instance, in a hypothetical adolescent whose friends all presented higher depression levels than himself, the odds of an increase was estimated at exp(1.45/3)=1.62. Consistent with a contagion process, participants whose friends presented higher depression levels tended to see their own depression levels increase. Comparing two hypothetical adolescents distinguished only in that the friends of the first presented depression levels that were on average one point higher than the friends of the second, our results suggested that the odds of an increase would be exp(0.44)=1.55 times higher for the first adolescent. Friends' popularity, but not gender, moderated the influence of friends on participants' depression symptoms. Impulsivity was associated with increased depression symptoms over time, especially in females. **Conclusion:** This research is the first to provide evidence that both interpersonal processes of assimilation and contagion may play a role in adolescent depression. Results stress the need for studies examining the role of proximate social, emotional and cognitive mechanisms implicated in the link between peer relations and adolescent depression.

Keywords: Depression, adolescence, social networks

Depression figures among the ten most important diseases of the global disease burden (Lopez, Mathers, Ezzati, Jamison, & Murray, 2006) affecting over 350 million people worldwide (WHO, 2012). Onset often occurs during adolescence (Pine, Cohen, Gurley, Brook, & Ma, 1998), with potentially severe consequences such as lower educational attainment (Gibb, Fergusson, & Horwood, 2010), impaired social relations (Gibb et al., 2010), direct self-injurious behavior (Brunner et al., 2014) and increased risk of obesity (Marmorstein, Iacono, & Legrand, 2014) and suicide (Gibb et al., 2010). Inherited and environmental familial factors, as well as psychosocial factors are associated with risk for depression (Happonen et al., 2002; Thapar, Collishaw, Pine, & Thapar, 2012). Among the latter, friendships likely constitute an important context for adolescent depression given youths' increased involvement with friends during this age period (Petersen, 1988).

Evidence of influence effects from friends' depression symptoms

In recent years, several longitudinal studies have shown that friends' depression symptoms may affect adolescents' own depressed mood (Brendgen, Lamarche, Wanner, & Vitaro, 2010; Cheadle & Goosby, 2012; Conway, Rancourt, Adelman, Burk, & Prinstein, 2011; Kiuru, Burk, Laursen, Nurmi, & Salmela-Aro, 2012; Van Zalk, Kerr, Branje, Stattin, & Meeus, 2010a, 2010b). A study on early adolescents found that youth who had depressed friends presented more elevated depression trajectories than friendless youths (Brendgen et al., 2010). Using data from a large, nationally representative sample on youth from grades 7 to 12, Reynolds and Crea (2015) also provided evidence of influence from friends' depression symptoms, albeit weak. In a study on the transition period to adolescence, the average levels of depression symptoms within friendship groups were positively related to youths' own depression symptoms (Conway et al., 2011).

A few studies have recently used stochastic actor-based (SAB) models (Snijders, van de Bunt, & Steglich, 2010) to examine the socialization of friends' depression during adolescence. These models have the distinctive advantage of adequately controlling for selection effects, as well as structural network effects (Steglich, Snijders, & Pearson, 2010). Two such studies conducted on a large community-based network of adolescents in Sweden showed that adolescents influence each other's depression symptoms (Van Zalk et al., 2010a, 2010b). This effect was most salient within friendships from outside school (Van Zalk et al., 2010a) and was mediated by failure anticipation (Van Zalk et al., 2010b). Giletta et al. (2012) reported evidence of depression influence for their sample of Italian

adolescents, but it was limited to best friendships between girls. Research by Kiuru et al. (2012) and Cheadle and Goosby (2012) also found that friends influence one another's depressive symptoms.

However, contradictory results emerge from two studies using SAB models. Fortuin et al. (2014) found a marginal effect of peers' internalizing symptoms over adolescents' own internalizing symptoms. Substantial differences in measures and controls used may help explain why, contrary to other studies, the results were only marginal. The measure of internalized problems included items on anxiety, depression and psychosomatic symptoms. The network measures were nominations of classmates whom the participants appreciated, thus these relationships may not have been intimate enough for discussions regarding internalized problems to occur. In addition, the study controlled for several externalizing behaviors (e.g. lying, fighting with a teacher, bullying another student), which may have contribute to reduced significance because common factors may contribute to both types of problems. Pachucki, Ozer, Barrat, and Cattuto (2015) found no evidence of influence from depression symptoms between early adolescents who interacted at school over a three months period. Again, differing methodologies may contribute to explain this divergent result. Baseline depression symptoms were low and may not have sufficiently changed over time for a socialization effect to occur.

Potential explanatory mechanisms of influence from friends' depressive symptoms

Several mechanisms may explain the influence from friends' depressive symptoms. Depressed people may, as a result of their attitudes and behaviors, induce negative affect in significant others (Coyne, 1976). Empathizing with a depressed person may lead to experiencing some of their negative affect (Hatfield, Rapson, & Le, 2011). Co-rumination, i.e. excessive discussion of problems, is associated with increased depression symptoms among adolescents (Hankin, Stone, & Wright, 2010; A. J. Rose, Carlson, & Waller, 2007; Schwartz-Mette & Rose, 2012; Stone, Hankin, Gibb, & Abela, 2011) (see however Starr and Davila (2009) and Dirghangi et al. (2015) for exceptions). Support dynamics within a relationship may be affected when one partner is depressive: providing support to depressed persons may be emotionally taxing and at the same time, depression may prevent them from supporting their partner when needed (Joiner & Katz, 1999). Individuals may also tend to mimic and synchronize their emotional expressions with those of relationship partners (Hatfield, Cacioppo, & Rapson, 1993) or integrate their appraisal style (Smith, Haynes, Lazarus, & Pope, 1993). In both cases, the result may be increased similarity between partners' depression levels. Another possible mechanism is adolescents'

tendency to conform to peer group norms regarding behaviors and emotions displays (Erikson, 1968; Newman & Newman, 1976), which may eventually lead to increased similarity between groups members, i.e. assimilation (Harris, 1995). Lastly, some researchers suggest that friends may protect against depression through social support (Herman-Stahl & Petersen, 1996), by buffering the impact of adverse life experiences (Rothon, Head, Klineberg, & Stansfeld, 2011) or by providing opportunities for pleasant experiences (Kiuru et al., 2012). These mental health benefits may be especially likely to occur within friendship networks where depressive symptoms generally tend to be low.

Overall, relatively few studies have used longitudinal social network analysis to investigate processes and moderators of depression symptoms socialization. In addition, while research results are generally consistent with a socialization effect, some diverging results exist and comparability between studies is limited by differences in research methodologies (e.g. measures of networks and depressive symptoms, controls used, developmental period). More research is thus needed to more definitely establish the existence of a socialization effect and better understand the context within which it occurs.

The present study

Contagion and assimilation

The present study contributes to a better understanding of adolescent depression in three ways. First, building on previous work (Kiuru et al., 2012), we examine two processes of depression symptoms socialization, namely contagion and assimilation. Distinguishing between these is informative because they assume different pathways of socialization. Contagion assumes a direct, unidirectional effect, i.e. worsening of depressive symptoms in adolescents whose friends present more severe symptoms. In other words, the symptoms of the less depressed members of a friendship network increase over time, thereby becoming closer to those of their more depressed friends. Underlying the assimilation concept is the premise that youth change their behaviors and attitudes to become more similar to the majority (Harris, 1995). Assimilation, then, considers two potential socialization pathways. For adolescents who present low levels of symptoms, membership in a network where symptoms levels are on average relatively high may in the long run contribute to increased symptoms. However, the opposite is also

conceivable: membership in a friendship network where symptoms are on average relatively low may contribute to decreased symptoms in adolescents who previously presented higher symptoms levels.

