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USING SOCIAL NETWORK ANALYSIS TO EXAMINE THE INTERSECTION OF  
ADOLESCENT FRIENDSHIPS AND HEALTH BEHAVIOR

by

Emily Long

A dissertation submitted in partial fulfillment  
of the requirements for the degree

of

DOCTOR OF PHILOSOPHY

in

Psychology

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Logan, Utah

2018

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## ABSTRACT

Using Social Network Analysis to Examine the Intersection of Adolescent  
Friendships and Health Behavior

by

Emily Long, Doctor of Philosophy

Utah State University, 2018

Major Professor: Ginger Lockhart, Ph.D.  
Department: Psychology

Adolescence marks a vulnerable developmental period for health behavior, and research demonstrates that social context and interpersonal relationships impact the health behavior choices of adolescents. Advances in the field of social network analysis allow researchers to rigorously examine the dynamics between adolescent social relationships and their health. Using perspectives from developmental theories, the present dissertation explicitly investigates the bidirectional relationship between adolescent friendships and critical components of adolescent health. Chapter 2 uses data from two high schools within the National Longitudinal Study of Adolescent to Adult Health (Add Health;  $n = 640$ ,  $n = 1156$ ) to examine two divergent health behaviors (i.e., alcohol use and physical activity) in conjunction in order to (1) model the differential impact of friendships on each behavior, and (2) investigate the relationship between the behaviors. Results demonstrate distinct differences in the mechanisms through which

adolescent friends impact patterns of alcohol use and physical activity. Chapter 3 uses data from the Social Network Study ( $N = 1563$ ) to concurrently model the impact of two forms of peer influence on adolescent cigarette use: (1) the effect from the level of smoking among an adolescent's friends, and (2) the effect from an adolescent's perceived social acceptability of smoking. Results demonstrate that adolescent smoking was significantly predicted by levels of perceived social acceptability, but not by the level of smoking within an adolescent's friendship group. Last, Chapter 4 applied a social network design to uncover the mechanisms through which chronic illness shapes adolescent friendships. Data from six high schools within Add Health ( $N = 461$ ) was used to investigate social marginalization, social withdrawal, and homophily based on chronic illness. Results demonstrate no significant evidence of these social processes, such that the patterns of friendship for adolescents with chronic illness and adolescents without chronic illness were similar. Separate abstracts are provided sequentially for each chapter within the dissertation.

(109 pages)

## PUBLIC ABSTRACT

Using Social Network Analysis to Examine the Intersection of Adolescent  
Friendships and Health Behavior

Emily Long

Adolescence marks a vulnerable developmental period for health behavior, and research demonstrates that social context and interpersonal relationships impact the health behavior choices of adolescents. In addition, theories of adolescent development suggest a bidirectional relationship between environmental factors, including social relationships, and health. Friendships are one of the most salient relationships during adolescence, and new methods from the field of social network analysis allow researchers to explicitly examine the mechanisms through which friends influence health behavior, and simultaneously, how health and health behavior impacts the formation of friendships. Importantly, social network methods (e.g., stochastic actor-based models, exponential random graph models) overcome statistical limitations of alternative methodology. For example, methods from social network analysis incorporate interdependencies between individuals in a social network (e.g., adolescents within a school) into the statistical modeling framework, and are capable of simultaneously estimating social and behavioral outcomes.

Through a sequence of three distinct studies, this project applies rigorous methods from social network analysis to investigate: (1) the differential impact of adolescent friendships on health-risk (e.g., alcohol use) and health-protective (e.g., physical activity)

behaviors; (2) the role of perceived social acceptability and peer influence in shaping adolescent cigarette use; and (3) the social consequences, including social withdrawal and social marginalization, of adolescents with chronic illness.

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Last, this research uses data from the National Longitudinal Study of Adolescent Health, a program project directed by Kathleen Mullan Harris and designed by J. Richard Udry, Peter S. Bearman, and Kathleen Mullan Harris at the University of North Carolina at Chapel Hill, and funded by grant PO1-HD31921 from the Eunice Kennedy Shriver National Institute of Child Health and Human Development, with cooperative funding from 23 other federal agencies and foundations. Special acknowledgement is due to Ronald R. Rindfuss and Barbara Entwisle for assistance in the original design. Information on how to obtain the Add Health data files is available on the Add Health website (<http://www.cpc.unc.edu/addhealth>). No direct support was received from grant



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# **CHAPTER 1**

## **INTRODUCTION**

Adolescence is a critical developmental period for health behavior and research consistently demonstrates that social context and interpersonal relationships influence a wide array of behaviors (Burk, Steglich, & Snijders, 2007; Umberson & Montez, 2010). In addition, developmental theories (Bronfenbrenner & Morris, 2006) assert that the sociocontextual environment is central to adolescent development, in that there is a continuous, bidirectional interaction between individual characteristics and sociocontextual factors. Through this framework, adolescent development is acknowledged as dynamic and changing, and health behavior (e.g., substance use, physical activity) results both from adolescents themselves, as well as their surroundings.

Given that friendships are one of the most salient relationships during adolescence (Parker et al., 2006), there is a critical need to understand the relation between health-risk behavior and friendships. Further, accumulating evidence indicates that peers can be effectively utilized in behavioral interventions to change maladaptive behavior and promote healthy behavior (Osgood et al., 2013b; Umberson & Montez, 2010; Valente, 2010, 2012). Consequently, adequate design of intervention and prevention programs targeting adolescent health depends upon a clear understanding of the peer mechanisms surrounding these behaviors.

Recent advances in the field of social network analysis allow researchers to explicitly examine the extent to which adolescent friendships shape health behavior, and conversely, how health behavior influences friendship. Broadly speaking, social network

analysis is an interdisciplinary field aimed at uncovering the structure of social connections among individuals. When applied to health behavior research, social network analysis is used to examine how specific attributes or behaviors both shape relationships, and are shaped by these social connections. In this way, social network methods mirror the framework of bioecological theory by explicitly modeling the bidirectional interaction between individual characteristics (e.g., health behavior) and sociocontextual factors (e.g., peer relationships).

