Does Sexual Onset Spread through Peer Network?

Diffusion of Sexual Onset among Adolescents

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Abstract

This study investigates diffusion of sexual onset through peer network among adolescents while controlling for friend selection. We test peer influence on the hazard of sexual onset controlling for friendship dynamics by using an advanced method, which integrates a proportional hazard model into the existing stochastic actor-based modeling. We use data from two saturated schools in the National Longitudinal Study of Adolescent Health, 1994-1996. Results suggest that peer influence increases the hazard of initiating sexual intercourse for adolescents. Both absolute and relative measures of exposure to friends who have initiated sexual intercourse, raise adolescents' risk of sexual debut, net of friend selection and other covariates. Peer influence on sexual onset is much stronger in our study than prior research, in which friendship dynamics were not properly considered.

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Sexual onset is one of the important life-course events that might change ones' life trajectories as it involves various subsequent outcomes. For instance, earlier initiation of sexual intercourse is associated with negative outcomes in adolescence, such as school dropout, poor school performance, lower mental health, sexually transmitted diseases, substance use, and teenage pregnancy (Armour and Haynie 2007; Madkour et al. 2010; Zimmer-Gembeck and Helfand 2008). These negative outcomes, in turn, are connected to lifetime detriment in education and income (Parkes et al. 2010). Accordingly, whether or not, when, and in which context to initiate sexual intercourse is instrumental in understanding adolescents' lives as one of the significant indicators for transition to adulthood.

Adolescent behaviors are strongly influenced by peers and friends. As they spend much time and heavily interact with peers more than family, peer groups and close friends become a direct reference for their behaviors. As similarity of behaviors among close friends is frequently observed, research also considers peer influence as a strong predictor of risky behaviors, such as depression, delinquency, drinking, obesity, and smoking (Light et al. 2013; Schaefer, Haas and Bishop 2012; Schaefer, Kornienko and Fox 2011). For instance, adolescents whose friends frequently smoke are more likely to smoke than others (Schaefer et al 2012). Likewise, literature suggests that peers' attitudes and behaviors affect individual sexual behaviors including sexual intercourse and pregnancy (Kinsman et al. 1998; Marín et al. 2000; Miller et al. 1997). Research also shows that sexually active adolescents are more likely than others to report friends who had initiated sex (Bearman 1999; Billy and Udry 1985b; Sieving et al. 2006).

Similarity in sexual behaviors among close friends in adolescence is common, but it is obscure about the causal mechanism, whether the observed similarity is due to friend selection based on similar behaviors or to peer influence among close friends. People tend to find friends

among those who share similar characteristics, and this also happens in peer networks in adolescence. The tendency toward homophily in friend selection makes it difficult to disentangle peer influence from the observed similarity among close friends. Given the significance of friends in the adolescent stage, ignoring such a selection effect can cause biased results. Furthermore, since friendship networks itself changes over time along with behavioral change, it is hard to disentangle peer influence from friend selection.

Thanks to advance in methodology, researchers began to consider both peer influence and friendship in empirical analysis at the same time. The Stochastic Actor-Based Model (SABM) is an advanced method of dynamic network modeling which jointly estimates evolution of networks and behavioral change (Snijders 1996; Snijders, van de Bunt and Steglich 2010). The SABM allows researchers to estimate peer influence on behaviors while controlling for evolution of freinship networks. In recent years, it has been frequently used for adolescent risky behaviors, such as depression, obesity, and smoking (Schaefer, Haas and Bishop 2012; Schaefer, Kornienko and Fox 2011). Taking a step forward, it became possible to integrate a hazard model into the existing SABMs for outcomes that are non-decreasing and dichotomous (Greenan 2013; Light et al. 2013). That is, we can estimiate time to an event while considering change in friedship networks. This innovative method is useful to test the diffusion of sexual initiation through peer networks in adolecence while controlling for friendship dynamics.

We investigate the dynamics of sexual onset between peer influence and friend selection in adolescent peer networks. With the innovative SABM hazard model, we estimate the hazard of sexual onset controlling for evolution of friendship networks. Unraveling peer influence from friend selection, we provide a better understanding of the complex mechanism between adolescent sexuality and friendship dynamics. As the initiation of sexual intercourse is

irrevocable, the progress to sexual onset among close friends can reveal how sexual behaviors are shared and spread through peer networks.

Peer Influence, Friend selection, and Sexual Onset

Adolescents' sexual behaviors are associated with contextual factors, such as family, neighborhood, and friends. These contextual factors offer a basis of socialization process and social controls. For instance, familial socioeconomic status, parental monitoring and support, and living with two parents tend to delay sexual initiation in adolescence (Browning, Leventhal and Brooks-Gunn 2005; Gardner, Martin and Brooks-Gunn 2012; Kincaid et al. 2012; Longmore et al. 2009; Longmore, Manning and Giordano 2001; Lyerly and Brunner Huber 2013). Neighborhood context like poverty rate also influences adolescents' sexual behaviors (Cubbin et al. 2010; Fletcher 2007; Gardner et al. 2012; Harding 2003).

The most important factor, however, might be friends because adolescents heavily interact with friends and they are more likely to find reference among peer groups (Wisnieski, Sieving and Garwick 2013). As adolescence is a stage that individual norms and behaviors are not yet firmly established, peers can be a useful source for modeling behaviors (e.g., Aseltine 1995; Biddle, Bank, and Marlin 1980). During adolescence which is full of sexual curiosity, sexual experience may get particular attentions among peer networks. Furthermore, sexual experience is more likely to be communicated and shared among close friends and then, it is more likely to motivate and promote others' sexual initiation. Such peer influence was frequently observed in other adolescent behaviors, such as drinking, smoking, and obesity (Kreager and Haynie 2011; Osgood et al. 2013; Shoham et al. 2012; Simpkins et al. 2013).