Several studies are consistent with the idea that adolescents tend to assimilate to their friends' depression symptoms (Cheadle & Goosby, 2012; Fortuin et al., 2014; Giletta et al., 2012; Kiuru et al., 2012; Van Zalk et al., 2010a, 2010b), thus the same is expected for the present research. Two studies tested for a contagion effect (Kiuru et al., 2012; Pachucki et al., 2015), neither of which confirmed it, but this may be partly due to features of the data used. In both studies, the network measures did not necessarily entail close relationships, which means that participants may not have been intimate enough to discuss topics pertaining to their mental state, or observe signs of distress in other members of their networks. The sample of one study (Kiuru et al., 2012) was composed of late adolescents (mean age=16), but influence processes tend to be more salient among younger individuals (Steinberg & Monahan, 2007). In the other study, low levels of depression among study participants may have contributed to the non-significant contagion effect (Pachucki et al., 2015). The dataset used for the present study may enable us to detect a contagion process because it covers a longer time interval points than previous studies, including a potentially sensitive period for depression socialization. Indeed, with a mean age of 14 at outset, influence effects are potentially strong. In addition, depression symptoms tend to increase during early adolescence (Brendgen et al., 2010; Buck & Dix, 2012; Cicchetti & Toth, 1998; Petersen et al., 1993), thus levels of depression in our sample are likely to be sufficiently elevated to detect a contagion effect.

Moderation by gender and friends' popularity

We investigate potential moderators of peer relations' effect, i.e. gender and friends' popularity. Girls tend to co-ruminate more than boys (Hankin et al., 2010; Rose, 2002; Rose et al., 2007; Smith & Rose, 2011) and the impact of co-rumination on depression may be stronger among them (Rose et al., 2007). However, these tendencies could be counteracted by higher levels of emotional support among females (Rose & Rudolph, 2006). Having at least one close friend has been associated with reduced risk for depression in genetically vulnerable girls (Brendgen et al., 2013). Boys' friendships tend to revolve around activities, providing occasions for pleasant experiences that may promote better moods (Rose, 2002). In addition, boys may limit displays of emotions such as sadness and anger for fear of social sanction (Zeman & Shipman, 1997), thus the socialization of depression may be weaker among them.

Current evidence is mixed regarding gender differences in the influence from friends' depression symptoms. While some researchers show significant effects limited to boys' networks (Cheadle & Goosby, 2012), others conclude that girls are more susceptible to the effect of peer relations (Conway et al., 2011; Giletta et al., 2012; Van Zalk et al., 2010b) or fail to uncover gender differences (Kiuru et al., 2012). Given inconsistent evidence, we refrain from formulating a specific hypothesis regarding the relative strength of this effect among girls and boys.

Popular friends may be more influential than less popular ones, but research on the moderating role of friends' popularity on the effect of peer relations is scarce. Evidence exists for problems such as alcohol use and delinquent behavior (Laursen, Hafen, Kerr, & Stattin, 2012). To our knowledge, only one study is available on adolescent depression; results showed a positive association between friends' peer-perceived popularity and susceptibility to depression contagion (Prinstein, 2007). While some researchers used measures of relative popularity, where popularity status was assigned according to relative scores within dyads (Laursen et al., 2012), others relied on absolute measures, i.e. peer-perceived popularity (Prinstein, 2007). The current study analyzes the number of friendship nominations, an absolute measure of friends' popularity that is not perception-based. Socialization processes may be moderated by friends' popularity if, for instance, adolescents are more prone to mimic and synchronize their emotional expressions to those of higher status friends, such as popular ones. Thus, we hypothesize that friends' popularity will be associated with higher levels of depression symptoms socialization.

Impulsivity, depression and gender

Finally, the effect of impulsivity on depression is tested, as well as moderation by gender of this effect. Impulsivity is characterized by lack of premeditation and perseverance, as well as a sense of urgency and propensity towards sensation-seeking (Whiteside & Lynam, 2001). Previous research has found links between impulsivity and depression in children (Cosi, Hernandez-Martinez, Canals, & Vigil-Colet, 2011) adolescents (d'Acremont & Van der Linden, 2007; Dussault, Brendgen, Vitaro, Wanner, & Tremblay, 2011) and adults (Clarke, 2011; Granö et al., 2007). For instance, a study of male adolescents from low SES areas found that impulsivity at age 14 predicted depression symptoms at age 17 (Dussault et al., 2011). Work by d'Acremont and Van der Linden (2007) on adolescents also found an association between impulsivity and depression, which was moderated by the appropriateness of

emotion regulation strategies. In addition, a study of an adult sample found that impulsive participants were 1.7 more likely to have been recently diagnosed with depression (Granö et al., 2007). Impulsivity has been associated with increased risk for suicide in major depressive disorder patients (Perroud, Baud, Mouthon, Courtet, & Malafosse, 2011). In addition, impulsivity and depressive episodes are observed in borderline personality disorder patients (Leichsenring, Leibing, Kruse, New, & Leweke, 2011).

Various explanations for the association between impulsivity and depression have been put forward. Impulsive individuals may experience more negative life events due to their impulsivity (Granö et al., 2007). Alternatively, poor emotion regulation strategies among impulsive individuals may put them at risk for depression (d'Acremont & Van der Linden, 2007). It is also possible that difficulties in anticipating consequences and planning actions impair the capacity of impulsive individuals to successfully navigate stressful life events (Clarke, 2011). Biological factors may also play a role in risk for both depression and high impulsivity (Cremniter et al., 1999; Spreux-Varoquaux et al., 2001).

Impulsivity appears to be gender-typed. From an early age, girls are on average better at self-regulation (Chapple & Johnson, 2007; Matthews, Ponitz, & Morrison, 2009). Evidence from research on gender and mental disorders suggests that the impact of high impulsivity may be worse in females. Individuals of the gender with the lowest prevalence of a disorder may experience greater impairment than individuals of the gender with the greater prevalence of the disorder (Eme, 1992). Evidence of this gender paradox exists for various disorders, among which are ADHD (Chronis-Tuscano et al., 2010; Elkins, Malone, Keyes, Iacono, & McGue, 2011) and conduct disorders (Keenan, Loeber, & Green, 1999). One potential explanation for this phenomenon is gender role violation. The behaviors typically associated with these disorders may be expected and more readily accepted in males. As a result, when displayed by females they may be associated with worse outcomes if, for example, they are met with harsher reprimand from educators or disapproval from peers.

Our study is one of the few to examine the effect of impulsivity on depression and moderation by gender. To the best of our knowledge, it is the first to do so using social network analysis. This allows an estimation of the effect of impulsivity net of the impact of potentially confounding links between impulsivity, peer relations and depression. Impulsive adolescents may indeed tend to form friendships with other impulsive youth as a result of shared tendencies to engage in substance use and gambling;

earlier studies have found these risk-taking to be associated with impulsivity in adolescents (Leeman, Hoff, Krishnan-Sarin, Patock-Peckham, & Potenza, 2014; Vitaro, Ferland, Jacques, & Ladouceur, 1998). Based on results from previous research, we hypothesize that impulsivity will be associated with increased depression symptoms, and that this effect will be stronger for females.

Methods

Participants and procedure

Participants were all year-nine students within seven schools located in London, selected from a pool of 21 schools participating in a wider clinical trial study on the effects of a school-based prevention program to reduce substance misuse (O'Leary-Barrett, Mackie, Castellanos-Ryan, Al-Khudhairy, & Conrod, 2010; O'Leary-Barrett et al., 2013). Eleven schools were excluded because they failed to meet data requirement for SAB models, i.e. at most 20% missing cases (Ripley, Snijders, Boda, Vörös, & Preciado, 2014). One school was excluded because it was single sex, making it unsuitable for the analysis of gender as a moderator of peer relations' effects. Another school was excluded because it could not commit to the full trial, and a last school withdrew from the study after baseline.

Participants filled a self-administered questionnaire during school hours on five occasions at six-month intervals. Participation was informed by passive consent from parents and active assent from students. Network data collection began at the second wave, in Spring 2008, thus the last four waves are used. After excluding unreliable cases based on inconsistency of responses across the survey or positive response to a sham item (n=249), 1114 adolescents had at least one data point. The sample size ranged from 1050 participants at time 1 to 970 at time 4. Of all participants, 46.8% were female and 45.2% were white. Mean age was 14.3 years at the first data point used.

Attrition was predicted by male gender (p=.001) and higher levels of conduct problems (p=.001). However, depression symptoms at baseline did not predict attrition, nor did several other indicators (anxiety symptoms at baseline, ethnicity, socioeconomic status and personality). Missing data on covariates and on friendship nominations were handled using the imputation method provided in the Siena (Simulation Investigation for Empirical Network Analyses) *R* module employed for data analyses (Ripley et al., 2014; Steglich et al., 2010).