Importantly, social network methods overcome critical limitations of alternative methodology. For example, friendships in social network data are auto-correlated and therefore violate assumptions of independence, thus precluding the use of conventional statistical techniques. In addition, structural features of a social network (i.e., the way individuals within a social network are connected) are known to play in role in subsequent relationship ties (Snijders, Steglich, & Schweinberger, 2007; Snijders, van de Bunt, & Steglich, 2010). Methods focused on dyadic relationships without controlling for effects of the social network in which these dyadic relationships are embedded are therefore limited. Given these methodological complexities, statistical models (e.g., stochastic actor-based models, SABS; exponential random graph models, ERGMs) have been developed that embed adolescents within their peer network and predict both social and behavioral outcomes.

These models specifically incorporate the structure and interdependence of social network data into the statistical modeling process, and are thus well situated to investigate the dynamic relationship between adolescent friendships and health behavior.

Consequently, the use of social network methods in fields such as developmental psychology and prevention science has grown rapidly in recent years. As such, a strong body of literature has emerged to highlight the reciprocal relationship between adolescent friendships and health behaviors such as substance use (Wang, Hipp, Butts, Jose, & Lakon, 2016), delinquency (Rulison, Kreager, & Osgood, 2014), and aggression (Laninga-Wijnen et al., 2017).

Despite these gains, social network analysis remains a new field and many critical questions regarding the dynamics between adolescent friendship and health remain. Specifically, adolescence is marked with simultaneous increases in health risk behavior and declines in health protective behavior (Kann et al., 2016), yet social network studies typically examine one behavior in isolation (Veenstra, Dijkstra, Steglich, & Zalk, 2013). As a result, little is known about the relationship between health risk and health protective behavior, especially in the context of friendships. Therefore, Chapter 2 examines two divergent health behaviors (i.e., alcohol use and physical activity) in conjunction in order to (1) model the differential impact of friendships on each behavior, and (2) investigate the relationship between the behaviors.

Further, though research suggests that adolescents are influenced by the substance use patterns of their friends, it is also known that some substances are perceived as more socially acceptable (Kulesza, Larimer, & Rao, 2013), particularly during adolescence (Eisenberg, Tounbourou, Catalano, & Hemphill, 2014). No research to date has considered the role of perceived acceptability when examining social influence on substance use. As a result, Chapter 3 concurrently investigates the impact of peer



influence and perceived social acceptability on longitudinal trends in adolescent cigarette use.

Last, a primary benefit of applying social network approaches to adolescent development lies in the ability to not only examine behavioral outcomes, but also model the ways through which individual attributes (e.g., health indicators) shape social outcomes (e.g., friendship). Findings suggest that adolescents with chronic illness are both socially isolated (Manning, Hemingway, & Redsell, 2013; Yeo & Sawyer, 2005) and engage in increased levels of health risk behavior (Barnes, Eisenber, & Resnick, 2010; Suris, Michaud, Akre, & Sawyer, 2008). Given this vulnerability, Chapter 4 applies a social network design to uncover the mechanisms through which chronic illness shapes adolescent friendships.

Findings from all three studies inform developmental research through the identification of novel intervention targets from a social network perspective. The specific applied impact of each study is discussed first in the respective chapter, and again in the concluding Chapter 5. Further, in order to ease interpretability of social network terms across an interdisciplinary audience, Chapters 2, 3, and 4 each contain a table detailing the name and interpretation of all parameters included in the final models.

## CHAPTER 2

### STUDY 1: NETWORK-BEHAVIOR DYNAMICS OF ADOLESCENT FRIENDSHIPS, ALCOHOL USE, AND PHYSICAL ACTIVITY<sup>1</sup>

#### Abstract

*Objective:* The coevolution of adolescent social networks, alcohol use, and physical activity is studied. Previous research has independently evaluated each behavior, overlooking the potential power of examining their development within a shared social context. The current study extends previous research by examining the dynamics of friendship networks and alcohol use and physical activity in conjunction, including the concurrent engagement in both behaviors, with a nationally representative sample of U.S. adolescents. Special attention is paid to differing patterns of peer selection and peer assimilation across behaviors. *Methods:* Data come from two high schools ( $n = 640$ ;  $n = 1,156$ ) within the National Longitudinal Study of Adolescent to Adult Health. Longitudinal stochastic actor-based models were used to separate peer selection and assimilation processes in order to differentiate the mechanisms linking friendships and both behaviors, as well as the relationship between alcohol use and physical activity. *Results:* Findings suggest distinct differences in the importance of peer selection and assimilation processes to adolescent alcohol use and physical activity. In both schools, adolescents selected friends based on similarity in alcohol use, but no selection effect was

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<sup>1</sup>Copyright © 2017 American Psychological Association. Reproduced with permission (see Appendix A). Coauthors: Tyson Barrett & Ginger Lockhart. Author release letter for Tyson Barrett is found in Appendix B.

found for physical activity. Conversely, assimilation to friends' behavior occurred for physical activity, yet evidence for alcohol assimilation was mixed. No significant relationship between alcohol use and physical activity emerged. *Conclusions:*

Intervention efforts that focus on friend influence in changing health behavior may have particular success with adolescent physical activity. Programs aimed at alcohol use would benefit from including an emphasis on preventing negative friend formations.

*Keywords:* adolescent health behavior, friendships, alcohol use, physical activity, stochastic actor-based models

## **Introduction**

Adolescence is a vulnerable developmental period for health behavior, with simultaneous declines in health-protective behaviors and increases in health-risk behaviors (Kann et al., 2016; U.S. Department of Health and Human Services [USDHHS], 2010). Knowledge of how adolescents become involved in health-risk and health-protective behaviors is crucial to developmental research. Alcohol use and physical activity display opposite trajectories during adolescence, with notable increases in alcohol use (Johnston, O'Malley, Bachman, & Schulenberg, 2013) and decreases in physical activity (Child Trends, 2010). Currently, alcohol is the number one most abused drug by U.S. youth (National Institute on Alcohol Abuse and Alcoholism [NIAAA], 2015), with nearly 70% of adolescents consuming alcohol by the 12<sup>th</sup> grade (Johnston et al., 2013). Conversely, it is estimated that only one fourth of U.S. high school students achieve the recommended level of physical activity set by the Centers for Disease

Control, and 15% of adolescents report no physical activity in the past week (Kann et al, 2016).

