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Onset to First Alcohol Use in Early Adolescence: A Network Diffusion Model

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Abstract

A novel version of Snijders's stochastic actor-based modeling (SABM) framework is applied to model the diffusion of first alcohol use through middle school-wide longitudinal networks of early adolescents, aged approximately 11–14 years. Models couple a standard SABM for friendship network evolution with a proportional hazard model for first alcohol use. Meta-analysis of individual models for 12 schools found significant effects for friendship selection based on the same alcohol use status, and for an increased rate of onset to first use based on exposure to already-onset peers. Onset rate was greater at higher grades and among participants who spent more unsupervised time with friends. Neither selection nor exposure effects interacted with grade, adult supervision, or gender.

The role of adolescents' peer relationships in their use of alcohol has been of long-standing scientific interest. This work is driven by a well-established and still growing list of risks of excessive alcohol use for this population, for example, increased risk of depression, suicide, and other problems during adolescence (Reifman & Windle, 1995; Windle, Miller-Tutzauer, & Domenico, 1992), as well as risk for heavier drinking and alcohol dependence (Grant et al., 2006; Guttmanova et al., 2011) and cognitive impairment reaching into adulthood (Hanson, Medina, Padula, Tapert, & Brown, 2011; Sher, 2006).

Adolescents who drink alcohol typically do so with similar-age friends, leading to ubiquitously observed *drinking clusters* (Bauman & Ennett, 1994). A number of increasingly sophisticated study designs and analyses have addressed the dynamics that form these clusters in natural settings (Ary, Tildesley, Hops, & Andrews, 1993; Kandel, 1978; Steglich, Snijders, & West, 2006; Urberg, Luo, Pilgrim, & Degirmencioglu, 2003).

However, the role of peers in "onset to drinking"—defined here as the transition from no experience with drinking alcohol to having a "first full drink" (e.g., Guttmanova et al., 2011; McGue, Iacono, Legrand, & Elkins, 2006)—has received little attention, even though early onset is considered a major risk for later alcohol-related problems and dependence. In this study, we apply a stochastic actor-based model (SABM; Snijders, van de Bunt, & Steglich, 2010) of dynamic social network evolution to link early adolescents' drinking onset to exposure to best friends who have already begun drinking. We use the term *exposure* instead of the more typical *influence* (or *socialization*) terminology, because it can apply to a range of mechanisms that may put youth at greater risk of onset if they have

drinking friends, including, for instance, social reinforcement of attitudes, modeling, norms, and logistical and informational facilitation (Aral, 2011), not all of which are influence in the usual sense. Our study utilizes and illustrates a novel variant of the SABM that combines the conditional Markov model for network evolution first proposed by Snijders (2001) with a proportional hazard rate model for alcohol onset (Cox, 1972; Greenan, 2013). Hazard models are commonly used to evaluate risk factors for time to an event (Yamaguchi, 1991). Network evolution and alcohol onset are modeled jointly, in order to separate selection and exposure effects on drinking clusters. This approach also differs from previous models of joint network and behavioral evolution (Steglich, Snijders, & Pearson, 2010) in its focus on predictors of relative risk for initiating drinking, rather than simply whether (or how much) drinking takes place, regardless of whether it is an onset event.

Early Onset to Drinking

Many studies have reported a relationship between early age of onset and risk for later alcohol dependence (Chou & Pickering, 1992; Grant & Dawson, 1997; Guttmanova et al., 2011), suicidal behavior (Cho, Hallfors, & Iritani, 2007; Swahn, Bossarte, & Sullivent, 2008), and other problems (Hingson, Heeren, Jamanka, & Howland, 2000). Although there is evidence that after drinking is initiated, risk for additional problems is fundamentally genetic (McGue et al., 2006; Pagan et al., 2006; Prescott & Kendler, 1999), one must nevertheless begin drinking before such risk becomes relevant. Genetically informative studies have also found that risk of earlier onset is largely environmentally determined (Kendler, Schmitt, Aggen, & Prescott, 2008; Pagan et al., 2006), which could include exposure to drinking peers and lack of parental and other adult supervision.

Peers and Onset to Drinking

The theoretical case for peer drinking affecting onset is somewhat mixed. Although early adolescence is a time when peer relationships become especially important (Gardner & Steinberg, 2005), there is also evidence that middle to older adolescents perceive more peer pressure to drink (Steinberg & Monahan, 2007), perhaps because drinking does not become widespread in adolescent populations until then (Burk, van der Vorst, Kerr, & Stattin, 2012). Very few studies have examined the issue empirically. Jessor and Jessor (1975) found an association between friends' drinking and onset to drinking among young adolescents, and Trucco and colleagues (2011) found a distinct peer exposure effect on onset while controlling for selection. Both studies measured friends' drinking behavior by participant reports.