Literature suggests that diverse sexual activities are significantly influenced by peers' attitudes and behaviors (Bearman and Brückner 1999; Boislard and Poulin 2011; Jaccard,

Blanton and Dodge 2005; Marín et al. 2000; Maxwell 2002). For instance, Bearman and Brückner (1999) reported that adolescents whose friends have initiated sexual intercourse have higher likelihood of sexual onset than others. At the same time, they also showed that the sexually active adolescents are more likely to have onset friends than others. The similarity of sexual onset status among friends is often regarded as evidence for peer influence, but both causal relationship and changing feature of friendship networks were not appropriately considered in prior research. Indeed, the observed similarity can also be attributable to friend selection based on homophily. Friendship ties are more likely to appear among those who have some analogy in characteristics and backgrounds. Failure to consider such selection can lead to biased results (Manski 1993).

A few studies attempted to separate peer influence from friend selection. Fletcher (2007) reported that 10 %p rise in sexual onset status at the school level increases the probability of one's sexual onset by 3 %p. Ali and Dawyer (2011) also found that 10 %p rise in sexual onset status among close friends is associated with a 4.7 % rise in the probability of sexual onset. Both studies utilized instrumental variables (IV) to adjust the issues of reflection and confound effects, which peer behaviors affect ego's behaviors and vice versa. These studies demonstrated the significance of peer influence on adolescent sexual onset, and utilizing IV method can be a useful way to control confounding effects. However, in practice finding appropriate IVs is not always easy and even in the case of such IVs are available, it is not clear whether the variation that IVs generate is enough to adjust confounding effects (McClellan and Newhouse 2000). More importantly, neither case considered dynamic changes in peer networks in their empirical models.

Adolescents frequently make and break up friendship ties as they grow up. Compared to other contextual factors like family and neighborhood, peer networks in adolescence are more subject to change and thus, research on peer influence should take into account the dynamic feature of peer networks (Light et al. 2013; Schaefer et al. 2012). For instance, Schaefer and colleagues (2012) suggested that adolescents tend to more smoke when their close friends smoke, but simultaneously they also choose smokers as friends; smoking behavior itself attracts friendship choices. A similar pattern can happen with regard to sexual behaviors.

As an exception, Haynie (2014) utilized SABMs to analyze sexual activity in adolescence and finds evidence for both friend selection and peer influence: adolescents select friends on the basis of the same sexual activity and close (nominated) friends' average sexual activity influences own activity, controlling for one another. However, they did not differentiate friend selection caused by sexual activity from the ones caused by other covariates; adolescents may select friends based on not only sexual activity, but also other behaviors, such as religion, smoking, and drinking. In addition to that, the outcome variable is whether adolescent had sexual intercourse between waves, which can increase or decrease over time. For that reason, her method is different from ours, the SABM hazard model.

Current Study

With the SABM hazard model, we test peer influence on sexual onset controlling for dynamic change in friendship networks. The SABMs developed by Snijder consider co-evolution of both friendship networks and behaviors and enable to disentangle peer influence from friend selection (Ripley et al. 2014). This method has been frequently used to test peer influence on adolescent behaviors, such as alcohol use (Cheadle et al. 2013; Cheadle and Williams 2013), depression (Schaefer, Kornienko, and Fox 2011), obesity (de la Haye et al. 2011) and smoking (Mercken et

al. 2009; Haas and Schaefer 2014). In recent years, Greenan (2015) extended it further into integrating a proportional hazard model. His method successfully applied to test the diffusion of first alcohol use among adolescent peer networks (Light et al. 2013). This innovative method essentially estimates how the hazard of happening a certain event multiplicity changes in response to explanatory variables while simultaneously taking into account evolution of friendship networks. The hazard indicates the risk of event per time unit, and in our context it represents the risk of sexual initiation per constant time period. As a progress to sexual initiation between waves can be considered as an incremental progress in a constant time interval, the SABM hazard model is appropriate for our study.

We focus on timing of sexual initiation and its diffusion in adolescent peer networks. Initiation of sexual intercourse is more likely to involve in anxiety, concerns, relational change, and shifts in life plan. Facing these changes, adolescents can be more vulnerable than others due to their inexperience and lack of resources. In other aspects, the privacy feature of sexual initiation makes it difficult for adolescents to consult with parents and teachers. In this case, adolescents seeking for advice and information are more likely to find close friends to get it out. At the same time, interaction between close friends also can raise chances of peer influence, motivating sexual initiation from one another. As initiating sexual intercourse is irretrievable, it offers a useful opportunity to test the diffusion of sexuality among peer networks in adolescence.

In fertility studies, diffusion and social interaction have been frequently used to explain the spread of small family size and contraceptive use in developing countries (*e.g.*, Bongaarts and Watkins 1996; Casterline 2001; Montgomery and Casterline 1996). Along with structural perspectives that focus on individual characteristics and social structure, diffusion theory provides valuable explanations how falling fertility spreads from one to another and how fertility

transition is accelerated and transmitted among neighboring countries (Bongaarts 2003; Casterline 2001; Cleland 2001). Although the theory includes the diffusion process at both macro and micro levels, research testing the diffusion of fertility behaviors is rare at the micro level, except for contraceptive use. By utilizing dyadic analysis of friends from high school graduates, Balbo and Barban (2014) found that fertility behaviors—childbearing—spreads between close friends controlling for other confound effects. As complete peer networks in high schools are much more complex than a simple dyadic friendship and thus, involve more dynamic interactions among close friends. Accordingly, one can easily expect greater peer influence on sexual onset than the prior study.

Our study examines two primary hypotheses. First, we test peer influence on sexual onset, whether exposure to sexually-active friends increases the hazard of sexual initiation. As the access to sexuality is limited in adolescence, peer networks can be one of important sources of learning process. Sexually active friends can share their experience, knowledge, and advice with non-onset friends. Friends who have initiated sexual intercourse can guide a pathway to sexual debut, and also can provide knowledge on contraceptive use and pregnancy. As friends who have initiated sexual intercourse increase, adolescents may have more tolerable attitudes toward sexual intercourse, regardless of how they initially thought about it. Thus, we hypothesize that having more onset friends increases the hazard of sexual onset controlling for friend selection.