Previous research indicates that peer group behavior in terms of alcohol use (see Leung, Toumbourou, & Hemphill, 2014, for a review) and physical activity (see MacDonald-Wallis, Jago, & Sterne, 2012; and Sawka, McCormack, Nettel-Aguirre, Hawe, & Doyle-Baker, 2013 for reviews) is consistently correlated with individual levels of these behaviors. The increased priority of peer relations and peer opinions during adolescence, as well as growing evidence that peers can be effectively utilized in behavioral interventions (Osgood et al., 2013b; Valente, 2012), demonstrate the importance of understanding the social context surrounding these behaviors.

To date, research on adolescent social networks and alcohol use and physical activity has neglected the simultaneous study of these behaviors, overlooking the power of examining their shared social context. Social connections during adolescence are potentially powerful tools to both change maladaptive behavior and promote healthy behavior (Umberson, Crosnoe, & Reczek, 2010; Valente, 2010), but the ability to use these relationships beneficially is hindered by a lack of understanding on peer dynamics across varying behaviors. Given that alcohol use and physical activity display opposite trajectories during adolescence, and research suggests the importance of peer relations for both behaviors (Leung et al., 2014, MacDonald-Wallis et al., 2012; Sawka et al., 2013), simultaneously exploring the social processes behind these behaviors offers critical insight into the role of friendships in adolescent health behavior development.

Further, the relationship between alcohol use and physical activity is not well

understood. Some evidence suggests that physical activity provides a protective effect against the use of alcohol (Terry-McElrath & O'Malley, 2011), while other studies have found higher physical activity levels linked to increased alcohol consumption (Bigelow, Villarruel, & Ronis, 2014). However, existing research has neglected to control for peer factors in this relationship. Physical activity as a protective factor against the use of alcohol could suggest the inclusion of physical activity components into alcohol prevention programs, however recommendations cannot be made until this relationship is explored while accounting for social network factors.

The current study addresses this important void by using recent advances in stochastic actor-based (SAB) models (Snijders et al., 2010) to longitudinally investigate the coevolution of adolescent friendship networks, alcohol use, and physical activity. This method allows alcohol use and physical activity to be nested within the shared social environment of an adolescent school network in order to model the processes through which friendships and both behaviors develop over time. In addition, the concurrent engagement in these behaviors is investigated, such that the effect of physical activity level on subsequent alcohol use, and the effect of alcohol use level on subsequent physical activity, is explored. The current study illuminates the complex interconnections between adolescent friendships, alcohol use, and physical activity in order to explore differences in the mechanisms of peer influence and highlight potential avenues for behavioral intervention (Leung et al., 2014; Umberson & Montez, 2010; Valente, 2010; Valente & Pumpuang, 2007).

## **Peer Mechanisms and Health Behavior**

Friendships are a central component to adolescent health and friendship groups tend to show similarities in health behaviors (Burk et al., 2007; McPherson, Smith-Lovin, & Cook, 2001; Umberson & Montez, 2010). The bioecological theory of development (Bronfenbrenner & Morris, 2006) asserts that adolescent development is driven by the bidirectional processes of selecting environments (e.g., friendship groups), and the subsequent influence of those environments on adolescents (e.g., behavioral choices). Through this framework, adolescent development is acknowledged as dynamic and changing, and health behavior, such as alcohol use and physical activity, results both from the adolescents themselves, as well as their surroundings.

Two peer mechanisms, selection and assimilation, capture these bidirectional processes. Peer selection refers to similarity existing prior to friendship formation, resulting in adolescents preferentially befriending those who are similar to themselves, while assimilation refers to similarity that develops after friendships have been established (Veenstra et al., 2013). When applied to interventions to alter adolescents' health behavior, selection suggests a focus on group formation processes, while assimilation suggests either disrupting negative relationships that have already formed or using peers to promote positive behavior change. Consequently, a clear representation of these processes can be decisive for the success or failure of prevention or intervention programs (Steglich, Snijders, & Pearson, 2010; Valente, 2010).

Separating the effects of selection and assimilation is methodologically challenging given the complexity inherent in studying dynamic interdependent data.

Recently developed SAB models (Snijders et al., 2010) overcome three primary limitations of previous methodology, allowing for more precise estimates of these underlying processes. First, previous methods focused on dyadic relationships without controlling for effects of the social network in which these dyadic relationships are embedded. Several structures of network formation (i.e., the way individuals within a social network are connected) are known to play in role in subsequent relationship ties. For example, friendships are more likely to form when two individuals have a friend in common, termed transitivity (Snijders et al., 2007). Second, the inherent interdependence of data between friendship partners in social network designs violates assumptions of independence underlying conventional statistical methods. Lastly, previous methods did not account for unobserved changes between observation periods resulting from the dynamic nature of relationships and behavior. For detailed descriptions of these limitations see Snijders et al. (2010) and Steglich et al. (2010).

SAB models address these challenges by specifically incorporating into the modeling process the interdependencies present in network data, and the dynamic, constantly evolving nature of selection and assimilation processes. SAB models test the effects of selection and assimilation by simultaneously representing changes in friendships and changes in behavior, while taking into account the effects of friendship network structure and individual and dyadic attributes (Snijders et al., 2010). Consequently, SAB models mirror the framework of bioecological theory by explicitly modeling the bidirectional processes of selecting environments (i.e., peer selection), and the subsequent influence of those environments on adolescents (i.e., peer assimilation).