Peers and Amount of Drinking

A much larger literature has addressed peer exposure effects for alcohol quantity or frequency. Drinking is deviant only in relation to age but it is an attractive adult-like activity for many adolescents (Jessor & Jessor, 1977); it is associated with socializing and being accepted (Veenstra, Huising, Dijkstra, & Lindenberg, 2010), and perhaps for this reason, is typical among high-status youth (Allen, Chango, Szewedo, Schad, & Marston, 2012). This dynamic motivates both selection and influence effects in teen drinking. Three recent studies of adolescent drinking (Burk et al., 2012; Knecht, Burk, Weesie, & Steglich, 2011; Mercken, Steglich, Knibbe, & de Vries, 2012) provide a particularly relevant empirical context for our work. Each addressed alcohol use among early adolescent youth, employed a multiwave longitudinal design with complete-network friendship (all pairwise relationships) and behavioral data, and applied SABM. Results showed some similarities but important differences as well.

Burk and colleagues (2012) compared selection and exposure effects associated with changes in drinking behavior for three age cohorts, addressing variation in exposure effects at different ages. They found that peer drinking clusters are mainly explained by selection effects up to about age 15, but exposure effects become important in midadolescence. In contrast, Mercken and colleagues (2012) found evidence of exposure effects at younger ages (ages 13–14) but not for older youth (ages 14–16), whereas alcohol-related selection appeared stronger for the older youth, although the alcohol selection effect approached significance for the youngest ages. Finally, Knecht et al. 2011 found drinking-related selection and a trend effect of exposure to drinking peers (ages predominantly 11–13). Note that none of these studies separated onset from subsequent drinking. In fact, conflating the two has been typical in empirical studies of peers and adolescent drinking, even though many theoretical treatments explicitly discuss onset as a distinct and salient phenomenon (Dodge et al., 2009; Petraitis, Flay, & Miller, 1995). Thus, it is possible that the selection and exposure effects reported have to do with onset only, subsequent drinking only, or both. In contrast, our analysis is limited to onset alone.

The previous discussion suggests hypotheses concerning the role peer affiliations play in onset to drinking. Although our discussion so far has focused on exposure effects, selection is important also, as relationships must be created before they can affect subsequent drinking.

H1. *Same drinking onset status predicts friendship selection.*

H2. *Exposure to already-drinking peers increases the risk for onset in nondrinking early adolescents.*

Gender, Grade, and Adult Monitoring

Gender has not typically been found to moderate selection or exposure effects for alcohol use (cf. Burk et al., 2012), but it may for onset, as the hypothesized greater importance of close friendships to girls (Schulenberg et al., 1999) may be more important than the greater susceptibility to drinking sometimes found for boys (Anderson, Tomlinson, Robinson, & Brown, 2011; Windle, 2000).

H3. *Same alcohol onset status is a more important source of selection preference for girls compared to boys.*

H4. *Exposure to already-drinking peers affects girls' rate of onset more than boys.*

If, indeed, drinking becomes an increasingly important peer-related activity as youth progress through early adolescence (Burk et al., 2012), onset may play an increasing role as both a reason for friendship selection and an element of peer exposure. Even though Mercken et al. (2012) did not find an age effect in an early adolescent sample, the theoretical case is plausible for alcohol onset. Earlier onset may index environmental risks for early problem behavior; in contrast, drinking in older youth is much more normative and is associated with popularity (Allen et al., 2012; Burk et al., 2012).

H5. *Effects of exposure to drinking peers will be stronger at higher grades.*

H6. *Selection preference for same drinking status will increase by grade.*

Besides peers, parents and other relevant adults are the most likely source of behavioral influence for early adolescent youth (Véronneau & Dishion, 2011). Previous studies have identified lack of monitoring and supervision as a key component of risk for substance use

among adolescents (Dishion, Nelson, & Kavanagh, 2003; Ryan, Jorm, & Lubman, 2010), which may be a result of failure by parents to supervise peer affiliations (Dodge et al., 2009). Vitaro, Brendgen, and Tremblay (2000) found that, although parental monitoring had a direct effect on problem behavior, it did not moderate associations with exposure to problem-behaving peers. However, Véronneau and Dishion (2011) found that parental monitoring buffered risks for problem behavior associated with peer relationship difficulties. Because both opportunities to drink and perceived acceptability of drinking could be affected by supervision, more monitoring may delay onset.