H1: Exposure to already-onset friends increases the hazard of sexual onset

Second, we test friend selection based on sexual onset status. Adolescents may refer to how sexual onset status is accepted and recognized among peer groups. When sexual activity is desired among adolescent peer networks, friends with sexual experience may be more popular and attract more friendship ties than others. However, a recent study (Haynie 2014) found that

the same status of sexual activity, rather than status itself, matters in friend selection. As sexual experience is a matter of privacy and difficult to say publicity, adolescents may want close friends to get it out, especially in such a sensitive period. In this sense, the same sexual onset status can be an important factor for friend selection. It is interesting to test whether onset status brings more friendship choices in adolescent peer networks. We hypothesize that the same onset status increases the probability of being friends.

H2: The same status of sexual onset increases the probability of being friends.

The timing of sexual initiation is also influenced by other factors, such as network effects and other covariates that influence adolescents' sexual behaviors. Previous research on peer networks (e.g., Goodreau, Kitts, and Morris 2009) suggested that endogenous network effects are important for the formation of friendship ties. For instance, adolescents are more likely to choose friends who are popular (popularity), how have selected ego as a friend (reciprocity), and who are friends of friends (transitivity). We take it into account these network effects in our empirical models to get precise estimates. We also take into account other covariates, such as age, gender, drinking, GPA, and religiosity, that might affect either friendship network or sexual initiation (Billy and Udry 1985b; Rostosky et al. 2004; Schvaneveldt et al. 2001; Zimmer-Gembeck and Helfand 2008). As maturity and puberty are required for sexual activity, age is positively associated with the hazard of sexual onset. Sexual activities also differ by gender (Billy and Udry 1985a; Henry et al. 2007). Sexual activities frequently occur while drinking. Frequent binge drinking can cause more spur-of-the-moments, resulting in earlier sexual debut. Academic performance and religiosity are known to delay the initiation of sexual intercourse (Adamczyk and Felson 2006; Lammers et al. 2000; Miller et al. 1997; Rostosky et al. 2004; Schvaneveldt et

al. 2001). As a result, we consider a number of covariates that relates to friend selection and sexual debut in adolescence.

Data and Methods

Data

The data for our study comes from the National Longitudinal Study of Adolescent Health (Add Health). Add health is a nationally representative sample of adolescents in grades 7-12 during the 1994-1995 academic year and repeated four times. The survey collected comprehensive information on individual characteristics, psychological and physical well-being, and contextual backgrounds, such as family, neighborhood, and friends. Information on peer networks was collected three times through first two waves. Each interview asked adolescents to nominate up to ten friends (five males and five females) in their school. At the first wave, both in-school and in-home interviews included section on peer networks. The in-school interview was conducted between September 1994 and April 1995 while the in-home interview of the wave I was done between April 1995 and December 1995. The peer networks were collected again through the in-home interview at wave II, which was conducted between April and August 1996. The three interviews have been conducted with about six- to eight-month intervals for each school although the time intervals between interviews vary with school.

We used the three interviews for the current study; the in-school interview at wave I for time 1, the in-home interview at wave I for time 2, and the in-home interview at wave II for time 3, in order. As most schools and students have continuously participated in the survey across interviews, we considered the peer networks measured at these three interviews as a longitudinal data of complete network information, which has a constant time interval (about 7 months) among three time points. Ignoring minor variation in time intervals allowed us to test the SABM

hazard model with three peer networks. Doing so leads to more reliable results than when we have a single change in peer networks. We checked the same model with a single change in peer networks between two in-home interviews, but the results were robust.

Due to relatively large sample sizes, two schools out of 16 saturated schools in the Add Health data were frequently chosen in previous studies. These schools were often known as the pseudonym "Jefferson High School" and "Sunshine High School." We also chose these schools to secure the adequate size for the analysis of peer networks. Both schools are large public schools, but Jefferson is a racially homogenous in rural Midwest while Sunshine is racially and ethnically diverse in suburban area of the West. In the purpose of having greater power, we pooled the data of two school-based peer networks for a multi-group analysis (Sniiders and Baerveldt 2003). We restricted our sample to those who have participated in all of three interviews. Consequently, the final sample includes 502 and 896 students for Jefferson and Sunshine, respectively.

Measures

Onset to first sex: Our primary outcome variable is sexual onset, a dichotomous variable about whether or not ever experienced sexual intercourse at each time point (0 = no, 1 = yes). Unlike other hazard models, the SABM hazard model regards time to an event as a constant time interval between time points; in our analysis, it becomes one or two time intervals across three time points. Sexual onset is measured through the following question, "Have you ever had sexual intercourse?" A question on the exact date is followed if responded "yes." If the response to the question is "yes," sexual onset status is coded 1 from the baseline (time 1) through the last time point. When the response was "no," sexual onset status is coded 0 at the baseline, but changes into 1 at the time of sexual initiation. This coding allows only an increase from 0 to 1. As in

other hazard models, respondents who have initiated sexual intercourse before time 1 were left-censored while those who did not transition to sexual onset by time 3 were right-censored. When the responses were inconsistent across interviews, we took the latest response assuming that the latest one is most accurate. Since information on sexual experience and relevant dates are not available at the in-school interview at wave 1 (time 1), we retrospectively estimated sexual onset from the information collected at later two interviews. We found a case that is obscure about sexual onset status. Considering this case as virgin, we included it into our analysis. Whether or not include the case does not affect our results.

Exposure to friends who have initiated sexual intercourse: Building on prior studies (Greenan 2015; Light et al. 2013), we consider two measures, *average exposure effect* and *total exposure effect* as two indicators of the behavioral diffusion. The former indicates the proportion of onset friends among the nominated friends while the latter refers to the total number of onset friends among the nominated. As two measures are highly correlated with one another, we tested them in two separate models, one at a time. Accordingly, our empirical models examine whether exposure to onset friends influences the hazard of own sexual onset while controlling for friend selection.

Network and structural effects: As in prior studies, we included a number of network structural effects into our analysis. For instance, friendships are more likely to be reciprocated, and friends of friends are more likely to become friends. Also, adolescents are more likely to want to be friends of whom are popular among peers. Failure to consider these tendencies can lead to biased results. We considered a set of structural effects including density, reciprocity, transitive triplets, transitive reciprocity triplets, indegree popularity, outdegree popularity, and outdegree activity.

Covariates: We also considered factors that might affect friendship networks. For instance, adolescents are more likely to make friendship ties with whom taking the same classes or the same extracurricular activities. These were known to be instrumental for forming friendship ties in a previous study. We also considered the numbers of class overlap and extracurricular activity overlap. While class overlap varies with time points, extracurricular activity overlap was measured at time 1 only due to survey design.