### **Empirical Evidence from Stochastic Actor-Based Models**

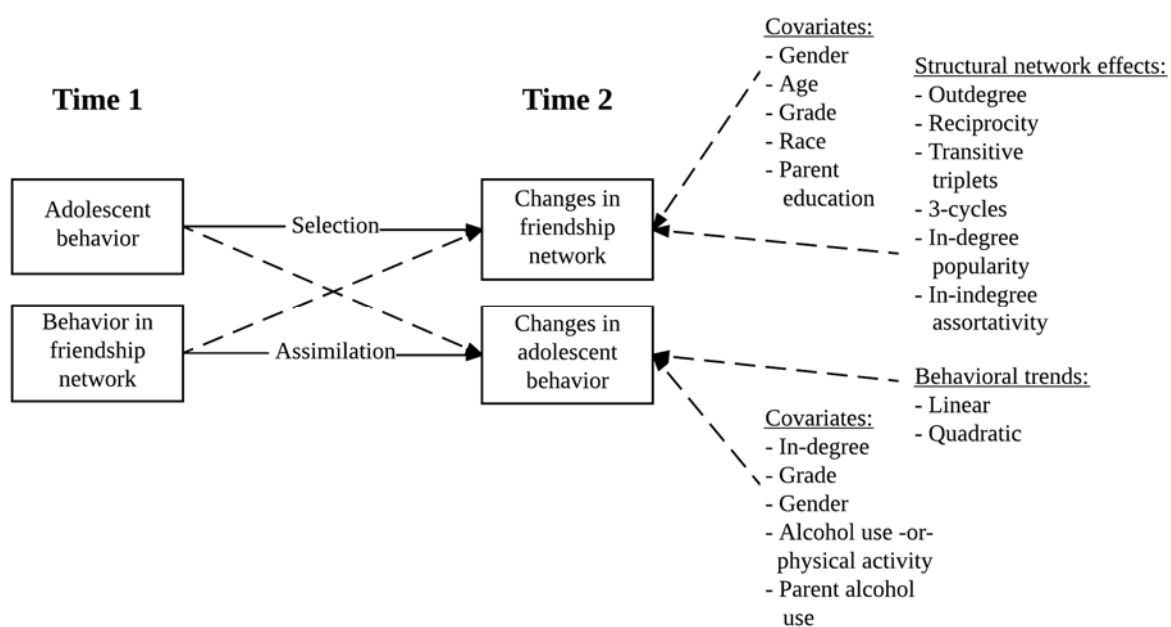
Previous studies that have employed SAB models to adolescent alcohol use and physical activity have been limited to independent investigations of each behavior, and further, have yielded mixed results. For alcohol use, some studies have found selection effects to be stronger (Knecht, Weesie, Burk, & Steglich, 2010; Mundt, Mercken, & Zakletskaia, 2012), while others support assimilation as the influential peer mechanism (Mathys, Burk, & Cillessen, 2013; Osgood et al., 2013a). Research on physical activity seems to indicate greater contribution from assimilation than selection (De la Haye, Robins, Mohr, & Wilson, 2011; Shoham et al., 2012), yet some evidence suggests the two processes are comparable in strength (Simpkins, Schaefer, Price, & Vest, 2013).

An early application of SAB models by Pearson et al. (2006) using a Scottish sample is the only existing study to offer preliminary insight into the relationship between adolescent friendships, alcohol use, and one form of physical activity, sports participation (e.g., football, gymnastics, skating). Results demonstrated significant effects of peer selection and assimilation on alcohol use, but not for sporting activity. The study also examined the concurrent engagement in alcohol use and sporting activity and found no significant relationship between the two behaviors. However, findings from this study are limited by the use of a dichotomous sporting activity variable and the exclusion of forms of physical activity outside of sports (e.g., jogging). Importantly, the study omits the quadratic shape effect, a necessary measure of the behavioral shape distribution (Ripley, Snijders, Boda, Vörös, & Preciado, 2018).

The current study extends previous research by examining the dynamics of



friendship networks and alcohol use and physical activity in conjunction, including the concurrent engagement in both behaviors, on a nationally representative sample of U.S. adolescents. To accomplish this, the following research questions are addressed: (1) Do adolescents select friends based on similar alcohol use behavior? (2) Do adolescents select friends based on similar physical activity behavior? (3) Do adolescents assimilate to their friends' alcohol use behavior? (4) Do adolescents assimilate to their friends' physical activity behavior? (5) Does the relative strength of peer selection and peer assimilation differ across these behaviors? (6) Does level of alcohol use predict level of physical activity, or vice versa, while controlling for important covariates? Figure 2-1 presents the conceptual framework for addressing these questions.



*Figure 2-1.* Conceptual representation of peer selection and peer assimilation effects using SAB models: Selection and assimilation effects are estimated for both alcohol use and physical activity, while taking into account: (1) individual behavior and behavior in the network at Time 1, (2) structural network effects, (3) behavioral tendencies, and (4) important covariates for friend selection and behavior development.

## Method

### Participants and Procedure

The current study is based on students in two of the largest high schools in The National Longitudinal Study of Adolescent to Adult Health (Add Health; Harris et al., 2009), a nationally representative multi-wave panel study of adolescents in grades 7-12 at the onset of the study in 1994. Add Health consists of a sample of 80 high schools and 52 middle schools from the US, selected with unequal probability of selection, stratified by region of country, urbanicity, school size, school type, and ethnicity ( $N = 90,118$ ). A subsample of 20,745 adolescents were pulled from the full sample to complete more comprehensive in-home surveys, conducted in 1995 (Wave I). Adolescents were re-interviewed approximately one year later (Wave II). The current study utilizes data from the Wave I and Wave II in-home interviews, as friendship and full behavioral data is limited to these waves.