H7. *Adult monitoring predicts delayed alcohol onset.*

H8. *Adult monitoring interacts negatively with exposure to drinking peers in predicting alcohol onset.*

Method

Study Design

Sixteen middle schools were recruited for participation in the School Social Environments study, a 3-year longitudinal study of student friendships and behavior. Schools were located in the western United States, and were chosen for recruitment based on a target enrollment range of 100 to 1,000 students and availability of school resources for conducting supervised, web-based surveys. Of the schools recruited, 14 participated in at least 1 year of the study. Eleven schools enrolled grades 6, 7, and 8; two schools enrolled only grades 7 and 8; and one school enrolled grades 6 through 12. The present study excluded the grade 6–12 school because of the uncertain effect of older adolescents on the same campus, and one other school that did not complete four assessments in one year. Enrollments in the remaining 12 schools included in this analysis varied from approximately 120 to 600 students, varying slightly by assessment wave. All students enrolled at any time during their school's 3-year participation were eligible to participate. All schools were exposed to the school-wide Positive Behavioral Intervention and Support program (PBIS; Horner et al., 2009; Sugai & Horner, 2006). Schools received stipends of \$750–\$2,000 per year of participation, depending on school size and willingness to commit to additional data collection beyond the project standard.

An Internal Review Board-approved implicit consent process determined student eligibility for participation, in which parents were provided the opportunity to opt out of participating in the study. Students were not compensated, except for entry in year-end prize lotteries for \$10–\$15 gift cards.

Assessments were conducted four times each school year, approximately 70–90 days apart. Students completed an online questionnaire, in English or Spanish, in a school computer lab under staff supervision. Assessments were completed in 8–10 minutes, with younger students and first-time participants requiring the most time. Students were able to opt out of participation at any time during the survey, without penalty, by clicking a button. At each student's first survey, sex, race, ethnicity, and prior lifetime substance use were assessed.

Participants

The sample included 6,609 students out of 7,707 (93%) enrolled in the 12 participating schools. Participants completed an average of 4.14 ($SD = 2.06$) assessments during up to 2 full years. Students were between 10 and 16 years of age at the time of their first assessment ($M = 12.45$, $SD = 1.07$). Participating students included 3,282 females and 3,243 males (84 students, 1.3% of the sample, did not report their sex). Forty percent of the sample ($n =$

2,641) identified themselves as non-White; of these, about two thirds were Latino, and the rest were primarily Native American.

Measures

Network—Students were first asked to choose, from a list of all students enrolled in the school and eligible for participation, all students with whom they had spent “free time” in the past month. Free time was defined as at least 10 minutes in which “you could talk about whatever you wanted,” and explicitly did not include class time or organized activities. The number of choices was unrestricted. Students were shown a list of all students they had chosen and asked to indicate for each a) on how many days in the past month they had spent free time with that student, and b) whether the student was a “best friend.” In this paper, best friend nominations defined the networks.

On about 1% of response occasions, participants named a great many others as best friends. Because such extreme degree outliers (EDOs) on the outdegree distribution suggest a different interpretation of best friend from most students, and because EDOs can destabilize the SABM iterative estimation algorithm, we treated all out-choices as missing (i.e., unknown) in these instances. Others’ choices of the EDO as a best friend were retained, however, and those not chosen by the EDO were still considered valid (zero rather than missing). This model-based available data approach is consistent with results reported by Huisman and Steglich (2008), where a similar scheme produced the best results.

Onset to first alcohol use—This measure was based on two questions. Participants were asked on their first (baseline) assessment how many times they had consumed an alcoholic drink (an entire drink, not just a sip) of any type, in their entire lives. If one or more times, the individual was coded as a 1 from their baseline wave through the last wave examined. If no previous use was reported, the individual was coded 0 at baseline. On subsequent (post baseline) assessments, participants were asked how many days out of the previous 30 they had consumed one or more alcoholic drinks. Any nonuser up to that wave who answered with a positive number was coded a 1 for that wave, and 1 thereafter. This procedure resulted in a within-person onset variable that could only increase, from 0 to 1.

As is common for such measures (Yamaguchi, 1991), exact onset times could not be determined. For individuals who reported to have drunk alcohol by the first wave, data were left-censored; for those who did not report any drinking up to the last wave in which they responded, data were right-censored. Other responses were interval-censored, as the time of onset could only be narrowed to a 30-day period prior to an assessment. Further uncertainty was introduced by the fact that our survey did not ask about drinking during the period from the previous assessment up to just before the 30 day current assessment window. Additionally, because most participants (48.6%) missed one or more surveys for which they were eligible (i.e., enrolled in school and not opted out of the study), it is possible that some would have reported onset on that survey, again producing an incorrectly delayed time of onset. Although a more comprehensive measure of onset would have been ideal, this procedure would likely give rise to a bias only in estimating the *absolute* rate of onset. However, our proportional hazard approach (Cox, 1972) considers *relative* rates of onset for different values of predictors. Censoring would not bias such a model unless predictor values were correlated with observed versus unobserved periods. This seemed an unlikely concern for the present analysis.