Our analysis also included other covariates, such as age, gender, delinquency, binge drinking (0=never, 1=rarely, and 2=sometimes), grade point average (GPA), religiosity, and race and ethnicity. Each covariate is included in the network function as ego, alter, and either similarity effect for continuous ones or same effect for categorical ones. As Jefferson High School is racially homogenous homogeneous, we consider only *covariate same effect* for race and ethnicity. Except for gender and religiosity that are time-invariant, all covariates are time-variant and measured at time 1 and 2. Binge drinking is measured with a question, "Over the past 12 months, on how many days have you gotten drunk or 'very, very high' on alcohol?" Since binge drinking is rare among adolescence and very positively skewed, we recoded it into three categories: 0 = never, 1 = rarely (once a month or less), and 2 = sometimes (over once a month). For GPA, we took average grades for four courses: English, mathematics, history/social studies, and science. Religiosity is an important predictor for sexual onset in adolescence (Rostosky et al. 2004). As in prior research (Rostosky, Regnerus and Wright 2003), we measured religiosity as sum of three items ranging from 1 (never/not at all important) to 4 (once a week or more/very important): frequency of religious services, self-rated importance of religion, and frequency of religious youth activities. Because these items are only available at time 2, we considered our religiosity measure as a time-invariant covariate. The religiosity measure shows adequate

internal consistency, $\alpha = .82$ and .71 for each school. As a result, our empirical models include these covariates into both friendship dynamics and behavior dynamics functions.

Analytic Strategy

Our analysis consists of two different parts. We first implemented cox proportional hazard model of sexual onset, and then conducted the SABM hazard model. This procedure is to display the difference in results between a model without friendship dynamics and another model with controlling it. In the first part, we model the hazard model of experiencing sexual debut for the given time period. Unlike ordinary cox models, we considered the period between time points (about 7 months) as a time unit so that the hazard ratios from the results can be comparable to those of the SABM hazard results. For the same reason, we imputed missing values of covariates with school-mean values, as in the SABM hazard models. Prior research often utilized event history analysis in order to estimate the hazard ratio or the relative risk of sexual onset. In such research, friendship ties are often inexplicitly assumed to be stable over time. A few studies tried to adjust friend selection by utilizing intrinsic estimator, but the unrealistic assumption of fixed friendship is unsolved and makes it difficult to identify peer effects on sexual onset. As different studies use different methods, time intervals, and samples, it is difficult to compare hazard ratios or relative risks across studies. Presenting the results from cox hazard models with the same data, we demonstrate advantages of our models over previous ones.

In the second part, we conducted the SABM hazard model to estimate the hazard ratio of sexual onset on exposure to onset friends while controlling for friend selection. As the SABM is efficient to test the co-evolution of friendship networks and behaviors controlling for one another, the application of SABMs to research on social networks and relevant behaviors has been gradually increasing in recent years. As a variant of SABMs, Greenan (2015) has developed the

SABM hazard model, which enables us to incorporate the proportional hazard model into existing dynamic network modeling when a behavioral outcome is a non-decreasing event. Like other SABMs, the SABM hazard model can also be implemented in the latest version of Simulation Investigation for Empirical Network Analysis (SIENA version 3).[1] The model consists of two functions, network dynamics and behavior dynamics. The network dynamic function controls both structural effects and friend selection for friendship dynamics, while the behavior function estimates the hazard ratio of sexual onset, which is proportional for covariates. As described above, we included average exposure and total exposure effects to already onset friends. This innovative method has proven useful in testing the initiation of alcohol use (Light et al. 2013) and cannabis smoking among adolescents (Greenan 2015).

To secure statistical power, we employed multi-group analysis with two schools, which assume the same parameters across groups. As we have three waves for two schools, out model includes four time periods—two time periods (intervals) for each school. In our case, the estimates for variables were fixed across the periods and then, freed selectively when time heterogeneity is observed.

Results

Descriptive Statistics

Table 1 represents descriptive statistics of two schools. The proportion of students who initiated sexual intercourse has risen across three time points in both schools. In Jefferson High School, the proportion of those who have initiated sexual intercourse was 26.1% at time 1, but rose to 43.0% at time 2 and 53.6% at time 3 respectively. The proportions were lower in Sunshine than Jefferson, but the ascending trend was similar with Jefferson: 24.8% at time 1, 43.2% at time 2, and 53.7% at time 3. The gradual increase in the students who have initiated sexual intercourse

[1] The Siena webpage: http://www.stats.ox.ac.uk/~snijders/siena/

reflects that sexual debut increasingly occurs between mid- and late adolescence. Given rapid growth of sexually active adolescents, sexual debut and relevant experience should be one of the prime concerns among peer groups. Regarding demographics, two school shares similar distributions in age and gender, except for race and ethnicity. The great majority in Jefferson are non-Hispanic whites whereas Sunshine is well blended in race and ethnicity. Adolescents in Jefferson are less religious and have more binge drinking than those in Sunshine. Trends in GPA for two schools crossed over between time 1 and 2, and thus Jefferson became to have higher GPA then Sunshine at time 2.

<Table 1 is about here>

Table 2 presents descriptive statistics for network structure. As SIENA assumes gradual evolution of networks, either marginal or radical change in networks is inappropriate for using SIENA. *Jaccard index,* which represents the distance between successive networks, is usually used to measure stability of networks. Although *Jaccard* value of more than .3 is desirable, but .2 or above is also fine (Ripley et al. 2014:16). In our sample, *Jaccard* values were .269 and .240 for two periods of Jefferson and .199 and .209 for another two periods of Sunshine. As all are around 0.20 or higher, we regarded them as appropriate for a SIENA analysis. Furthermore, low *Jaccard* values should not be a problem when overall networks are decreasing over time as in out sample (Ripley et al. 2014:16). As a result, our sample has enough amount of changes in peer networks for the use of SIENA.