Measures

Depression symptoms. Depression symptoms were measured using the Depression subscale from the Brief Symptoms Inventory (Derogatis, 1993). Participants were asked to rate the extent to which they had experienced depression symptoms over the past six months on a five point scale (*not at all*, *a little bit*, *moderately*, *quite a bit*, *often*). Seven items were used: "*Feeling sad", "Feeling lonely", "Feeling no interest in things", "Feeling hopeless about the future"*, "*Feelings of worthlessness*", "*Your feelings being easily hurt*" and "*Thoughts of ending your life"*. Scores were computed by summing items. Based on published guidelines (Derogatis, 1993), between 7.8% and 9% of participants fell within the abnormal range (Cronbach α = 0.85 and 0.92 across time points). SAB models require transformation of continuous behavioral outcomes into ordinal variables (Snijders et al., 2010), hence scores were categorized using as cut-off points increments of 1 around the mean of the z-scores (lowest through 0=1; 0 through 1=2; 1 through 2=3; 2 through highest=4).

Impulsivity. Impulsivity levels were assessed using the Substance Use Risk Profile Scale (SURPS) personality inventory (see Woicik, Stewart, Pihl, and Conrod (2009) for a detailed description of the SURPS). Participants were asked to rate the extent to which they agreed with statements regarding impulsivity on a four point scale (*Strongly disagree, Disagree, Agree, Strongly agree*). Five items were used, for instance: "*I often don't think things through before I speak"; "I often involve myself in situations that I later regret being involved in"; "I usually act without stopping to think".* An impulsivity score was computed by summing items (Cronbach α = 0.70 and 0.76 across time points).

Demographics. Participants provided information on gender (boy=0, girl=1) and ethnicity (non-white=0, white=1) using a multiple-choice procedure. The original ethnicity indicator comprised several categories (e.g. "White – British", "White – Other", "Mixed – White and Black African", etc.). Recoding it into a dichotomous variable was deemed sufficient because the intent was to control for inclinations to select friends sharing the same ethnic background.

Network data. Friends nominations were collected by asking participants to name up to five school friends within their year. Each of the seven schools studied constitutes a network, with sizes ranging from 108 to 209 (mean=163).

Statistical analysis

Examining the effects of peer relations on depression can be done by assessing how adolescents' depressive symptoms change as a function of their friends' own symptoms. SAB models implemented in the RSiena package allow this by simultaneously modeling the evolution of friendship networks and depressive symptoms. Changes in depressive symptoms and friendship ties are conditional on one another in the analysis and potential confounders, such as selection and network structure, can be controlled (Ripley et al., 2014; Snijders et al., 2010; Steglich et al., 2010). The parameters used for the estimation represent probabilities for specific types of changes in network and depressive symptoms.

The focal parameter *assimilation*, measured using the SIENA effects *average similarity*, expressed the tendency for adolescents to see their depression levels increase or decrease so as to become more similar to their friends'. The focal parameter *contagion* (SIENA effects *average alter)* captured the tendency for adolescents whose friends presented higher depression levels to see their own levels increase. The focal parameter *assimilation x female* operationalized the moderating effect of being female on susceptibility to depression assimilation. The interaction term *assimilation x friends' popularity* operationalized the moderating effect of friends' popularity, expressing the increased tendency for adolescents whose friends received more friendship nominations to present depression levels that were similar to their friends'. The *impulsivity* parameter and the interaction term *impulsivity x female* respectively captured the main effect of impulsivity on depression and the impact of being female on this effect.

In addition to the focal parameters, four more effects were added to the depression dynamics part of the model. *Depression linear shape* accounted for the tendency towards higher levels of depression in the network. The *depression quadratic shape* captured feedback effects of depression levels at previous time points. A positive estimate indicated a reinforcing tendency: the higher adolescents' depression levels, the more likely they were to increase subsequently. A negative effect implied a self-correcting tendency: the higher adolescents' depression levels at previous time points, the less likely they were to worsen. Taken together, the linear and quadratic effects capture individual tendencies and as such, they must be included in all SIENA network and behavior co-evolution models. The *effect from being female* parameter captured gender differences in depression levels during adolescence (Hyde, Mezulis, & Abramson, 2008; Silberg et al., 1999). *Baseline depression*, which was collected at

wave 1 (six months prior to the first data points used to model network and depression symptoms co-evolution), was added to control for baseline heterogeneity on depression symptoms. In SAB models, at any point in time the probabilities of change depend on the current state of depression symptoms among network members, which leaves unaddressed the potential bias that may result from differences between participants in depression symptoms prior to the observation period.

To avoid bias in the focal parameters, several parameters were used to account for selection effects, structural network effects and covariate effects. Controlling for selection was necessary because similarity on depression levels can be due not only to the effect of peer relations, but also to a tendency in adolescents to choose friends who present similar depression levels (Cheadle & Goosby, 2012; Giletta et al., 2012; Kiuru et al., 2012; Schaefer, Kornienko, & Fox, 2011; Van Zalk et al., 2010a, 2010b). Three parameters were added to adjust for this potential confounder. The *depression ego* and *depression alter* effects respectively captured the extent to which higher depression levels were associated with higher numbers of given and received nominations. The *depression similarity* parameter indicated whether adolescents who presented similar depression levels were more likely to be friends.

Structural network effects captured general dynamics that induced changes in friendship networks. Decisions on which specific structural effects to include were based on a combination of prior knowledge of adolescent friendship networks, (Veenstra, Dijkstra, Steglich, & Van Zalk, 2013) possibility of confounding effects with depression-related selection effects, results of score type tests and fit indices. *Outdegree* accounted for the basic tendency to nominate friends. Similar to an intercept, this effect is included in all SAB models (Veenstra & Steglich, 2012). *Reciprocity* accounted for the tendency to reciprocate friendships. Transitivity, i.e. the tendency towards clustering within networks, was modeled using two effects*, transitive triplets* and *two-paths* effects. These respectively captured the tendencies to nominate friends of friends and, oppositely, to refrain from nominating friends of friends. *Popularity* measured the tendency of adolescents who received many friendship nominations to receive extra nominations. The effects of reciprocity, transitivity and popularity may have varied according to depression symptoms levels. Reciprocity may have been lower among adolescent who presented high levels of depression symptoms if they tended to withdraw from social interactions, as suggested by Schaefer, Kornienko and Fox (2011). Transitivity may also have been

weaker among depressive youth if they tended to occupy the periphery of the network as a result of withdrawal or exclusion from others. Depressive symptoms may have made adolescents less attractive as friends and as a result, depressive youth may have been less popular. *Activity* accounted for the tendency of adolescents who nominated many friends to nominate extra friends. The *zero outdegree* effect accounted for the tendency to refrain from nominating friends. It was added to improve the representation of the outdegree distribution. Time heterogeneity was detected for *outdegree*, *reciprocity* and *zero outdegree* effects. Therefore, as recommended in Lospinoso, Schweinberger, Snijders, and Ripley (2011), time dummies were added for relevant time periods.

Three parameters were used to account for the effect of each covariate (i.e. gender, ethnicity and impulsivity) on friend selection: *ego* effects measured whether adolescents with higher values tended to nominate more friends, *alter* effects measured whether actors with higher scores on the covariate tended to receive more nominations and *similarity* effects (or *same* effects, for dichotomous covariates) captured the tendency to select friends with similar value on the covariates.

Finally, network and behavior rate parameters for each period were also added. They are required in all SAB models to indicate the number of opportunities for change in network and behavior for each participant. As such, these estimates could not take a value of zero, thus testing that they were different from zero was senseless and as a result, no *P*-value was given for them (Snijders et al., 2010).

A series of six models were estimated. For each model we first ran separate, identical analysis for each school. Then, estimates obtained for each school were combined into meta-analyses (Ripley et al., 2014; Snijders et al., 2010). The first and second models assessed the basic contagion and assimilation effects. Separate analyses for these alternative processes were necessary because of high correlations in the SIENA effects measuring each process. The net effect of gender on depression symptoms was estimated in the third model. In the fourth and fifth models, the effects of gender, then friends' popularity as moderators of depression assimilation were tested. Our intent was to test gender as moderator of both assimilation and contagion, but we were unable to do so because of convergence problems. SIENA does not currently allow testing the effect of friends' popularity as a moderator of depression contagion, hence we were only able to test for depression symptoms assimilation. The last model assessed the effect of impulsivity and the moderating impact of gender on impulsivity.