Adult monitoring—Participants were asked to report the number of days out of the 30 days prior to the assessment that they had spent free time with friends with “no adult

supervising.” Responses were collapsed to a 0–10 scale for descriptive consistency with other frequency-based behavior variables, a rescaling that did not materially affect results.

Same ethnicity—Ethnicity was ascertained by asking participants to check how they would “describe [their] race or ethnicity.” Choices were: White–European American, Black–African American, Latino–Hispanic, Asian American or Pacific Islander, Native American (Indian), or Other. Multiple selections were allowed. If two individuals matched on any checked choice, they were coded as having the same ethnicity. This variable was a dyadic covariate, that is, a (symmetrical) property of pairs of individuals. This approach provides a parsimonious control for ethnicity-based friendship selection in a network model, particularly when ethnic differences are not the focus of the model.

Gender and grade—Gender was assessed by self-report at each participant’s baseline survey and coded 0 for male, 1 for female. Grade in school was also included in both the network and alcohol onset portions of the model. Grade was selected because, in addition to providing a control for age, it also provided a type of proximity control, because same-grade youth were more likely to have classes together.

Analysis Approach

Stochastic actor-based models—Analyses were conducted using SABM for the network and alcohol onset measures (Snijders, 2001; Snijders et al., 2010) implemented in the R package RSiena (Ripley, Snijders, & Preciado, 2012). Network tie changes and behavior changes are modeled simultaneously as coevolving Markov processes. Individuals make friendship choices independently at randomly selected times. Choice probabilities are given by a multinomial logit distribution that can depend on characteristics of the actor (e.g., gender, grade, level of modeled behaviors), of individuals the actor is linked to (e.g., number or proportion of friends who drink alcohol), or of characteristics of the linkage (e.g., to an actor of same or different ethnicity). Behavior change is usually modeled similarly, but, in this study, the onset model is novel, as explained further on. Parameters associated with each predictor are estimated using a method-of-moments approach (Godambe, 1991) that involves repeatedly simulating the model-implied network and behavioral evolution, adjusting the interim parameter values at each step to improve the selected fit criterion.

Data missing by design included participants who did not join the study until they enrolled at a participating school, and those who left after being promoted out of the school. RSiena handles this type of missingness by *composition change* (Huisman & Snijders, 2003). Other types of missingness are handled in RSiena with the objective of minimizing their effects on the analysis (Huisman & Steglich, 2008; Snijders et al., 2010).

The stochastic actor-based diffusion model—For the alcohol onset variable, we model the time to an event (Singer & Willett, 2003; Yamaguchi, 1991). The proportional odds model (Cox, 1972), also called Cox regression, is an appropriate approach. It is a multiplicative model: for a given explanatory variable s , a 1-unit increase in s implies an increase in the hazard of a nondrinking individual i to start drinking at a given time by a factor of e^{β_s} , where β_s is the statistical parameter (weight) associated with variable s . For static networks, proportional odds models incorporating influence from connected alters have been discussed by, for example, Strang and Tuma (1993) and Valente (2005). The integration of a proportional odds time-to-event model with a SABM for network dynamics, as used here, is new. Greenan (2013) has shown that this combination can be made by specifying that the behavioral dependent variable in the SABM (here, the binary variable alcohol onset) is nondecreasing, and that risk predictor variables are included in the so-called *behavioral rate function* (Ripley et al., 2012), which specifies the relative rate at

which the event (alcohol onset) occurs. In this study, the primary risk predictor variable is the average proportion of drinkers among one's best friends who have started drinking before time t .

Model development—Models were estimated, for each school separately, for the set of waves available. The recommended (Snijders et al., 2010) forward-selection process was followed, which tends to provide better start values as model complexity increases. We developed models for friendship change first, specifying unconditional-rate-only models for alcohol onset variables. Once stable network models were obtained, explanatory effects of interest were added to the alcohol onset portions of the models.

For the network portion of the model, selection based on same alcohol onset status was of prime concern (main effect and interactions). However, as for any multivariate statistical model, validly inferring selection effects depends on controlling for correlated alternatives. The most basic such alternatives are those associated with proximity, either physical proximity (e.g., taking the same classes) or network proximity (e.g., being friends with one another's friends). Gender and ethnicity selection effects may also be correlated with alcohol-based selection. We controlled for these effects by including same grade, same ethnicity, same gender, reciprocity (friendship choices have a tendency to be reciprocated), transitivity (friends of friends are more likely to become friends) and 3-cycles (an inverse measure of hierarchy; see Snijders et al., 2010) as predictors of friendship selection, in addition to drinking onset status for ego (the chooser) and alter (the chosen). These effects have been widely studied and are typically strong predictors of friendship formation. Fortunately, moreover, whereas specific selection effect parameters may be biased by a failure to include more fundamental effects, omission of some context effects for the sake of parsimony appears not to affect behavior-based selection and exposure effects greatly, as long as a reasonable set of known determinants of network dynamics are included (Steglich, Sinclair, Holliday, & Moore, 2012).