Only 16 schools in the Add Health dataset collected complete longitudinal network data, a requirement of the present study. Of these potential schools, 14 were eliminated for high rates of attrition, low response rates ( $< 75\%$ ), or missing friendship data at Wave I. Although SAB models can accommodate missing data, high rates of nonresponse and missingness are likely to result in biased parameter estimates (Huisman & Steglich, 2008). The sample schools represent two different types of public high schools in the U.S. School A ( $n = 640$ ) is located in the Midwest and composed of a racially homogeneous student body, whereas School B ( $n = 1,156$ ) is located in the West and is more racially diverse. Analyses were conducted on each school separately, to

reflect the two distinct networks and allow for qualitative comparisons in discussion of results.

The current study focuses on students in grades 9-11 at Wave I, as these students were more likely to remain part of their school network at Wave II, and 12<sup>th</sup> grade students at Wave I were not re-interviewed. Students not eligible for participation at Wave I were excluded from the sample. Despite the age of the data, Add Health remains one of the most comprehensive sources of friendship and behavioral data for social network analyses. Further, research continues to demonstrate the relevance of Add Health data to the study of friendship network characteristics and a wide array of adolescent health behaviors (see Jeon & Goodson, 2015, for a review).

## **Measures**

Friendship ties. Sociometric data in the form of friendship nominations collected at Wave I and Wave II serve as the friendship measure. Adolescents were asked to identify their five closest female and five closest male friends from a provided roster. ID codes were used to link adolescents to nominated friends, creating friendship networks as well as allowing for behavioral data to be collected directly from adolescents. Nominations for out-of-school friends were not considered, as data was not collected on these individuals. In this way, friendships are restricted to those occurring within the school in which the adolescent is enrolled, allowing for the formation of two complete networks (i.e., School A and School B) of adolescents, a requirement of our analyses. An administrative error in Add Health occurred during friendship data collection, resulting in a small subset of students (approximately 5% of the sample) who were only able to

nominate one male and female friend. These students were flagged and a limited nomination variable was included in the network evolution model in order to control for any effects from this error.

**Alcohol use.** Alcohol use is assessed through one question measuring the frequency of alcohol consumption within the last year, with answers ranging from never to more than once a week. Alcohol use is coded as follows: 1 (no use), 2 (once or twice a year), 3 (three to 12 times), 4 (monthly), 5 (weekly), and 6 (more than once a week).

**Physical activity.** Physical activity is measured through one question on various forms of physical activity. Adolescents were asked how many times in the past week they had participated in three types of physical activities: a) active sports, such as baseball, softball, basketball, soccer, swimming, or football, b) exercise, such as jogging, walking, karate, jumping rope, gymnastics, or dancing, and c) rollerblading, rollerskating, skateboarding, or bicycling. Responses ranged from 0 (not at all) to 3 (5 or more times). Items were summed to create a variable ranging from 0 to 9.

**Demographic control variables.** In order to provide accurate estimates of associations between adolescent friendships and alcohol use and physical activity, potential predictors associated with friendship formation and both behaviors must be controlled (Steglich et al., 2010). Literature consistently demonstrates that adolescent social relations form around basic demographic characteristics such as gender, grade, race, and parental education (McPherson et al., 2001). Accordingly, the current study incorporates these important demographic variables. Gender is coded as male or female. Grade is coded as grade level at Wave I. Parental education was assessed on a four-point

scale, ranging from less than a high school education to post-college. Race/ethnicity was categorical and only included in network processes for School B, given that School A was composed almost entirely of one racial identity. Gender and grade were also used as basic demographic predictors for both behaviors. Pre-analytic score testing procedures (Schweinberger, 2012), discussed in model selection procedures, established parental drinking as an additional demographic control variable for alcohol use. Parental drinking was assessed on a 5-point scale representing frequency of parental consumption.

**Missing data.** Two forms of missing data were present in the current sample; item nonresponse (i.e., completed survey with one or more missing responses) and participant non-response (i.e., attrition). Item nonresponse was imputed by the SIENA software, but treated as noninformative in parameter estimation (Huisman & Steglich, 2008). In this method, missingness in dependent behavioral variables is treated with imputation of previously observed values if missingness occurs at Wave II, and imputation of values from Wave II if missingness occurs at the first observation. Missingness in both observations results in imputation of the observationwise mode of the variable. Missing covariate data is treated by using the sample mean. Participant nonresponse was treated by coding outgoing friendship ties as missing for adolescents who still attended the school at Wave II, but did not complete a survey. Structural zeros were used for adolescents who no longer attended the school at Wave II (Ripley et al., 2018). The method of treating missing data as noninformative is described in detail in Huisman and Steglich (2008), with an overview provided in Ripley et al. (2018).

## **Plan of Analysis**

The current study investigates the coevolution of adolescent friendships, alcohol use, and physical activity using stochastic actor-based (SAB) models for network-behavior dynamics (Snijders et al., 2010), specified using SIENA version 4.0 (Ripley et al., 2018). The overall modeling process determines the probabilities associated with an adolescent making changes to their social ties or behavior, given the current network structure and behavior of others. Friendship network and behavioral change are represented by parameter estimates derived from a continuous-time Markov process, which repeatedly imputes likely change trajectories occurring between measurement periods. Friendship ties and behavior observed at Wave I are treated as exogenous in the model, and an iterative, simulation-based algorithm is carried out until simulated data adequately represent observed data at Wave II (technical description of statistical estimation procedures available in Snijders et al., 2007, 2010).

Separate network evolution and behavior evolution models are integrated, as the current state for the continuously changing friendship network is the dynamic constraint for the behavioral changes, and vice versa. The friendship network evolution model captures the rules governing friendship changes by testing a set of parameters upon which friendship choice probabilities depend. Similarly, behavior evolution models determine the rules governing behavioral change by testing a set of parameters upon which behavior change probabilities depend. Parameter estimates are approximately normally distributed and are thus tested for significance based on a t-ratio (estimate divided by the standard error; Snijders et al., 2010).