<Table 2 is about here>

Figure 1 depicts the co-evolution of peer networks and the initiation of sexual intercourse for two schools over three time points. A vertex indicates each actor while a node shows a friendship tie. A colored vertex represents timing of sexual onset over three time points: gray = virgin, orange =

onset by time 1, red = onset between time 1 and 2, and dark red = onset between time 2 and 3. The figure shows that Jefferson's peer networks are much denser than Sunshine while the network size is smaller in Jefferson than the other. The density gradually declines over three time points in both schools. The colored vertices (orange, red, and dark red) also tend to increase and spread through neighboring ties, suggesting that a growing number of adolescents have initiated sexual intercourse for the observed time period. As it reaches to the last time point, a few cliques with colored vertices appear, but it is hard to say if sexual onset diffuses through peer networks.

<Figure 1 is about here>

Cox proportional hazard model

Table 3 represents the results of Cox proportional hazard models. In the table, exposure to the friends who have initiated sexual intercourse—both in absolute number and proportion among the nominated—is positively associated with ego's own hazard of sexual onset. Having an additional friend who have initiated sexual intercourse is associated with 15% rise in the hazard of sexual onset, controlling for age, gender, race and ethnicity, binge drinking, GPA, and religiosity. For an additional onset friend, 15% rise in the hazard of sexual debut is significant and influential. For instance, if an adolescent has two onset friends more than average at time 1, her/his hazard of sexual debut would rise by about 32% higher than average others ($1.15 * 1.15 = 1.32$).

In the right column, the proportion of friends who have initiated sexual intercourse among the nominated is also significantly and positively associated with the hazard of sexual onset. Compared to those who have all non-onset friends, having all onset friends has 58% higher hazard of sexual onset. It may be more realistic to say that the hazard of initiating sexual intercourse rises by 5.8% for 10%p rise in onset friends among the nominated friends. These

exposure effects are higher than previous studies, though direct comparison is impossible due to difference in methods, time-intervals, and analytic samples. However, it should be noted that our models took into account dynamic change in friendship networks that might confound peer effects, and thus these models should be distinguished from previous studies.

<Table 3 is about here>

SABM Results

Table 4 summarizes the multi-group analysis results of SIENA hazard models as a SABM. We conducted two separate models for total and average exposure effects for each. The results for network structural effects are almost identical between two models and consistent with prior studies using similar methods (*e.g.*, Schaefer et al. 2012). As these effects are not our primary concerns in this study, we do not explain in details. The models in Table 4 include time dummies that take it into account time heterogeneity across periods and schools. Considering time dummies is essentially to get a better estimates while improving goodness of model fit (Lospinoso et al. 2011). Simply, any parameter including a time dummy have a different effect size for a corresponding period. As interpreting these time dummies is incidental to our research questions, we do not explain all these dummies.

Network dynamics. The results for network dynamics indicates peer networks in adolescence are mainly influenced by homophily. The network dynamics suggested adolescents tend to select friends among those who share similar characteristics, such as gender, age, race/ethnicity, alcohol use, GPA and religiosity. At the same time, difference in covariates also attracted more friendship ties. For instance, friendship ties more appeared when ego is female, younger, and less religious. Furthermore, adolescents preferred those who have a frequent binge

drinking habit. By and large these homophily and friendship preference are consistent with prior studies using the same dataset (*e.g.*, Schaefer et al. 2012; Haas and Schaefer 2014).

One of our main interests is whether friendship ties are selected by sexual onset status. The results support one of our hypotheses (H2) and confirm a tendency of homophily: adolescents tend to make a friend who has the same onset status. Controlling for other covariates, adolescents are 1.30 times more likely to make a friendship tie when peers have t*he same onset status* ($e^{.262} = 1.30$). However, this is the case for Jefferson and the period between time 1 and time 2. The effect size varies with period and schools. The friendship towards the same sexual onset status decreased over time in Jefferson. Interestingly, the time dummy for Sunshine's period 1 (S1) is negative and enough to cancel out the main effect. It suggests that the same sexual onset status was less important in Sunshine and further decreased into a negative direction, which implies that the same sexual onset status is not helpful for maintaining friendship ties. However, we could not find any evidence for *ego and alter effects* of sexual onset status. It suggests that sexual onset status itself does not attract friendship ties, but the same status is an important factor to be a friend in adolescent peer networks. As a result, friend selection exists and in part contributes to similarity in sexual onset status and its timing among close friends in adolescence.

Behavior Dynamics. Our primary concern is peer effects on sexual onset, whether adolescents' first sex is influenced by close friends who already initiated it. For the covariates of behavior dynamic function, we were not able to find appropriate time dummies. As described, we tested the same model with two measures of the diffusion of innovation, *total exposure effect* and *average exposure effect*.

In the context of sexual onset, *total exposure effect* indicates the number of friends who have initiated sexual intercourse among nominated friends. Our model tests whether or not and to what extent this effect affects the hazard of *ego*'s sexual onset. In our result, *total exposure effect* is also strongly and positively associated with the hazard of sexual onset. To be specific, having one more onset friend is connected to about 44% rise in the hazard of sexual onset ($e^{(0.363)} = 1.44$, $p < .001$). This effect size is much higher than that in the previous cox hazard model that did not consider such selection effect.

The second model for *average exposure effect* also shows similar results. *Average exposure effect* represents the proportion of friends who initiated sexual intercourse among nominated friends. We found strong and positive average exposure effect on the hazard of sexual onset (2.037, $p < .001$). Controlling for friend selection and other covariates, one unit increases in the average exposure effect leads to 7.67 times higher hazard of sexual onset ($e^{2.037} = 7.67$, $p < .001$). When it is translated it into 10% increase in the proportion of onset friends, the effect is equivalent to 23% higher hazard of sexual onset ($e^{2.037 * .1} = 1.23$).

It is noteworthy that both *total and average exposure effects* have very strong impact on adolescents' sexual onset in our analysis. It is impossible to compare effect size across studies, but 44% rise in the sexual onset hazard for an additional onset friend is much higher than that in prior research that studied peer effects (Ali and Dwyer 2011). The large difference in peer effects from the cox model above is in part attributable to the statistical method we used. The advanced network method enabled us to estimate peer effects controlling for friend selection. Meanwhile, the hazard of sexual onset is also influenced by other covariates, such as GPA, frequency drinking frequency, and religiosity. As expected, school performance and religiosity tend to delay sexual onset while binge drinking accelerates it.