The alcohol onset model predictors included baseline period-specific rate parameters, rate by grade, rate by gender, rate by adult supervision, and rate by exposure to peers who have already started to use alcohol. Substantively important but nonsignificant effects were retained in all models for which convergence was acceptable (Ripley et al., 2012), but in a few cases some of these effects had to be dropped (i.e., set to zero) to achieve convergence. This approach is typical for many classes of statistical models (Gelman & Hill, 2007). Wave dummies (Lospinoso, Schweinberger, Snijders, & Ripley, 2011) were examined in early model development work. Their inclusion did not materially affect substantive results and conclusions, but sometimes resulted in model convergence issues. Thus, it was decided not to attempt a systematic exploration of variation between waves for the present study.

After models with good convergence (convergence t -ratios less than .10, reasonable standard errors; Ripley et al., 2012) were estimated for each school, parameters were pooled across individual school models using meta-analysis (Cochran, 1954; Ripley et al., 2012; Snijders & Baerveldt, 2003), which also provides information on effect variation across schools. The meta-analysis assumes that the 12 schools come from the same population. Statistical significance for population means was inferred using the normal distribution-based t -test described by Snijders and Baerveldt (2003).

Results

Descriptive Overview

Table 1 shows basic descriptive results by wave, and Table 2 shows the same information by school. Some variation is to be expected, because the waves involved different sets of

schools and new cohorts of students each year. Average enrollment declined about 10% from wave 1 to wave 8, and the average number of opt-outs (survey-ineligible students) increased, probably reflecting a modest level of both institutional and individual survey fatigue. Out-choices (outdegree) averaged about 2.8 to 3.6, and declined somewhat over time. Other network statistics (reciprocity, transitivity, and 3-cycles) changed little over time. Reciprocity was lower than in comparable studies (Burk et al., 2012; Mercken et al., 2012), perhaps reflecting a broader than usual friendship criterion suggested by survey wording (“...one of my best friends...”), or the lack of a limit on number of friendship choices. Days per month participants reported spending free time with friends with no adult supervision varied across waves, trending upwards during the course of each school year.

School averages across each school’s participating waves are shown in Table 2. Number of participants varied by a factor of about 5 across the full range. Response rates were uniformly acceptable (about 80% or better; Huisman & Steglich, 2008). Percent non-White ethnicity varied across schools but all schools had a substantial number of non-White students. Network statistics and, especially, unsupervised time spent with peers varied somewhat across schools. Onset to first alcohol use was just below 30% for students entering sixth grade, rising to about 58% by the end of eighth grade, comparable to other studies of early adolescent drinking (Guttmannova et al., 2011).

Meta-Analysis

Table 3 summarizes meta-analysis results of school-by-school models for first alcohol use. The *mean parameter* columns contain the estimated mean in the population of schools, whereas the *standard deviation* columns refer to the standard deviation in this population, corrected for unreliability of the individual observed school means. Network change rates, not shown, were generally between 10 to 20. These rates correspond to the number of tie changes an actor could make from one observation occasion to the next (Snijders et al., 2010). Even so, best friend nominations varied considerably even over these relatively short interwave periods, with Jaccard coefficients (measuring choice stability on a 0–1 scale) in a range of about .20–.30. The unlimited choice network assessment combined with school-wide choice sets probably were responsible. Nevertheless, SABM is generally tractable with such data (Ripley et al., 2012), and in any case, final model quality, measured by convergence and reasonable standard error estimates, is the ultimate criterion.

For network evolution, friendship choices were predicted as expected, by ego outdegrees (the fewer friends ego has chosen, the more likely that another will be added), reciprocity (if alter has already chosen ego, ego is more likely to choose alter, or alter drops his or her choice), transitivity (ego is more likely to choose alters who are friends of existing friends), 3-cycles (a tendency to avoid intransitive friendship structures, that is, *a* chooses *b* chooses *c* chooses *a*), same or adjacent grade, same gender and ethnicity, as well as effects of the gender and grade of ego and alter. These effects are known alternatives to friendship formation based on drinking similarity, hence controlling for them is important. Effect directions and approximate magnitudes were similar to those obtained in other SABM studies of adolescent friendships (e.g., Burk et al., 2012; Knecht et al., 2011; Mercken et al., 2012).