Results

Descriptive statistics of networks by wave are presented in table 1. Network densities (the proportions of existing ties among all possible ties) were low, ranging from 0.8% to 2.7%. Average degrees indicate that participants nominated on average between 1 and 3 friends. The proportion of reciprocated friendship nominations varied widely across networks and data points, ranging from 20.1% to 41.5%.

(Insert table 1 here)

Table 2 presents statistics on network and depressive symptoms changes by period. In all but one case, Jaccard indices were above the 20% threshold, indicating sufficient stability in the network for SIENA analysis (Ripley et al., 2014). Hamming distances showed large numbers of tie changes across waves and there were substantial numbers of changes in depression symptoms over time, providing confidence that enough variation across waves existed for our research purposes.

(Insert table 2 here)

For each effect, table 3 presents mean estimates across schools and standard errors. More detailed results including rate parameters, network variables added to improve model fit and time dummy variables are available in online supplement S1. With respect to model fit, indices attested to adequate representation of indegrees, outdegrees and depression symptoms distribution.

(Insert table 3 here)

Depression symptoms dynamics: control effects

Control effects for depression symptoms dynamics are presented in the top portion of table 3. Participants generally tended to score below the midpoint of the scale (*linear shape* estimate). Adolescents who reported more severe symptoms at a previous time point were more likely to see their symptoms worsen over time (*quadratic shape* estimate) than previously less depressed participants. Adolescents who presented worse depression symptoms and females were more likely to see their depression levels increase over time (*baseline depression* and *effect from being female* estimates).

Depression symptoms dynamics: socialization and moderation effects

Results from model 1 were consistent with a contagion effect of depression symptoms within friendships networks (β=0.44, SE=0.11, P =.01). One way to understand this result in a more concrete fashion is by comparing two hypothetical adolescents, who would differ only in that the friends of the first would present depression levels on average one point higher than the friends of the second. Applied to our result, this hypothetical situation would translate in odds of increased depression symptoms that would be 1.55 times higher (exp(0.44)=1.55) for the first adolescent than for the second. Additional verifications revealed that the effect of contagion slightly decreased from 0.44 to 0.30 and became marginally significant upon adding the effect from being female parameter, and was unaffected by the further inclusion of the effect from impulsivity and impulsivity x female parameters.

As shown in model 2, the results were also consistent with an assimilation effect of depression symptoms within the networks (β=1.45, SE=0.35, P=.006). The assimilation parameter expressed the log odds of the largest possible change which, on the four point scale used here, corresponded to a three points change. Therefore, in a hypothetical adolescent whose friends all presented worse depression symptoms than him, the odds of an increase in depression levels was estimated at exp(1.45/3)=1.62.

The effect from being female was tested in model 3. Results revealed that being female was associated with higher odds of increased depression symptoms over the observation period (β=0.52, SE=0.04, P<.001). Once the effect from being female was taken into account, the assimilation effect decreased from 1.45 to 1.11, but remained significant. There was, however, no evidence in model 4 that the assimilation of depression symptoms within the friendship networks was moderated by gender (β=0.72, SE=0.96, P=.487). In model 5, contrary to expectations, friends' popularity was negatively related to depression symptoms assimilation (β=-0.35, SE=0.13, P=.038). Potential explanations for this unexpected finding are offered in the discussion.

Depression dynamics: effect from impulsivity

The results from model 6 showed that adolescents' impulsivity was associated with higher odds of increasing depression levels over time, but the effect was marginally significant (β=0.04, SE=0.02, P=.091). In addition, the impact of impulsivity on the odds of increasing depression levels was stronger

for females, as suggested by the positive, significant interaction term impulsivity x female (β=0.04, SE=0.02, P=.040).

Network dynamics: structural effects

Structural effects for network dynamics are presented at the bottom of table 3. The positive *outdegree* estimate indicated a general tendency to nominate friends, over and above the effect of the remaining network and covariate effects. Adolescents tended to reciprocate friendship nominations and to form clusters (*transitive triplets* and *distance two* estimates) within the networks. Popularity slightly increased the odds of future nominations (*indegree popularity* estimate). Adolescents who had already nominated many friends were less likely to subsequently create new friendships (*outdegree activity* estimate).

Network dynamics: selection and covariate effects

Participants tended to nominate friends of the same gender and ethnicity (*same gender* and *same ethnicity* estimates). There was a marginal tendency for adolescents to select friends who presented similar depression levels (*depression similarity* estimate). Females received and gave slightly more nominations than males, but the weak effects were not consistently significant across models (*female alter* and *female ego* estimates). Adolescents who presented higher levels of depressive symptoms gave slightly more nominations (*depression alter* estimate). There was no evidence of selection based on depression similarity (*depression similarity* estimate). However, participants had a tendency to nominate friends who has similar impulsivity scores as themselves (*impulsivity similarity* estimate).

Discussion

The first goal of this study was to examine the roles of contagion and assimilation as potential processes through which friends may affect each other's depression symptoms during adolescence. Consistent with a contagion process, having friends who presented higher depression symptoms was associated with stronger odds of increased symptoms over time. Adolescents also tended to see their depression levels change and become more similar to their friends', consistent with an assimilation process. Our study is the first to provide evidence that both interpersonal processes may play a role in adolescent depression. Previous studies examining both processes either found results consistent only with assimilation (Kiuru et al., 2012) or found evidence of neither process (Pachucki et al., 2015).

The second contribution of this study was the investigation of friends' popularity and gender as potential moderators of depression symptoms socialization. No gender difference was found on susceptibility to friends' influence. Nevertheless, we cannot exclude the possibility that opposite effects operated simultaneously and cancelled each other with respect to depression assimilation among adolescent girls. For instance, girls may have received more emotional support from friends than boys (Rose & Rudolph, 2006), which may have helped alleviate depression symptoms, while their higher propensity to co-ruminate (Rose, 2002; Rose et al., 2007; Smith & Rose, 2011) may simultaneously have aggravated depressive symptoms.

Our results revealed that friends' popularity moderated the effect of peer relations on depression levels, but the effect was negative, contrary to expectations derived from the one other study available on this topic (Prinstein, 2007). Hence, belonging to a friendship network composed of popular adolescents was associated with weaker depressive symptoms assimilation. We can only speculate about potential explanations for this unexpected finding. Our measure of popularity, i.e. number of friendship nominations, was not an optimal measure of social status within the network. The positive effect revealed in Prinstein (2007) was based on a measure of friends' *peer-perceived* popularity, which perhaps more effectively accounted for their social status. Instead, our measure may have partly captured a tendency for interactions in highly connected friendship networks to be more superficial and therefore, perhaps less conducive to depression symptoms socialization. Alternatively, unmeasured characteristics of individuals who tend to choose as friends highly connected peers and that make them less susceptible to depression socialization may account for this unexpected result.

Lastly, we assessed the effect of impulsivity on average depression levels and examined the extent to which it differed by gender. Results showed that impulsivity was associated with increased odds of depression symptoms intensification over time and this effect was stronger for females. Our findings are thus consistent with the gender paradox hypothesis in relation to impulsivity. That is, the effect of impulsivity, a characteristic most commonly associated with males, has more detrimental effects in females than males. It should be noted, however, that the main effect of impulsivity was marginally significant. More research is thus needed to confirm these tentative findings.

Limitation, strengths and conclusion

Some limitations of this research need to be acknowledged. Analyses were conducted on a small subsample of schools, thus results may not generalize to other adolescent friendship networks. Nominations were limited to same-year school friends, which may have resulted in an under-estimation of selection and influence effects with respect to depression. Indeed, previous findings indicate stronger effects within friendships outside of school (Van Zalk et al., 2010a). High correlations between measures of assimilation and contagion processes prevented simultaneous tests within a single model, making us unable to assess their importance relative to one another. Some assumptions inherent to SAB models may have been somewhat unrealistic. For instance, the assumptions that participants knew of all existing relations within their network and purposely chose friendships seemed rather far-fetched, particularly when applied to larger networks. Nevertheless, SAB models are currently the sole available method that allows estimating the effect of peer relations on adolescent depression while adequately controlling for adolescents' tendencies to select friends who present similar depression levels. Only a few studies have been conducted using this sophisticated method. Our study was also among the few to examine gender and friends' popularity as moderators of the effect of peer relations. The data used contained more waves and shorter measurement intervals than most previous studies, and covered a sensitive developmental period for the various mechanisms involved. Finally, models were carefully built based on prior knowledge of adolescents networks and using fit indices that are seldom used, having only recently become available in SIENA (Huitsing, Snijders, Van Duijn, & Veenstra, 2014)

Overall, our findings suggest that friendship networks affect adolescent depression. We cannot tell from the present data which specific mechanisms accounted for the processes of assimilation and contagion uncovered in the analyses. Studies examining the role of potential mechanisms such as co-rumination, negative affect transmission, and conformity to group norms are needed. Another important direction for future research would be to explore the role played by friends' popularity in depressive symptoms socialization and compare various indicators of popularity in order to clarify contradictory findings. Finally, more research is needed to confirm our tentative finding on the particularly damaging impact of impulsivity on depression symptoms among females.