<Table 4 is about here>

Discussion and Conclusion

The initiation of sexual intercourse among adolescents have been a point of interest among scholars due to the significance in adolescents' well-being and its impacts on subsequent life trajectories. Many studies have reported similarity in sexual activities among adolescent friends; it often used to be considered as evidence of peer influence on sexual onset among adolescents. However, it was unclear whether the observed similarity in sexual initiation among close friends was due to friendship homophily (selection) or to peer influence. We addressed this by utilizing advanced SABM hazard model that considers co-evolution of friendship networks and behaviors together. The results of our study supported both friend selection and peer influence. Adolescents tend to choose friends with the same sexual onset status, whether or not they have initiated sexual intercourse. At the same time, exposure to friends who have initiated sexual intercourse, significantly increase *ego*'s hazard of sexual onset among adolescents. These friend selections and peer influences are significant even after controlling for one another.

Peer influence on adolescents' sexual initiation is stronger than our expectation. Although it is essentially impossible to compare effect size across studies, which have different samples, methods, and measures, the large gap in peer influence is interesting. Our models are basically distinguished from previous research in that change in friendship networks is considered. Accordingly, the advanced method helped to disentangle peer influence from friend selection in a more efficient way, resulting in stronger peer influence effect on sexual onset. Furthermore, our study measured direct peer influence from close friends while previous studies considered peer influence through an aggregate measure. The difference in effect size is in part attributable to the differences in these measures.

A strength of our study is that we tested peer influence on the hazard of sexual onset while simultaneously modeling the effect of onset status on friend selection. Adolescents are more likely gathered among those who share the same onset status. However, we were not able to see that sexual experience is popular among adolescents. Given that sexual experience is private, it might be important for adolescents to have a friend that they are able to discuss these similar experiences with. Early onset adolescents are likely much more comfortable to share their experience, concern, and information with close friends who have initiated sexual intercourse than with parents. For non-onset adolescents, staying with non-onset friends can help them to maintain their non-onset status minimizing peer influence from onset friends. The reason for friendship segregation by sexual initiation needs further investigation, but it is substantive for policy implications. For instance, intervention programs can be diversified with the composition of sexual onset among adolescents in a group. Simultaneously, a growing number of onset friends around non-onset adolescents can be a good indicator of imminent sexual debut for non-onset adolescents. In this case, those around the corresponding adolescents, such as parents and teachers, also can prepare to minimize adverse reactions.

A limitation of our study is that we were not able to test diverse interactions of gender differences, mainly due to lack of statistical power. Sexual behaviors and friend selection differ by gender. In particular, sexual experience is more likely to be shared and often boosted among male adolescents than females. If male adolescents desire and aspire sexual initiation more than female adolescents, they are more likely to be a friend with whom has more experience. Improved network data will allow to test such gender differences in the diffusion of sexual onset among adolescents.

Our study provides concrete empirical evidence for the diffusion of sexual onset among adolescent peer networks. As expected peer influence was one of the most important determinants for the timing of sexual onset among adolescents. Yet, the impact was much stronger than expectation. Given peer influence and friendship homophily of onset status in our study, initiation of sexual experience can trigger subsequent initiations among close friends and spread through neighboring peer groups. Our study also suggests the need for additional research about how relevant information on pregnancy and contraceptive use is acquired and distributed through peer networks.

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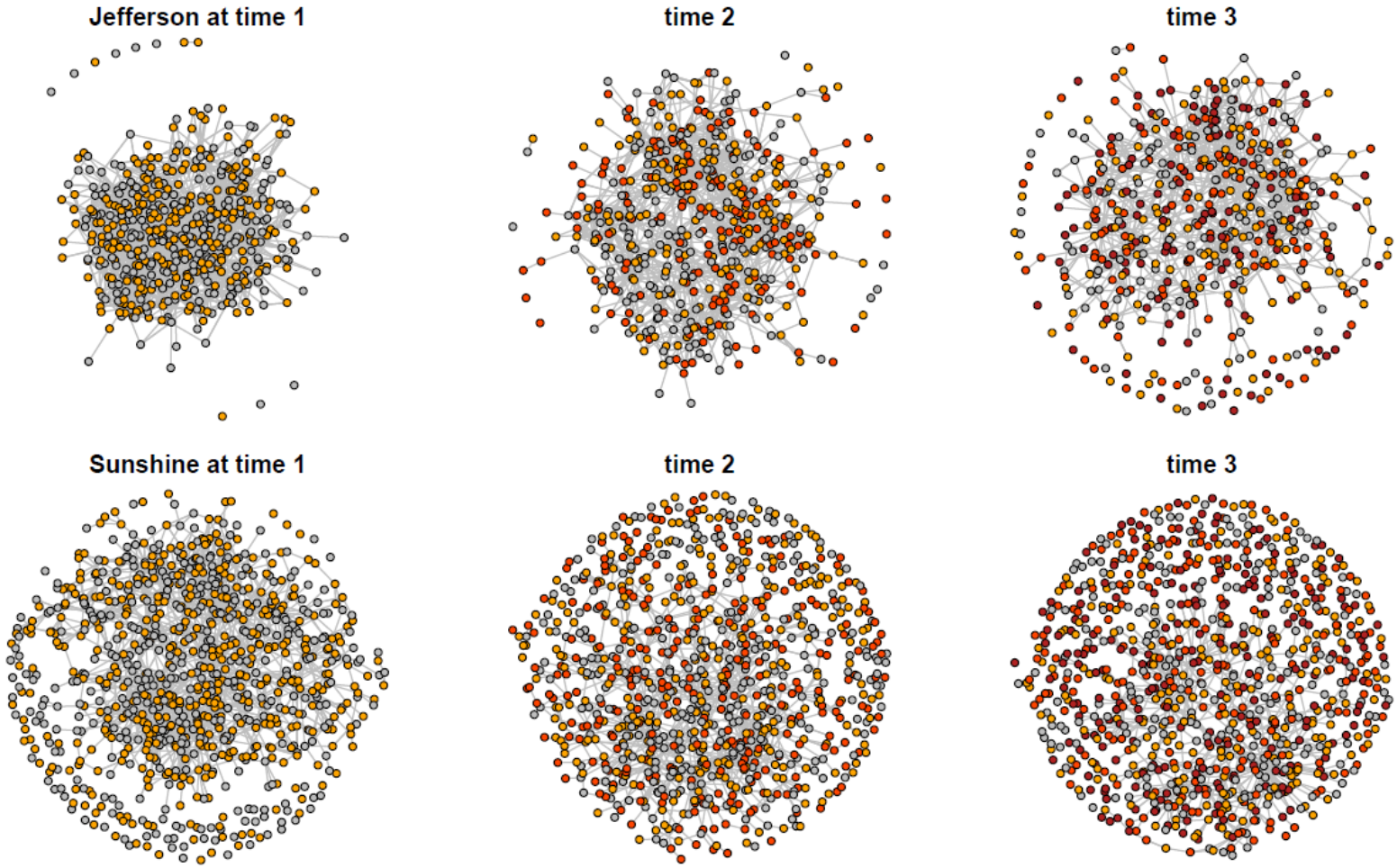
Figure 1: Co-evolution of friendship networks and sexual onset status for two schools