Turning to the selection and exposure effects of primary interest, Table 3 shows that students tend to select friends based on having the same alcohol onset status (drinker or nondrinker), net of covariates ($t(11) = 8.5, p < .001$) (**H1**). This effect did not vary across schools, as shown by the nonsignificant estimated standard deviation. Additional details can be obtained by constructing an *ego–alter selection table* (Table 4), showing the model-predicted propensities to select alters with the same or different drinking onset status, given ego’s drinking onset status (Ripley et al., 2012, Section 13.3). The log-odds ratio for

choosing as a friend a particular person with the same onset status as oneself, compared to another person with a different onset status, assuming both have identical attributes as well as network embeddedness, is $0.039 - (-0.012) = 0.51$ for nonusers, whereas it is $0.025 - (-0.060) = 0.85$ for users. Thus, users are more selective in choosing friends based on same drinking status.

Exposure to already-onset peers (**H2**) was also a highly significant predictor of onset to drinking ($\chi^2(9) = 5.13, p < .001$) and, like the selection effect, did not vary significantly across schools from the pooled mean effect of 1.39. This effect describes a hazard ratio of $e^{1.39} = 4.01$ that differentiates the probability of onset for a student with no drinkers as friends from a student with only drinkers as friends (a unit increase in the proportion of drinking friends). In addition, the hazard rate for first alcohol onset increased with each grade by about $e^{0.14} = 15\%$, reflecting accelerating onset from grades 6–8. The hazard rate for onset was also associated ($\chi^2(11) = 15.1, p < .001$) with the amount of student-reported adult supervision when with friends (**H7**). Rate of onset was about four times greater for youth reporting 30 days of unsupervised time with friends in the previous month, compared to those reporting none. These effects did not vary across schools; standard deviation ² statistics were all nonsignificant.

Selection and Exposure Interactions Not Found

In addition to the meta-analysis, school-by-school models tested for interactions of both selection and exposure effects with gender (**H3, H4**), grade (**H5, H6**), and days without adult supervision (**H8**). No such effects were found in any school. Even in larger schools, models including these interaction terms often failed to converge or produce reasonable standard error estimates, suggesting a conclusion of small or zero effect sizes rather than a lack of data.

Discussion

To summarize, we find evidence in an early adolescent population age approximately 11–14 (grades 6–8) for both selection of friends on the basis of the same alcohol onset status, and an increased risk of onset for youth with a higher proportion of friends with previous onset. These findings clarify the roles of selection and exposure in the earliest years of adolescence in terms of onset to first alcohol use, showing a positive selection-and-influence feedback process that explains how drinking diffuses through this population over time based on friendship linkages. Additionally, rate of onset increases from grade 6 to 8, and it is larger for youth who spend more unsupervised time with peers. Rate did not vary by gender, however, and the selection and exposure effects were not moderated by grade, adult supervision, or gender with either selection or exposure.

The primary novel feature of this analysis is our integration of a dynamic network model (a SABM) for friendship changes with a proportional hazard model for onset to alcohol use. Our analysis represents the first example of this broadly applicable modeling framework. A model of onset may also be thought of as a diffusion process. Diffusion is a natural phenomenon in networks, and long an important topic for network studies (e.g., Granovetter, 1973; Katz & Lazarsfeld, 1955; Rogers, 1995; Valente, 2005). The SABM network hazard model provides an approach for estimating data-driven network diffusion models for ideas, information, innovations, and even the spread of diseases—indeed, of any individual characteristic that can be usefully thought of as being acquired through network linkages.

In the course of applying this new modeling approach, alcohol onset is uniquely measured and not confounded with level of use. This has not been typical in previous studies (e.g.,

Burk et al., 2012; Knecht et al., 2011; Mercken et al., 2012). The role of peer exposure to the initiation of alcohol use is thus clarified by our findings.

Evidence from this study provides one possible mechanism for what Kendler and colleagues (2008) termed the *socially mediated hypothesis* linking early age of onset to later alcohol dependence and problems. This hypothesis proposes that the primarily genetic risk of later alcohol-related problems is mediated by exposure to environmental risk largely responsible for onset. Consistent with this view, our results suggest that undersupervised youth who begin drinking relatively early may provide the environmental *point of entry* for drinking behavior in early adolescent social ecologies predicted by genetically informative studies (e.g., Kendler et al., 2008; McGue et al., 2006), by exposing their friends to drinking. Further, drinking peer clusters are self-reinforcing, in that drinkers have an affinity for other drinkers as friends. This property of drinking behavior would tend to perpetuate consumption and lead to alcohol-related problems, especially among genetically vulnerable youth, for instance, those high on lack of harm avoidance and poor impulse control, or who require more alcohol to feel intoxicated (Schuckit et al., 2012). Such youth are quite possibly no more vulnerable to exposure-related risk for onset than their peers, but pay a price later on.