Table 1: Descriptive statistics of networks by wave

School	Wave	Density	Average degree	Number of ties	Reciprocity Index	Impulsivity (mean[SD])
1	1	0.022	2.7	307	41.5%	12.5 [3.1]
	2	0.021	2.5	279	38.1%	12.8 [3.1]
	3	0.023	2.9	290	36.4%	12.6 [2.9]
	4	0.021	2.6	263	32.2%	12.5 [2.7]
2	1	0.018	2.9	412	35.3%	12.3 [2.5]
	2	0.019	2.9	421	40.7%	12.4 [2.5]
	3	0.017	2.6	361	35.4%	12.5 [2.5]
	4	0.016	2.5	345	29.2%	12.2 [3]
3	1	0.016	3.1	579	35.3%	11.9 [2.9]
	2	0.013	2.3	454	30.4%	11.6 [2.9]
	3	0.014	2.8	529	31.2%	11.5 [3.1]
	4	0.012	2.4	452	22.5%	11.5 [3.2]
4	1	0.014	2.2	311	37.0%	12 [2.9]
	2	0.016	2.3	327	28.3%	12 [3.4]
	3	0.015	2.2	303	28.7%	11.9 [3]
	4	0.013	1.9	249	25.1%	11.6 [3]
5	1	0.013	2.6	532	37.9%	12.4 [2.8]
	2	0.013	2.8	542	37.5%	12.2 [3]
	3	0.012	2.5	492	35.5%	12.4 [2.6]
	4	0.012	2.6	493	38.3%	12.2 [2.9]
6	1	0.027	2.9	266	26.9%	12.5 [2.9]
	2	0.024	2.6	221	34.0%	12 [2.9]
	3	0.024	2.6	247	25.1%	11.8 [3.2]
	4	0.020	2.1	431	28.4%	12.6 [3.1]
7	1	0.012	2.4	415	36.0%	12.7 [2.7]
	2	0.012	2.3	224	31.1%	12.2 [2.5]
	3	0.008	1.5	350	20.1%	12.4 [2.8]
	4	0.012	2.3	431	36.1%	11.5 [2.8]

Table 2: Descriptive statistics of networks by period

School	Period	Jaccard indice	Hamming distance	N. decreased depression	N. increased depression
1	1	37.8%	260	35	30
	2	36.4%	250	23	25
	3	36.4%	241	23	29
2	1	36.0%	381	24	33
	2	34.0%	375	25	31
	3	33.5%	334	27	33
3	1	33.8%	473	29	21
	2	32.8%	471	30	22
	3	33.5%	474	25	27
4	1	31.0%	325	25	21
	2	30.8%	323	26	20
	3	29.8%	280	17	21
5	1	41.0%	434	43	33
	2	37.3%	456	37	25
	3	40.6%	398	28	27
6	1	26.3%	247	21	20
	2	25.1%	254	26	9
	3	17.4%	242	9	17
7	1	34.4%	387	33	21
	2	20.5%	383	25	10
	3	32.6%	271	9	17

Table 3: Unstandardized parameter estimates for friendship networks and depressive symptoms dynamics

	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
	Est.	**SE**	**Est.**	**SE**	**Est.**	**SE**	**Est.**	**SE**	**Est.**	**SE**	**Est.**	**SE**
Depression dynamics												
Linear shape depression	-1.22***	0.14	-1.11***	0.14	-1.15***	0.14	-1.16***	0.14	-1.14***	0.14	-1.15***	0.14
Quadratic shape depression	0.26***	0.04	0.35***	0.03	0.29***	0.04	0.29***	0.04	0.29***	0.04	0.27***	0.04
Baseline depression	0.32***	0.04	0.32***	0.03	0.30***	0.04	0.31***	0.04	0.31***	0.04	0.29***	0.04
Contagion	0.44**	0.11										
Assimilation			1.45**	0.35	1.11**	0.37	0.89	0.50	2.42*	0.76	1.12**	0.37
Effect from being female					0.52***	0.04	0.52***	0.10	0.51***	0.04	0.51***	0.05
Assimilation x female							0.72	0.96				
Assimilation x friends' popularity									-0.35*	0.13		
Effect from impulsivity											0.04+	0.02
Effect from impulsivity x female											0.04*	0.02
Network dynamics												
Outdegree	1.76***	0.20	1.74***	0.21	1.57***	0.27	1.73***	0.23	1.98***	0.24	1.90***	0.25
Reciprocity	1.83***	0.08	1.83***	0.08	1.84***	0.07	1.83***	0.08	1.83***	0.07	1.83***	0.07
Transitive triplets	0.47***	0.03	0.48***	0.03	0.47***	0.03	0.47***	0.03	0.48***	0.03	0.48***	0.03
Two-paths	-0.27***	0.02	-0.27***	0.02	-0.27***	0.02	-0.27***	0.02	-0.26***	0.02	-0.26***	0.02
Indegree popularity (sqrt)	0.33***	0.04	0.33***	0.04	0.33***	0.04	0.33***	0.04	0.31***	0.04	0.31***	0.04
Outdegree activity (sqrt)	-1.93***	0.08	-1.93***	0.08	-1.88***	0.09	-1.93***	0.08	-2.01***	0.09	-1.98***	0.09
Female alter	0.08+	0.04	0.08+	0.04	0.08	0.04	0.07	0.04	0.07	0.04	0.08	0.04
Female ego	0.06+	0.03	0.06*	0.03	0.06+	0.03	0.06+	0.03	0.07+	0.03	0.06+	0.03
Same sex	0.68***	0.06	0.68***	0.06	0.68***	0.07	0.69***	0.07	0.68***	0.06	0.67***	0.06
White alter	0.01	0.04	0.01	0.05	0.01	0.05	0.01	0.05	0.00	0.04	0.00	0.04
White ego	0.08	0.05	0.08	0.05	0.08	0.05	0.07	0.05	0.09	0.05	0.08	0.05
Same ethnicity	0.36***	0.03	0.36***	0.03	0.36***	0.03	0.35***	0.03	0.34***	0.03	0.34***	0.03
Depression alter	0.05	0.03	0.06	0.03	0.06	0.03	0.06	0.03	0.05	0.03	0.06	0.03

	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
	Est.	**SE**	**Est.**	**SE**	**Est.**	**SE**	**Est.**	**SE**	**Est.**	**SE**	**Est.**	**SE**
Depression ego	0.10^{+}	0.04	0.10^{+}	0.05	0.10^{+}	0.04	0.10^{+}	0.04	0.09	0.04	0.10^{+}	0.04
Depression similarity	0.24	0.29	0.23	0.27	0.16	0.23	0.22	0.26	0.17	0.25	0.20	0.26
Impulsivity alter	-0.01	0.00	-0.01	0.01	-0.01	0.00	-0.01	0.01	-0.01	0.01	-0.01	0.00
Impulsivity ego	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.01
Impulsivity similarity	0.19*	0.07	0.19*	0.07	0.19*	0.07	0.18*	0.07	0.19*	0.07	0.19*	0.07

$^{***}p < .001$; $^{**}p < .01$; $^{**}p < .05$; $^{+}p < .1$;

The rate functions, as well as network effects added-improve model fit, are not displayed here. The model also accounts for time heterogeneity in outdegree and reciprocity by use of time dummy variables. Complete results are available in online supplement S1.