### **Model Specification and Model Selection Procedures**

The SAB model for the current study was created from three sub-models; one to simulate the evolution of the friendship network, one to simulate the evolution of alcohol use, and one to simulate the evolution of physical activity. The combined final model consists of each submodel and simulates selection and assimilation processes simultaneously, controlling each process for the other. Theoretical considerations and established forward model selection procedures (described in Burk et al., 2007; Snijders et al., 2010) using Neyman-Rao score tests (Schweinberger, 2012) were used in model building.

Basic tendencies known to play a role in friendship formation (Snijders, 2001; van de Bunt, Van Duijn, & Snijders, 1999), called endogenous network effects, were included as structural control variables in the network evolution model. Outdegree and reciprocity are included by default in the model. The outdegree parameter represents the overall tendency of adolescents to have outgoing ties (i.e., number of friendship choices made by adolescents). The reciprocity parameter represents the number of reciprocated choices in friendship nominations. Two network closure effects were included; transitive triplets and three cycles. The transitive triplets parameters indicates the tendency of adolescents to become friends with adolescents their friends are already connected to (i.e., friends of my friends become my friends), while the three-cycles parameter represents the tendency to form ties with a friendship nominator's nominator.

Two effects related to social status were also included as structural controls for friendship formation. In-degree popularity was included to capture the tendency of

adolescents to nominate individuals with high in-degrees (i.e., incoming friendship nominations, representing popularity). In-in degree assortativity represents the tendency of adolescents to nominate those with similar levels of popularity to themselves. Additional control variables included friendship selection based on similarity in grade level, gender, parental education, and race in School B.

Behavior-based peer selection effects related to alcohol use and physical activity were also included in this model. Network effects for alcohol use included selection based on similarity on alcohol use, the effect of alcohol use on number of friends chosen (alcohol ego), and the effect of alcohol use on number of incoming friend nominations (alcohol alter). Network effects for physical activity included selection based on similarity on physical activity, the effect of physical activity on number of friends chosen (physical activity ego), and the effect of physical activity on number of incoming friend nominations (physical activity alter).

The alcohol use evolution and physical activity evolution sub-models included parameters related to behavior assimilation, as well as other functions upon which changes in alcohol use or physical activity may depend. Behavioral assimilation was measured using the total similarity effect, or the tendency of adolescents to adopt levels of alcohol use or physical activity similar to their friends, proportional to the number of friends. Control effects for behavior evolution included linear and quadratic effects, to capture the shape distribution of both behaviors. Additional controls include the effect of grade, gender, and parental alcohol use on adolescent alcohol use, and the effect of grade and gender on physical activity. Score tests (Schweinberger, 2012; Snijders et al., 2010)



were used to check for any confounding effects of race on alcohol use and physical activity in School B and indicated that the inclusion of these parameters did not improve model fit. Consequently, race was not retained in the final behavioral model for School B. Lastly, alcohol in-degree and physical activity in-degree were used to represent the effect of being a popular student on levels of either behavior.

The concurrent engagement in both alcohol use and physical activity was included to capture the relationship between the two health behaviors. The effect of alcohol use on physical activity level, and the effect of physical activity on alcohol use level were included in the behavior evolution models to illuminate this relationship. A full list of all parameters retained in the final models is presented in Table 2-1. Convergence criterion of  $t < 0.1$  was applied to all models, reflecting deviations of estimates from observed, or target, values (Ripley et al., 2015). Overall maximum convergence ratio standards of  $< 0.20$  were also used.

## **Results**

### **Descriptive Statistics**

Table 2-2 provides descriptive statistics for School A and School B. In both schools, the average level of alcohol use remained relatively stable from Wave I to Wave II, whereas physical activity levels decreased. Chi-square tests (for categorical variables) and two-tailed  $t$  tests (for continuous variables) were used to test for differences between the two schools on each variable. Rates of alcohol use in School A were higher than School B ( $p < .001$ ), while physical

Table 2-1

*Interpretation of Parameters in Final Model*

Parameter	Interpretation
Friendship network dynamics	
Outdegree	Tendency to have outgoing ties
Reciprocity	Tendency to reciprocate friendship choices
Transitive triplets	Tendency of adolescents to become friends with adolescents their friends are already connected to
3-cycles	Tendency to form ties with a friendship nominator's nominator
In-degree popularity	Tendency to nominate individuals with high in-degrees
In-indegree assortativity	Tendency to nominate those with similar levels of popularity to themselves
Grade similarity	Preference for friendships with individuals in same grade
Gender similarity	Preference for friendships with individuals of same gender
Parental education similarity	Preference for friendships with individuals whose parents are of similar education level
Race similarity	Tendency to become friends with individuals of your same race
Alcohol/physical activity ego	Effect of alcohol use/ physical activity on number of friends chosen
Alcohol/physical activity alter	Effect of alcohol use/physical on number of incoming friend nominations
Alcohol/physical similarity ( <i>peer selection</i> )	Friend selection based on similarity in alcohol use/physical activity
Behavior dynamics	
Linear shape	Overall tendency of weight control
Quadratic shape	Quadratic shape of weight control
Alcohol use/physical activity indegree	Effect of high in-degree (e.g., popularity) on level of alcohol use/physical activity
Total similarity on alcohol use/physical activity ( <i>peer assimilation/influence</i> )	Tendency to adopt level of alcohol use/physical activity of friends
Effect from grade	Effect of grade level on alcohol use/physical activity
Effect from gender	Effect of gender on alcohol use/physical activity
Effect from alcohol use/physical	Effect of alcohol use on physical activity, or effect of physical activity on alcohol use
Effect from parental alcohol use	Effect of parental use of alcohol on adolescent alcohol

activity levels were comparable between schools. Adolescents in School A were connected to more friends on average than adolescents in School B ( $p < .001$ ), yet the most notable difference between the two sample schools is ethnic composition ( $p < .001$ ). Descriptive statistics of additional covariates are also reported in Table 2-2.