Our results differ from those of Burk et al. (2012), who found exposure effects only in older adolescents. Whereas sociocultural differences between samples (U.S. vs. Swedish youth) could explain the difference, it may also be that onset *but not later consumption* is mediated by peer exposure in younger adolescents. Indeed, because onset and consumption are confounded in most youth consumption measures, including the Burk study, it is not clear whether Burk and colleagues' results were driven by consumption or by onset. Analyses comparing peer effects on initiation versus acceleration of drinking across adolescence are needed.

As we hypothesized, adult monitoring was found to be an important direct predictor of rate of onset, but it did not moderate alcohol-related selection or exposure effects. Studies that look at onset using different measures, for example, parental knowledge of their children's activities and child disclosure, are needed, however (Kerr & Stattin, 2000; Kerr, Stattin, & Burk, 2010). Further, dynamic cascade theory (Dodge et al., 2009) proposes a dynamic interchange between youth behavior and parenting, which could be examined in a more elaborate SABM with a broader parenting measure.

Limitations

This work differed from other studies of adolescent friendship networks and substance use in several potentially important ways. First, four assessments per year is unusual, though not unprecedented (e.g., Knecht et al., 2011, also obtained four assessments, but only for a single year). Our data showed some tendency to select fewer alters over time, which may have reflected survey fatigue, because participants would learn that every alter selected as someone you spend free time with would be followed up with further questions. The absolute average participation decline of about 25% from wave 1 to wave 8 is not trivial, and its absolute significance is unclear. It is somewhat reassuring that parameter estimates for the three schools for which fewer than eight waves of data were available were not different from the other schools.

Additionally, this study employed an unlimited friendship choice format in which any other study participant was available to be chosen. Some previous methodological studies have recommended that because false negative links are more damaging than false positive links, no limits be placed on numbers of friends participants can select (e.g., Borgatti, Carley, & Krackhardt, 2006). Other studies, however, suggest that the impact of false positive and

false negative links is quite complicated and contingent (Wang, Shi, McFarland, & Lescovec, 2012). Given this, our decision to exclude extreme outdegree outliers seems reasonable, particularly in light of our inability to identify any predictors of these outliers.

Finally, the time-to-onset measure available to us was incomplete: at each wave, only drinking during the 30 days prior to the assessment was obtained. This would lead to some instances of missed onset, biasing the overall rate of onset in a downward direction. Fortunately, a proportional hazard model can still estimate *relative* hazard rates accurately, provided that drinking during the observed periods is not correlated with predictors. This could not be empirically addressed, given the uniform absence of data from one assessment to 30 days prior to the next, but we see no strong reason to expect such correlations.

Future Directions

Our goal in this study has been concerned with understanding the role of peer friendships in onset to drinking among young adolescents. This topic has been little studied up to now. We have alluded to the relevance of peer exposure as a mechanism or causal pathway affecting risk of onset, but in the course of doing so, we have touched on a number of more specific and potentially important distinct peer-related mechanisms. These include some that can be reasonably termed *influence* in the ordinary sense of the term, that is, as something that persuades, affecting attitudes or motivations. Other mechanisms may build on existing attitudes and motivations (a willingness to drink alcohol, the need for peer acceptance) and be more facilitative and logistical, for instance, informing peers about social events where there will be a supply of alcoholic beverages or providing a place to drink without interference by adults and company to drink with. A few studies have begun to address exposure-related mechanisms (e.g., Burk et al., 2012; Molloy, Gest, & Rulison, 2011), but progress will probably require more detailed information about the nature and content of friendship relationships, as well as the individual characteristics that may be changed by exposure to drinking peers and possibly mediate the likelihood of first use (e.g., self-concept; Molloy et al., 2011). The SABM framework can, in principle, model many such mechanisms as coevolving dynamic systems, simultaneously in the same model, if suitable data are available (cf. Snijders, Lomi, & Torló, 2012).

Considerable progress has been made in the last few decades towards understanding how to study adolescent peer social dynamics. These methodological advances are giving us a more confident and nuanced understanding of dynamic mechanisms that affect drinking and other forms of substance use among youth. In this paper, novel methodology has allowed us to make an initial statement about peer exposure risks for drinking onset. Our results suggest that future studies need to find ways to separate onset measures from drinking patterns once onset has occurred, as the populations at risk and the risk mechanisms themselves may be different for each.