References

Brendgen, M., Lamarche, V., Wanner, B., & Vitaro, F. (2010). Links between friendship relations and early adolescents' trajectories of depressed mood. *Dev Psychol, 46*(2), 491-501. doi: 10.1037/a0017413

Brendgen, M., Vitaro, F., Bukowski, W. M., Dionne, G., Tremblay, R. E., & Boivin, M. (2013). Can friends protect genetically vulnerable children from depression? *Dev Psychopathol, 25*(2), 277-289. doi: 10.1017/S0954579412001058

Brunner, R., Kaess, M., Parzer, P., Fischer, G., Carli, V., Hoven, C. W., . . . Wasserman, D. (2014). Life-time prevalence and psychosocial correlates of adolescent direct self-injurious behavior: a comparative study of findings in 11 European countries. *J Child Psychol Psychiatry, 55*(4), 337-348. doi: 10.1111/jcpp.12166

Buck, K. A., & Dix, T. (2012). Can developmental changes in inhibition and peer relationships explain why depressive symptoms increase in early adolescence? *J Youth Adolesc, 41*(4), 403-413. doi: 10.1007/s10964-011-9651-9

Chapple, C. L., & Johnson, K. A. (2007). Gender differences in impulsivity. *Youth Violence and Juvenile Justice, 5*(3), 221-234.

Cheadle, J. E., & Goosby, B. J. (2012). The Small School Friendship Dynamics of Adolescent Depressive Symptoms. *Soc Ment Health, 2*(2), 99-119. doi: 10.1177/2156869312445211

Chronis-Tuscano, A., Molina, B. S., Pelham, W. E., Applegate, B., Dahlke, A., Overmyer, M., & Lahey, B. B. (2010). Very early predictors of adolescent depression and suicide attempts in children with attention-deficit/hyperactivity disorder. *Archives of General Psychiatry, 67*(10), 1044-1051.

Cicchetti, D., & Toth, S. l. (1998). The development of depression in children and adolescents. *American Psychologist, 53*(2), 221-241.

Clarke, D. (2011). The Moderating Effect of Impulsivity on the Relationship Between Stressful Life Events and Depression Among College Women. *International Journal of Mental Health and Addiction, 10*(2), 152-161. doi: 10.1007/s11469-011-9333-6

Conway, C. C., Rancourt, D., Adelman, C. B., Burk, W. J., & Prinstein, M. J. (2011). Depression socialization within friendship groups at the transition to adolescence: the roles of gender and group centrality as moderators of peer influence. *J Abnorm Psychol, 120*(4), 857-867. doi: 10.1037/a0024779

Cosi, S., Hernandez-Martinez, C., Canals, J., & Vigil-Colet, A. (2011). Impulsivity and internalizing disorders in childhood. *Psychiatry Res, 190*(2-3), 342-347. doi: 10.1016/j.psychres.2011.05.036

Coyne, J. C. (1976). Depression and the response of others. *J Abnorm Psychol, 85*(2), 186-193.

Cremniter, D., Jamain, S., Kollenbach, K., Alvarez, J. C., Lecrubier, Y., Gilton, A., . . . Spreux-Varoquaux, O. (1999). CSF 5-HIAA levels are lower in impulsive as compared to nonimpulsive violent suicide attempters and control subjects. *Biological Psychiatry, 45*(12), 1572-1579.

d'Acremont, M., & Van der Linden, M. (2007). How is impulsivity related to depression in adolescence? Evidence from a French validation of the cognitive emotion regulation questionnaire. *J Adolesc, 30*(2), 271-282. doi: 10.1016/j.adolescence.2006.02.007

Derogatis, L. R. (1993). *Brief Symptom Inventory*. Mineapolis, MN: NCS Pearson.

Dirghangi, S., Kahn, G., Laursen, B., Brendgen, M., Vitaro, F., Dionne, G., & Boivin, M. (2015). Co-Rumination Cultivates Anxiety: A Genetically Informed Study of Friend Influence During Early Adolescence. *Dev Psychol*. doi: 10.1037/a0038848

Dussault, F., Brendgen, M., Vitaro, F., Wanner, B., & Tremblay, R. E. (2011). Longitudinal links between impulsivity, gambling problems and depressive symptoms: a transactional model from adolescence to early adulthood. *J Child Psychol Psychiatry, 52*(2), 130-138. doi: 10.1111/j.1469-7610.2010.02313.x

Elkins, I. J., Malone, S., Keyes, M., Iacono, W. G., & McGue, M. (2011). The impact of attention-deficit/hyperactivity disorder on preadolescent adjustment may be greater for girls than for boys. *J Clin Child Adolesc Psychol, 40*(4), 532-545. doi: 10.1080/15374416.2011.581621

Eme, R. F. (1992). Selective Females Affliction in the Developmental Disorders of Childhood: A Literature Review. *Journal of Clinical Child Psychology, 21*(4), 354-364. doi: 10.1207/s15374424jccp2104_5

Erikson, E. H. (1968). *Identity, youth and crisis*. New York: Norton.

Fortuin, J., van Geel, M., & Vedder, P. (2014). Peer Influences on Internalizing and Externalizing Problems among Adolescents: A Longitudinal Social Network Analysis. *J Youth Adolesc*. doi: 10.1007/s10964-014-0168-x

Gibb, S. J., Fergusson, D. M., & Horwood, L. J. (2010). Burden of psychiatric disorder in young adulthood and life outcomes at age 30. *Br J Psychiatry, 197*(2), 122-127. doi: 10.1192/bjp.bp.109.076570

Giletta, M., Scholte, R. H., Prinstein, M. J., Engels, R. C., Rabaglietti, E., & Burk, W. J. (2012). Friendship context matters: examining the domain specificity of alcohol and depression socialization among adolescents. *J Abnorm Child Psychol, 40*(7), 1027-1043. doi: 10.1007/s10802-012-9625-8

Granö, N., Keltikangas-Järvinen, L., Kouvonen, A., Virtanen, M., Elovainio, M., Vahtera, J., & Kivimäki, M. (2007). Impulsivity as a predictor of newly diagnosed depression. *Scandinavian journal of psychology, 48*(2), 173-179. doi: 10.1111/j.1467-9450.2006.00566.x

Hankin, B. L., Stone, L., & Wright, P. A. (2010). Corumination, interpersonal stress generation, and internalizing symptoms: accumulating effects and transactional influences in a multiwave study of adolescents. *Dev Psychopathol, 22*(1), 217-235. doi: 10.1017/S0954579409990368

Happonen, M., Pulkkinen, L., Kaprio, J., Van der Meere, J., Viken, R. J., & Rose, R. J. (2002). The heritability of depressive symptoms: multiple informants and multiple measures. *Journal of Child Psychology and Psychiatry, 43*(4), 417-479.

Harris, J. R. (1995). Where is the child's environment? A group socialization theory of development. *Psychol Rev, 102*(3), 458-489.

Hatfield, E., Cacioppo, J. T., & Rapson, R. L. (1993). Emotional contagion. *Current Directions in Psychological Science, 2*(3), 96-99.

Hatfield, E., Rapson, R. L., & Le, Y. C. L. (2011). Emotional Contagion and Empathy. In J. Decety & W. Ickes (Eds.), *The social neuroscience of empathy* (pp. 19-30). Cambridge, Massachussetts: The MIT Press.

Herman-Stahl, M., & Petersen, A. C. (1996). The protective role of coping and social resources for depressive symptoms among young adolescents. *J Youth Adolesc, 25*(6), 733-753.

Huitsing, G., Snijders, T. A., Van Duijn, M. A., & Veenstra, R. (2014). Victims, bullies, and their defenders: a longitudinal study of the coevolution of positive and negative networks. *Dev Psychopathol, 26*(3), 645-659. doi: 10.1017/S0954579414000297

Hyde, J. S., Mezulis, A. H., & Abramson, L. Y. (2008). The ABCs of depression: integrating affective, biological, and cognitive models to explain the emergence of the gender difference in depression. *Psychol Rev, 115*(2), 291-313. doi: 10.1037/0033-295X.115.2.291

Joiner, T. E., & Katz, J. (1999). Contagion of Depressive Symptoms and Mood: Meta-analytic Review and Explanations From Cognitive, Behavioral, and Interpersonal Viewpoints. *Clinical Psychology: Science and Practice, 6*(2), 149-164.

Keenan, K., Loeber, R., & Green, S. (1999). Conduct disorder in girls: A review of the literature. *Clinical Child and Family Psychology Review, 2*(1), 3-19.