Notes: vertices = actors; nodes = nominations; gray = virgin; colored = sexual onset (orange = by time 1, red = by time 2, and dark red = by time 3).

Table 1: Descriptive statistics of behavior dynamics

	T1	T2	T3	Min	Max	Overall
Jefferson High School (N=502)						
Sexual onset	0.261	0.430	0.536	0	1	0.409
Female	0.470	-	-	0	1	0.470
Age	15.392	-	-	14	18	15.392
Race/Ethnicity						
White	0.982	-	-	0	1	0.982
Black	0.000	-	-	0	0	0.000
Hispanic	0.008	-	-	0	1	0.008
Asian and others	0.010	-	-	0	1	0.010
Religiosity	6.853	-	-	3	12	6.853
Truncated roster	0.058	-	-	0	1	0.058
Binge drinking [a]	1.138	1.466	-	0	6	1.302
GPA [a]	2.580	2.649	-	1	4	2.615
Extra. activities overlap [b]	0.251	-	-	0	9	0.251
Class overlap [c]	0.891	0.450	-	0	12	0.679
Sunshine High School (N=896)						
Sexual onset	0.248	0.432	0.537	0	1	0.406
Female	0.499	-	-	0	1	0.499
Age	15.675	-	-	14	19	15.675
Race/Ethnicity						
White	0.061	-	-	0	1	0.061
Black	0.231	-	-	0	1	0.231
Hispanic	0.384	-	-	0	1	0.384
Asian and others	0.324	-	-	0	1	0.324
Religiosity	8.509	-	-	3	12	8.509
Truncated roster	0.064	-	-	0	1	0.064
Binge drinking [a]	0.588	1.041	-	0	6	0.815
GPA [a]	2.717	2.523	-	1	4	2.616
Extra. activities overlap [b]	0.117	-	-	0	32	0.117
Class overlap [c]	0.501	0.341	-	0		0.421

Note: [a] time-varying actor covariate; [b] constant dyadic covariate; [c] time-varying dyadic covariate.

Table 2. Descriptive statistics of network structure

	Jefferson High School			Sunshine High School		
	Time 1	Time 2	Time 3	Time 1	Time 2	Time 3
Density	0.009	0.007	0.005	0.003	0.002	0.001
Average degree	4.357	3.434	2.703	2.262	1.599	1.227
Number of ties	2,187	1,724	1,357	2,027	1,433	1,099
Missing fraction	0	0	0	0	0	0
Mutuality (total)	251,502	251,502	251,502	801,920	801,920	801,920
mutual	960	732	574	816	482	380
asymmetric	2454	1984	1566	2422	1902	1438
null	248,088	248,786	249,362	798,682	799,536	800,102
Jaccard Index	0.269		0.240	0.199		0.209

Table 3. Cox hazard model of sexual onset on the number and proportion of onset friends with time variant covariates

	Number of onset friends				Prop. of onset friends			
	b		SE	HR	b		SE	HR
Age	0.164	***	0.043	1.18	0.163		0.043	1.18
Female	-0.011		0.075	0.99	-0.006		0.075	0.99
Race and ethnicity (ref=white)								
Black	0.611	**	0.187	1.84	0.604	**	0.186	1.83
Hispanic	0.095		0.178	1.10	0.096		0.177	1.10
Asian and others	-0.136		0.191	0.87	-0.131		0.190	0.88
Dummy for Sunshine (=1)	0.061		0.175	1.06	-0.010		0.172	0.99
Binge drinking (0, 1, 2) [a]	0.220	***	0.023	1.25	0.219	***	0.023	1.25
GPA [a]	-0.246	***	0.051	0.78	-0.247	***	0.051	0.78
Religiosity	-0.053	***	0.014	0.95	-0.052	***	0.014	0.95
Number of onset friends [a]	0.136	***	0.037	1.15				
Prop of onset friends [a]					0.459	**	0.173	1.58
-2LL	10312.775				10312.775			

Note: N=1,398; 353 cases were left-censored while 648 cases were right-censored; [a]. Time-varying covariates; religiosity is measured at time 2 as time-invariant; the duration between time points was used as a time unit (see the text for details); Breslow method was used for ties.