### **Friendship Network Evolution**

Results for the friendship network evolution portion of the final models for School A and School B are reported in Table 2-3. As expected, several endogenous network properties (i.e., outdegree, reciprocity, transitive triplets, and three cycles) emerged as significant in both schools. The significant and positive in-degree popularity and significant and negative in-in degree assortativity parameters suggest adolescents have a tendency in both schools to nominate peers who are popular, although only in-degree popularity was significant in School B. In addition, friendships formed based on similarity in grade, gender, and parental education across both schools. As expected, friendships also formed around racial similarities in School B, with significant effects for students identifying as African American or Asian.

Evidence for friend selection based on similarity in alcohol use was found in both School A ( $b = .93, p < .001, OR: 2.53$ ) and School B ( $b = 1.46, p < .001, OR: 4.31$ ). Conversely, friend selection based on similarity in physical activity was not significant in either school. The significant and positive alter effect for alcohol use in School A demonstrates that adolescents who engaged in higher levels of drinking were preferred as friends. Last, the physical activity ego effect was significant in both schools, however School A showed a positive relationship, whereas School B indicated a negative effect.

Table 2-2

*Descriptive Statistics and Network Characteristics*

Characteristic	School A (n = 640)			School B (n = 1,156)			p value
	Mean	SD	%	Mean	SD	%	
Alcohol use							
Wave I	2.53	1.43		2.07	1.45		< .001
Wave II	2.61	1.54		2.00	1.49		< .001
Physical activity							
Wave I	3.82	2.09		3.67	2.03		.410
Wave II	3.06	2.22		2.84	2.14		.084
Network							
Wave I number of friends	3.96	2.48		1.79	2.00		< .001
Wave II number of friends	2.99	2.28		1.31	1.64		< .001
Adolescents who left network			4.1			8.4	-
Jaccard index	0.24			0.20			-
Response rate			78			83	-
Age	16.5	0.97		16.4	0.83		.022
Race							< .001
White			98.8			23.4	
African American/Black			< 1			25.2	
American Indian			4.0			3.8	
Asian/Pacific Islander			1.2			32.4	
Other			< 1			22.7	
Gender							.416
Male			53.6			51.4	
Female			46.4			48.6	
Parental education							< .001
Less than high school			8.4			22.6	
High school			35.9			15.4	
Some college			30.6			21.8	
College graduate			14.2			14.3	
Missing			10.9			26.0	
Parent alcohol use							< .001
Never			25.9			44.7	
1 day per month or less			38.4			20.3	
2 - 3 days per month			12.3			4.4	
1 - 2 days per week			10.2			4.0	
3 or more days per week			2.2			0.5	
Missing			10.9			26.0	
Grade (Wave I)							< .001
9th			36.6			< 1	
10th			35.2			49.8	
11th			28.2			49.7	

*Note.* p values are from two-tailed *t* tests for continuous variables (where the means and SD's are shown) and chi-square tests for categorical variables (where the percentages are shown).

Table 2-3

*Coefficients and Standard Errors of Final Models: Network Evolution*

Parameter	School A			School B		
	Coefficient	SE	Significance	Coefficient	SE	Significance
Rate	13.793	0.62	***	6.983	0.32	
Endogenous network processes						
Outdegree	-3.277	0.06	***	-4.863	0.11	***
Reciprocity	2.630	0.08	***	2.714	0.14	***
Transitive triplets	0.664	0.43	***	1.206	0.09	***
3-cycles	-0.456	0.08	***	-1.101	0.15	***
In-degree popularity	0.066	0.01	***	0.043	0.02	*
In-in degree assortativity	-0.114	0.03	***	-0.103	0.06	
Individual attributes						
Grade						
Similarity	0.762	0.06	***	1.102	0.11	***
Gender						
Similarity	0.153	0.04	***	0.388	0.05	***
Race						
White similarity	----	----		0.105	0.07	
Black similarity	----	----		1.257	0.11	***
Asian similarity	----	----		1.047	0.10	***
American Indian similarity	----	----		-0.219	0.12	
Other race similarity	----	----		-0.017	0.07	
Parental education						
Similarity	0.203	0.08	*	0.266	0.13	*
Limited nominations	0.455	0.09	***	.041	0.19	
Alcohol						
Ego	0.034	0.03		0.022	0.06	
Alter	0.057	0.03	*	0.042	0.05	
Similarity	.926	0.23	***	1.461	0.34	***
Physical activity						
Ego	0.045	0.02	*	-0.095	0.04	*
Alter	0.036	0.02		0.013	0.03	
Similarity	0.12	0.40		0.124	0.71	

\*  $p < 0.05$ .\*\*  $p < 0.01$ .\*\*\*  $p < 0.001$ .

## **Behavior Evolution**

**Alcohol use.** Results for the alcohol use evolution portion of the final models for School A and School B are reported in Table 2-4. The focal parameter of peer assimilation on alcohol use, the total similarity effect, was only significant in School B ( $b = .617, p < .05, OR: 1.85$ ). The linear and quadratic shape parameters, measures of the distributional shape of alcohol use, were statistically significant in both schools. The negative value of the linear shape parameter indicates that adolescents tend to report low levels of alcohol use overall. The positive quadratic shape parameter demonstrates changes in alcohol use differed as a function of initial levels, with higher levels predicting further increases.

In terms of individual attributes, there was a significant effect of gender on alcohol use in School A, with males displaying a higher tendency to drink. Popularity did not have an effect on alcohol use in either school, indicated by non-significant alcohol in-degree effects. Lastly, support for the concurrent engagement in alcohol use and physical activity behaviors was not found, as higher levels of physical activity were not associated with subsequent alcohol use level in either school.

**Physical activity.** Results for the physical activity evolution portion of the final models for School A and School B are reported in Table 2-4. The focal parameter of peer assimilation on physical activity, the total similarity effect, was significant in both School A ( $b = .903, p < .001, OR: 2.47$ ) and School B ( $b = .729, p < .001, OR: 2.07$ ). In terms of the behavioral shape distribution of physical activity, the linear shape parameter was negative and significant, indicating low overall physical activity levels in both schools.