Kiuru, N., Burk, W. J., Laursen, B., Nurmi, J. E., & Salmela-Aro, K. (2012). Is depression contagious? A test of alternative peer socialization mechanisms of depressive symptoms in adolescent peer networks. *J Adolesc Health, 50*(3), 250-255. doi: 10.1016/j.jadohealth.2011.06.013

Laursen, B., Hafen, C. A., Kerr, M., & Stattin, H. (2012). Friend influence over adolescent problem behaviors as a function of relative peer acceptance: to be liked is to be emulated. *J Abnorm Psychol, 121*(1), 88-94. doi: 10.1037/a0024707

Leeman, R. F., Hoff, R. A., Krishnan-Sarin, S., Patock-Peckham, J. A., & Potenza, M. N. (2014). Impulsivity, sensation-seeking, and part-time job status in relation to substance use and gambling in adolescents. *J Adolesc Health, 54*(4), 460-466. doi: 10.1016/j.jadohealth.2013.09.014

Leichsenring, F., Leibing, E., Kruse, J., New, A. S., & Leweke, F. (2011). Borderline personality disorder. *The Lancet, 377*(9759), 74-84. doi: 10.1016/s0140-6736(10)61422-5

Lopez, A. D., Mathers, C. D., Ezzati, M., Jamison, D. T., & Murray, C. J. L. (2006). Global and regional burden of disease and risk factors, 2001: systematic analysis of population health data. *The Lancet, 367*(9524), 1747-1757. doi: 10.1016/s0140-6736(06)68770-9

Lospinoso, J. A., Schweinberger, M., Snijders, T. A., & Ripley, R. M. (2011). Assessing and accounting for time heterogeneity in stochastic actor oriented models. *Adv Data Anal Classif, 5*(2), 147-176. doi: 10.1007/s11634-010-0076-1

Marmorstein, N. R., Iacono, W. G., & Legrand, L. (2014). Obesity and depression in adolescence and beyond: reciprocal risks. *Int J Obes (Lond), 38*(7), 906-911. doi: 10.1038/ijo.2014.19

Matthews, J. S., Ponitz, C. C., & Morrison, F. J. (2009). Early gender differences in self-regulation and academic achievement. *Journal of Educational Psychology, 101*(3), 689-704.

Newman, P. R., & Newman, B. M. (1976). Early adolescence and its conflict: Group identity vs. alienation. *Adolescence, 11*(42), 261-274.

O'Leary-Barrett, M., Mackie, C. J., Castellanos-Ryan, N., Al-Khudhairy, N., & Conrod, P. J. (2010). Personality-targeted interventions delay uptake of drinking and decrease risk of alcohol-related problems when delivered by teachers. *Journal of the American Academy of Child & Adolescent Psychiatry, 49*(9), 954-963.

O'Leary-Barrett, M., Topper, L., Al-Khudhairy, N., Pihl, R. O., Castellanos-Ryan, N., Mackie, C. J., & Conrod, P. J. (2013). Two-year impact of personality-targeted, teacher-delivered interventions on youth internalizing and externalizing problems: a cluster-randomized trial. *J Am Acad Child Adolesc Psychiatry, 52*(9), 911-920. doi: 10.1016/j.jaac.2013.05.020

Pachucki, M. C., Ozer, E. J., Barrat, A., & Cattuto, C. (2015). Mental health and social networks in early adolescence: A dynamic study of objectively-measured social interaction behaviors. *Soc Sci Med, 125*, 40-50. doi: 10.1016/j.socscimed.2014.04.015

Perroud, N., Baud, P., Mouthon, D., Courtet, P., & Malafosse, A. (2011). Impulsivity, aggression and suicidal behavior in unipolar and bipolar disorders. *J Affect Disord, 134*(1-3), 112-118. doi: 10.1016/j.jad.2011.05.048

Petersen, A. C. (1988). Adolescent development. *Annu Rev Psychol, 39*(1), 583-607.

Petersen, A. C., Compas, B. E., Brooks-Gunn, J., Stemmler, M., Ey, S., & Grant, K. E. (1993). Depression in adolescence. *American Psychologist, 48*(2), 155-168.

Pine, D. S., Cohen, P., Gurley, D., Brook, J., & Ma, Y. (1998). The risk for early-adulthood anxiety and depressive disorders in adolescents with anxiety and depressive disorders. *Arch Gen Psychiatry, 55*(1), 56-64.

Prinstein, M. J. (2007). Moderators of peer contagion: a longitudinal examination of depression socialization between adolescents and their best friends. *J Clin Child Adolesc Psychol, 36*(2), 159-170. doi: 10.1080/15374410701274934

Reynolds, A. D., & Crea, T. M. (2015). Peer influence processes for youth delinquency and depression. *J Adolesc, 43*, 83-95. doi: 10.1016/j.adolescence.2015.05.013

Ripley, R. M., Snijders, T. A. B., Boda, Z., Vörös, A., & Preciado, P. (2014). *Manual for RSiena*

Rose, A. J. (2002). Co-rumination in the friendships of girls and boys. *Child Dev, 73*(6), 1830-1843.

Rose, A. J., Carlson, W., & Waller, E. M. (2007). Prospective associations of co-rumination with friendship and emotional adjustment: considering the socioemotional trade-offs of co-rumination. *Dev Psychol, 43*(4), 1019-1031. doi: 10.1037/0012-1649.43.4.1019

Rose, A. J., & Rudolph, K. D. (2006). A review of sex differences in peer relationship processes: potential trade-offs for the emotional and behavioral development of girls and boys. *Psychol Bull, 132*(1), 98-131. doi: 10.1037/0033-2909.132.1.98

Rothon, C., Head, J., Klineberg, E., & Stansfeld, S. (2011). Can social support protect bullied adolescents from adverse outcomes? A prospective study on the effects of bullying on the educational achievement and mental health of adolescents at secondary schools in East London. *J Adolesc, 34*(3), 579-588. doi: 10.1016/j.adolescence.2010.02.007

Schaefer, D. R., Kornienko, O., & Fox, A. M. (2011). Misery Does Not Love Company: Network Selection Mechanisms and Depression Homophily. *American Sociological Review, 76*(5), 764-785. doi: 10.1177/0003122411420813

Schwartz-Mette, R. A., & Rose, A. J. (2012). Co-rumination mediates contagion of internalizing symptoms within youths' friendships. *Dev Psychol, 48*(5), 1355-1365. doi: 10.1037/a0027484

Silberg, J., Pickles, A., Rutter, M., Hewitt, J., Simonoff, E., Maes, H., . . . Eaves, L. (1999). The influence of genetic factors and life stress on depression among adolescent girls. *Archives of General Psychiatry, 56*(3), 225-232.

Smith, C. A., Haynes, K. N., Lazarus, R. S., & Pope, L. K. (1993). In search of the" hot" cognitions: attributions, appraisals, and their relation to emotion. *Journal of personality and social psychology, 65*(5), 916-929.

Smith, R. L., & Rose, A. J. (2011). The "cost of caring" in youths' friendships: considering associations among social perspective taking, co-rumination, and empathetic distress. *Dev Psychol, 47*(6), 1792-1803. doi: 10.1037/a0025309

Snijders, T. A. B., van de Bunt, G. G., & Steglich, C. E. G. (2010). Introduction to stochastic actor-based models for network dynamics. *Social Networks, 32*(1), 44-60. doi: 10.1016/j.socnet.2009.02.004

Spreux-Varoquaux, O., Alvarez, J. C., Berlin, I., Batista, G., Despierre, P. G., Gilton, A., & Cremniter, D. (2001). Differential abnormalities in plasma 5-HIAA and platelet serotonin concentrations in violent suicide attempters relationships with impulsivity and depression. *Life Sciences, 69*(6), 647-657.

Starr, L. R., & Davila, J. (2009). Clarifying co-rumination: associations with internalizing symptoms and romantic involvement among adolescent girls. *J Adolesc, 32*(1), 19-37. doi: 10.1016/j.adolescence.2007.12.005

Steglich, C., Snijders, T. A., & Pearson, M. (2010). Dynamic networks and behavior: Separating selection from influence. *Sociological methodology, 40*(1), 329-393.