Table 4. SIENA hazard models on the diffusion of sexual onset in peer networks of adolescents

	Total exposure			Average exposure		
	b		*SE*	*b*		*SE*
Network Dynamics						
Rate: Jefferson, period 1	12.129	***	0.469	12.140	***	0.450
Rate: Jefferson, period 2	11.672	***	0.553	11.675	***	0.585
Rate: Sunshine, period 1	9.789	***	0.437	9.800	***	0.420
Rate: Sunshine, period 2	6.345	***	0.541	6.359	***	0.351
Effect of truncated roster on rate	-0.579	***	0.133	-0.578	***	0.142
J2 x effect of truncated roster on rate	0.144		0.345	0.151		0.363
S1 x effect of truncated roster on rate	-0.084		0.218	-0.091		0.219
outdegree (density)	-5.422	***	0.271	-5.372	***	0.164
J2	0.199		0.278	0.068		0.283
S1	-1.576	***	0.243	-1.755	***	0.227
S2	-3.418	***	0.836	-3.579	***	0.509
reciprocity	3.033	***	0.139	3.028	***	0.081
int. J2 x reciprocity	0.073		0.121	0.085		0.121
int. S1 x reciprocity	0.060		0.107	0.071		0.105
int. S2 x reciprocity	0.985	*	0.430	0.997	***	0.238
transitive triplets	0.942	***	0.037	0.944	***	0.036
J2 x transitive triplets	0.056		0.059	0.055		0.060
S1 x transitive triplets	0.069	†	0.041	0.065		0.041
S2 x transitive triplets	0.397	***	0.101	0.398	***	0.102
transitive recipr. triplets	-0.881	***	0.052	-0.881	***	0.054
J2 x transitive recipr. triplets	-0.093		0.098	-0.096		0.100
S2 x transitive recipr. triplets	-0.552	***	0.143	-0.560	***	0.150
indegree–popularity (sqrt)	0.446	**	0.172	0.439	***	0.084
S2 x indegree–popularity (sqrt)	0.352		0.532	0.350		0.260
outdegree–popularity (sqrt)	-0.539	***	0.090	-0.542	***	0.055
J2 x outdegree–popularity(sqrt)	-0.013		0.066	-0.014		0.072
S2 x outdegree–popularity(sqrt)	-0.170		0.284	-0.170		0.159
outdegree–activity (sqrt)	0.156	***	0.025	0.152	***	0.026
J2 x outdegree–activity (sqrt)	0.222	***	0.053	0.238	***	0.056

S1 x outdegree–activity (sqrt)	0.295	***	0.056	0.317	***	0.056
S2 x outdegree–activity (sqrt)	0.678	***	0.073	0.695	***	0.074
course overlap	0.137	***	0.009	0.137	***	0.009
int. J2 x course overlap	0.102	***	0.020	0.102	***	0.020
int. S1 x course overlap	0.051	**	0.016	0.051	**	0.016
int. S2 x course overlap	0.138	***	0.025	0.139	***	0.023
extracurricular activity overlap	0.160	***	0.017	0.160	***	0.016
int. J2 x extra. activity overlap	0.093	*	0.039	0.093	*	0.038
sexual onset alter	-0.066		0.043	-0.063		0.040
S2 x sexual onset alter	-0.142		0.110	-0.147		0.087
sexual onset ego	-0.074	†	0.043	-0.070		0.046
same sexual onset	0.262	***	0.045	0.255	***	0.043
int. J2 x same sexual onset	-0.192	†	0.112	-0.181		0.105
int. S1 x same sexual onset	-0.285	*	0.125	-0.272	*	0.118
int. S2 x same sexual onset	-0.482	***	0.118	-0.469	***	0.116
GPA alter	0.005		0.043	0.007		0.024
int. S2 x GPA alter	0.084		0.119	0.083		0.062
GPA ego	-0.024		0.026	-0.022		0.024
int. S2 x GPA ego	-0.022		0.068	-0.021		0.059
GPA similarity	0.408	***	0.080	0.411	***	0.066
J2 x GPA similarity	0.268	†	0.161	0.267		0.147
binge drinking alter	0.030	**	0.011	0.031	**	0.011
binge drinking ego	0.014		0.013	0.014		0.013
binge drinking similarity	0.399	***	0.077	0.402	***	0.078
age alter	0.039	*	0.020	0.039		0.020
int. S1 x age alter	-0.147	***	0.039	-0.148	***	0.036
int. S2 x age alter	0.116	*	0.051	0.117	*	0.054
age ego	-0.043	*	0.019	-0.044	*	0.019
int. S1 x age ego	-0.075	†	0.044	-0.076		0.046
age similarity	1.302	***	0.103	1.299	***	0.096
female alter	-0.010		0.036	-0.010		0.029
int. S1 x female alter	0.169	*	0.066	0.168	**	0.059
female ego	-0.102	***	0.030	-0.103	***	0.031
same female	0.335	***	0.034	0.332	***	0.030

int. J2 x same female	-0.073		0.059	-0.073		0.058
int. S2 x same female	0.387	***	0.092	0.386	***	0.082
same race	0.884	***	0.055	0.866	***	0.049
int. J2 x same race	-0.637	**	0.201	-0.568	**	0.205
int. S1 x same race	0.837	***	0.170	0.931	***	0.165
int. S2 x same race	0.869	***	0.205	0.961	***	0.173
religiosity alter	-0.004		0.006	-0.003		0.005
religiosity ego	-0.007		0.006	-0.006		0.006
int. J2 x religiosity ego	0.017		0.012	0.017		0.012
int. S1 x religiosity ego	-0.029	*	0.014	-0.030	*	0.014
religiosity similarity	0.132	*	0.060	0.134	*	0.059
truncated roster ego	-1.161	***	0.233	-1.151	***	0.256
int. J2 x truncated roster ego	3.246	***	0.458	3.226	***	0.503
int. S2 x truncated roster ego	2.905	***	0.480	2.887	***	0.527
Behavior Dynamics						
Rate: Jefferson, period 1	0.243	***	0.042	0.201	***	0.045
Rate: Jefferson, period 2	0.194	***	0.037	0.135	***	0.040
Rate: Sunshine, period 1	0.586	***	0.057	0.379	***	0.091
Rate: Sunshine, period 2	0.376	***	0.045	0.208	***	0.061
total exposure effect on rate of sexual onset	0.363	***	0.063			
average exposure effect on rate of sexual onset				2.037	***	0.465
GPA effect on rate of sexual onset	-0.327	***	0.072	-0.249	**	0.076
binge drinking effect on rate of sexual onset	0.303	***	0.036	0.300	***	0.037
age effect on rate of sexual onset	0.161	**	0.062	0.126		0.066
female effect on rate of sexual onset	-0.073		0.112	-0.053		0.109
religiosity effect on rate of sexual onset	-0.098	***	0.022	-0.093		0.021

Note: N=1,398; J2, S1, and S2 indicate time dummy of friendship ego for Jefferson period 2, Sunshine period 1 and 2, respectively; † $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, and *** $p < 0.001$