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Table 1
Descriptive Statistics of School Networks and Students By Wave

	W1	W2	W3	W4	W5	W6	W7	W8
Average enrollment	440.00	437.25	437.83	400.82	402.60	399.70	398.80	395.30
Average ineligible	24.25	25.58	25.83	17.82	31.90	31.70	30.90	30.80
Average surveyed	337.67	336.75	334.83	290.91	308.00	300.80	299.40	298.60
Average response rate	81%	81%	81%	75%	83%	81%	81%	81%
Average percent female	49%	50%	49%	51%	50%	50%	50%	50%
Average percent non-White	42%	56%	56%	26% ^a	35%	40%	22%	42%
Average outdegree	3.58	3.52	3.42	3.03	3.03	2.90	3.00	2.83
Reciprocity fraction	.17	.17	.17	.17	.16	.16	.17	.16
Transitivity index	.21	.21	.22	.22	.22	.22	.23	.22
3-Cycle Index	.19	.19	.19	.18	.19	.18	.19	.18
Average days no adult supervision	8.72	8.82	9.68	9.26	8.78	8.72	8.99	9.66

Note. Eight waves of data are included for 10 schools; one school dropped out after wave 4, and one school provided consistent data for waves 1–3 only.

^aOne school with a high percentage of non-White students missed this wave because of scheduling problems, leading to the observed drop in non-White participants in Wave 4.

Table 2
Descriptive Statistics of School Networks and Students By School

	<i>School</i>											
	1	2	3	4	5 ^a	6	7	8	9	10	11	12
Waves participated	8	8	4	8	4	3	8	8	8	8	8	8
Average ^b enrollment	426	210	132	685	395	851	448	244	700	574	228	360
Average ineligible	29	13	4	13	23	99	33	13	59	39	9	33
Average surveyed	314	170	108	498	296	663	343	179	531	399	192	304
Average response rate	79%	86%	84%	74%	79%	88%	82%	77%	82%	74%	87%	93%
Average percent female	53%	46%	47%	52%	47%	48%	51%	52%	48%	49%	44%	58%
Average percent non-White	36%	19%	18%	27%	22%	56%	31%	29%	47%	83%	26%	37%
Average outdegree	3.73	3.97	3.69	2.27	3.89	3.75	3.61	4.54	3.20	2.36	2.61	3.17
Reciprocity fraction	.16	.18	.17	.16	.15	.17	.19	.19	.15	.13	.18	.21
Transitivity index	.21	.30	.31	.17	.20	.18	.25	.26	.20	.20	.24	.28
3-Cycle Index ^c	.18	.17	.15	.23	.18	.21	.17	.18	.19	.19	.16	.15
Average days no adult supervision, previous month	12.12	10.17	10.92	7.40	8.99	10.75	9.08	7.91	9.26	7.74	9.82	7.81

^a Grades 7–8 only.

^b All averages are per wave participated, weighted by number of participants per wave.

^c Fraction of connected triads of the form $i \rightarrow h \rightarrow j$.

Table 3
Onset to First Alcohol Use: Results of RSIENA Meta-Analytic Procedure (12 Schools)

	Mean Parameter		Standard Deviation		df
	Estimate	SE	Estimate	2	
Network Dynamics					
Outdegree	-3.394***	0.120	0.417***	1610.7	11
Reciprocity	1.585***	0.055	0.192***	112.0	11
Transitive triplets	0.584***	0.037	0.127***	415.5	11
3-Cycles	-0.527***	0.031	0.106***	47.6	11
Gender female - ego	0.033	0.022	0.071***	44.6	10
Gender female - alter	-0.061**	0.015	0.052***	41.1	11
Same gender	0.494***	0.021	0.072***	93.5	11
Same ethnicity	0.120**	0.033	0.110***	267.8	10
Grade - ego	0.089**	0.025	0.088***	136.1	11
Grade - alter	-0.121***	0.018	0.061***	60.9	10
Similar grade	1.456***	0.133	0.460***	1107.4	11
Alcohol onset - ego	0.031*	0.013	0.042**	28.4	10
Alcohol onset - alter	0.017	0.021	0.069***	52.4	10
Same alcohol onset (selection)	0.068***	0.008	0.027	11.3	11
Behavior Dynamics					
Average exposure effect on rate of alcohol onset (exposure)	1.390***	0.271	0.689	3.2	9
Grade effect on rate of alcohol onset	0.142*	0.057	0.177	12.8	10
Days no adult supervision effect on rate of alcohol onset	0.136***	0.009	0.043	9.4	11

* $p < .05$.

** $p < .01$.

*** $p < .001$.

Table 4
Friendship Selection Table for Onset to Alcohol Use

Onset Status	Chosen (Alter)	
	Not Onset	Onset
Chooser (Ego)		
Not Onset	0.039	−0.012
Onset	−0.060	0.025

Note. Shows the net effect of onset status of ego (the chooser) and alter (the chosen) on the Alcohol Onset Model's (see Table 3) *evaluation function*, i.e., the tendency to select or not select others as friends based on their alcohol onset status.