Steinberg, L., & Monahan, K. C. (2007). Age differences in resistance to peer influence. *Dev Psychol, 43*(6), 1531-1543. doi: 10.1037/0012-1649.43.6.1531

Stone, L. B., Hankin, B. L., Gibb, B. E., & Abela, J. R. (2011). Co-rumination predicts the onset of depressive disorders during adolescence. *J Abnorm Psychol, 120*(3), 752-757. doi: 10.1037/a0023384

Thapar, A., Collishaw, S., Pine, D. S., & Thapar, A. K. (2012). Depression in adolescence. *The Lancet, 379*(9820), 1056-1067. doi: 10.1016/s0140-6736(11)60871-4

Van Zalk, M. H., Kerr, M., Branje, S. J., Stattin, H., & Meeus, W. H. (2010a). It takes three: selection, influence, and de-selection processes of depression in adolescent friendship networks. *Dev Psychol, 46*(4), 927-938. doi: 10.1037/a0019661

Van Zalk, M. H., Kerr, M., Branje, S. J., Stattin, H., & Meeus, W. H. (2010b). Peer contagion and adolescent depression: the role of failure anticipation. *J Clin Child Adolesc Psychol, 39*(6), 837-848. doi: 10.1080/15374416.2010.517164

Veenstra, R., Dijkstra, J. K., Steglich, C., & Van Zalk, M. H. W. (2013). Network-Behavior Dynamics. *Journal of Research on Adolescence, 23*(3), 399-412. doi: 10.1111/jora.12070

Veenstra, R., & Steglich, C. (2012). *Actor-based model for network and behavior dynamics*. New York: Guilford Press.

Vitaro, F., Ferland, F., Jacques, C., & Ladouceur, R. (1998). Gambling, substance use, and impulsivity during adolescence. *Psychology of Addictive Behaviors, 12*(3), 185-194.

Whiteside, S. P., & Lynam, D. R. (2001). The five factor model and impulsivity: Using a structural model of personality to understand impulsivity. *Personality and individual differences, 30*(4), 669-689.

WHO. (2012). Depression: A Global Crisis: World Health Organisation-World Federation for Mental Health.

Woicik, P. A., Stewart, S. H., Pihl, R. O., & Conrod, P. J. (2009). The Substance Use Risk Profile Scale: a scale measuring traits linked to reinforcement-specific substance use profiles. *Addict Behav, 34*(12), 1042-1055. doi: 10.1016/j.addbeh.2009.07.001

Zeman, J., & Shipman, K. (1997). Social-contextual influences on expectancies for managing anger and sadness: the transition from middle childhood to adolescence. *Dev Psychol, 33*(6), 917-924.

Table S1: Unstandardized parameter estimates for friendship networks and depressive symptoms dynamics (complete results)

	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
	Est.	**SE**	**Est.**	**SE**	**Est.**	**SE**	**Est.**	**SE**	**Est.**	**SE**	**Est.**	**SE**
Depression dynamics												
Rate function period 1: depression	1.84	0.19	1.93	0.27	1.98	0.26	1.94	0.27	1.79	0.20	1.98	0.24
Rate function period 2: depression	1.76	0.21	1.64	0.14	1.77	0.18	1.90	0.29	1.68	0.16	1.75	0.18
Rate function period 3: depression	1.75	0.28	1.96	0.35	1.76	0.29	1.70	0.27	1.78	0.30	1.77	0.30
Linear shape depression	-1.22***	0.14	-1.11***	0.14	-1.15***	0.14	-1.16***	0.14	-1.14***	0.14	-1.15***	0.14
Quadratic shape depression	0.26***	0.04	0.35***	0.03	0.29***	0.04	0.29***	0.04	0.29***	0.04	0.27***	0.04
Contagion	0.44**	0.11										
Assimilation			1.45**	0.35	1.11**	0.37	0.89	0.50	2.42*	0.76	1.12**	0.37
Baseline depression	0.32***	0.04	0.32***	0.03	0.30***	0.04	0.31***	0.04	0.31***	0.04	0.29***	0.04
Effect from being female					0.52***	0.04	0.52***	0.10	0.51***	0.04	0.51***	0.05
Assimilation among females							0.72	0.96				
Assimilation x friends' popularity									-0.35*	0.13		
Effect from impulsivity											0.04+	0.02
Effect from impulsivity*female											0.04*	0.02
Network dynamics												
Rate function period 1: network	7.53	0.51	7.68	0.54	7.52	0.52	7.55	0.53	7.54	0.52	7.60	0.54
Rate function period 2: network	9.49	0.75	9.24	0.73	9.43	0.75	9.28	0.74	9.42	0.77	9.50	0.75
Rate function period 3: network	8.47	1.51	7.72	1.02	7.61	0.89	7.86	1.11	7.87	1.14	7.22	0.62
Outdegree	1.76***	0.20	1.74***	0.21	1.57***	0.27	1.73***	0.23	1.98***	0.24	1.90***	0.25
Reciprocity	1.83***	0.08	1.83***	0.08	1.84***	0.07	1.83***	0.08	1.83***	0.07	1.83***	0.07
Transitive triplets	0.47***	0.03	0.48***	0.03	0.47***	0.03	0.47***	0.03	0.48***	0.03	0.48***	0.03
Two-paths	-0.27***	0.02	-0.27***	0.02	-0.27***	0.02	-0.27***	0.02	-0.26***	0.02	-0.26***	0.02
Indegree popularity (sqrt)	0.33***	0.04	0.33***	0.04	0.33***	0.04	0.33***	0.04	0.31***	0.04	0.31***	0.04
Outdegree activity (sqrt)	-1.93***	0.08	-1.93***	0.08	-1.88***	0.09	-1.93***	0.08	-2.01***	0.09	-1.98***	0.09
Zero outdegrees	-6.67***	0.37	-6.69***	0.38	-6.58***	0.37	-6.62***	0.39	-6.87***	0.40	-6.80***	0.39

	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
	Est.	**SE**	**Est.**	**SE**	**Est.**	**SE**	**Est.**	**SE**	**Est.**	**SE**	**Est.**	**SE**
Female alter	0.08^{+}	0.04	0.08^{+}	0.04	0.08	0.04	0.07	0.04	0.07	0.04	0.08	0.04
Female ego	0.06^{+}	0.03	0.06*	0.03	0.06^{+}	0.03	0.06^{+}	0.03	0.07^{+}	0.03	0.06^{+}	0.03
Same sex	0.68***	0.06	0.68***	0.06	0.68***	0.07	0.69***	0.07	0.68***	0.06	0.67***	0.06
White alter	0.01	0.04	0.01	0.05	0.01	0.05	0.01	0.05	0.00	0.04	0.00	0.04
White ego	0.08	0.05	0.08	0.05	0.08	0.05	0.07	0.05	0.09	0.05	0.08	0.05
Same ethnicity	0.36***	0.03	0.36***	0.03	0.36***	0.03	0.35***	0.03	0.34***	0.03	0.34***	0.03
Depression alter	0.05	0.03	0.06	0.03	0.06	0.03	0.06	0.03	0.05	0.03	0.06	0.03
Depression ego	0.10^{+}	0.04	0.10^{+}	0.05	0.10^{+}	0.04	0.10^{+}	0.04	0.09	0.04	0.10^{+}	0.04
Depression similarity	0.24	0.29	0.23	0.27	0.16	0.23	0.22	0.26	0.17	0.25	0.20	0.26
Impulsivity alter	-0.01	0.00	-0.01	0.01	-0.01	0.00	-0.01	0.01	-0.01	0.01	-0.01	0.00
Impulsivity ego	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.01
Impulsivity similarity	0.19*	0.07	0.19*	0.07	0.19*	0.07	0.18*	0.07	0.19*	0.07	0.19*	0.07
Outdegree time dummy period 2	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.13	0.11	0.12
Outdegree time dummy period 3	0.17	0.09	0.17^{+}	0.08	0.16^{+}	0.07	0.16^{+}	0.08	0.17^{+}	0.08	0.16^{+}	0.09
Reciprocity time dummy period 3	0.07	0.37	0.07	0.37	0.06	0.37	0.08	0.37	0.07	0.38	0.08	0.37
Zero outdegrees time dummy period 2	-0.85^{+}	0.35	-1.11^{+}	0.43	-1.03^{+}	0.43	-1.01^{+}	0.41	-0.87^{+}	0.36	-0.87^{+}	0.36
Zero outdegrees time dummy period 3	-1.23*	0.35	-1.27*	0.34	-1.02*	0.28	-1.08*	0.32	-1.27*	0.35	1.12*	0.33

$^{***}p < .001$; $^{**}p < .01$; $^{**}p < .05$; $^{+}p < .1$;