Table 2-4

*Coefficients and Standard Errors of Final Models: Behavior Evolution*

Parameter	School A			School B		
	Coefficient	SE	Significance	Coefficient	SE	Significance
Effects predicting alcohol use						
Rate	4.630	0.45	***	7.209	1.05	***
Linear shape	-0.189	0.07	**	-0.779	0.05	***
Quadratic shape	0.081	0.02	***	0.187	0.01	***
In-degree	-0.011	0.02		0.036	0.03	
Individual attributes						
Effect from grade	0.043	0.04		-0.002	0.05	
Effect from gender	-0.187	0.07	**	-0.12	0.06	
Effect from parental alcohol use	0.023	0.03		-0.022	0.03	
Effect from physical activity	-0.006	0.03		-0.021	0.03	
Friend assimilation effects						
Total similarity	0.259	0.18		0.617	0.30	*
Effects predicting physical activity						
Rate	13.602	1.36	***	15.785	1.64	***
Linear shape	-0.228	0.04	***	-0.183	0.03	***
Quadratic shape	0.020	0.01	*	-0.011	0.01	*
In-degree	0.016	0.01		0.016	0.09	
Individual attributes						
Effect from grade	-0.006	0.02		-0.043	0.02	
Effect from gender	-0.060	0.04		-0.049	0.02	*
Effect from alcohol behavior	0.005	0.02		-0.011	0.01	
Friend assimilation effects						
Total similarity	0.903	0.19	***	0.729	0.27	**

\*  $p < 0.05$ .\*\*  $p < 0.01$ .\*\*\*  $p < 0.001$ .

The significant and positive quadratic shape in School A represents the tendency for adolescents to move toward either end of the physical activity scale. The significant and negative quadratic shape in School B indicate that higher initial physical activity levels were associated with lower likelihood of further increases. The evolution of physical activity behavior did not vary by adolescents' grade or in-degree, however, there

was a significant and negative effect of gender on physical activity in School B, with girls engaging in less physical activity than boys. Lastly, no evidence was found for the effect of alcohol use level on subsequent physical activity behavior in either school.

### **Discussion**

According to developmental theories (Bronfenbrenner & Morris, 2006), adolescent friendships and health behavior mutually influence each other over time. Consequently, adequate design of intervention and prevention programs aimed at critical health behaviors, such as alcohol use and physical activity, depends upon a clear understanding of the peer mechanisms surrounding these behaviors. Advances in the field of social network analysis, specifically the development of SAB models, provides a rigorous statistical framework to investigate the coevolution of adolescent friendships and health. Although the advent of social media and technology-based friendships has expanded the landscape of adolescent social lives in recent years (Lenhart, 2013), evidence for the impact of these new forms of relationships on health behavior is mixed (Huang, Soto, Fujimoto, & Valente, 2014). Further, schools are frequently used as intervention settings for programs targeting health behaviors (Stigler, Neusel, & Perry, 2011), therefore necessitating a carefully delineated picture of how the processes of peer selection and peer assimilation unfold in school-based friendships. Therefore, the main goal of the present study was to test selection and assimilation processes in the coevolution of adolescent friendship networks and alcohol use and physical activity behavior in two different U.S. high schools.



### **Predicting Friendship Ties**

The current study controlled for a number of alternative mechanisms through which friendships and both behaviors could develop. Consistent with previous research, findings show that friendship formation followed basic network properties, such that adolescents preferred reciprocated and triadic friendships (Burk et al., 2007; Snijders & Baerveldt, 2003). Adolescents also selected friends based on popularity, as well as similarity in gender, grade, parental education level, and race, when applicable.

Of prominent interest to the current study, support for friend selection based on similarity in alcohol use was found in both schools. For example, an adolescent who did not drink had odds 2.53 times higher to form a friendship with another nondrinking adolescent compared to befriending an adolescent who drank once or twice a year (one unit increase on alcohol scale) in School A, (i.e.,  $e^{0.93} = 2.53$ ), and 4.31 times higher in School B (i.e.,  $e^{1.46} = 4.31$ ). In contrast, adolescents did not select friends based on similarity in physical activity in either school. This consistency is particularly notable given the distinct differences between the two sample schools and demonstrates that adolescents chose friends based on behavioral similarity, but alcohol use was a more relevant health behavior to friendship formation than physical activity.

The current findings are in line with previous studies that demonstrated the importance of peer selection on alcohol use (Knecht et al., 2010; Mundt et al., 2012; Simpkins et al., 2013), yet differ from research in which a strong selection effect for physical activity was found (de la Haye et al., 2011). Typically, alcohol use offers ample social opportunities (e.g., parties) for adolescents to meet others with similar behavior,

thus promoting friendship formation. On the other hand, physical activity behaviors in and of themselves may not offer this increased social component.

There was mixed evidence for the relative popularity of adolescents who were dependent on their alcohol use or physical activity levels. In School A, adolescents who engaged in higher levels of alcohol use had a higher probability of being selected as friends, yet this same friend preference was not found in School B. Table 2-2 showed that rates of alcohol use were higher in School A than School B, potentially suggesting that schools with higher overall alcohol use are particularly conducive to promoting popularity of alcohol-using adolescents. Physical activity level had no bearing on incoming friend nominations in either school, indicating that physical activity behaviors were not tied to popularity.

Taken together, friendships were more likely among adolescents who were similar to each other on alcohol use behavior, and were not more likely among adolescents with similar physical activity behavior. These patterns were consistent across samples, despite differences in the nature of the two schools. In addition, higher level of alcohol use in School A was associated with incoming friendship ties, indicating social desirability of this behavior. Results suggest that interventions aimed at alcohol use would benefit from a focus on preventing negative friend formations, in addition to efforts to combat alcohol-based popularity in schools with higher rates of alcohol use. In contrast, a strong emphasis on friend selection processes in physical activity interventions may be unwarranted.

### **Predicting Alcohol Use and Physical Activity**

Findings from both schools demonstrate that adolescents adjusted their physical activity behavior to that of their friends, but evidence of assimilation to friends' alcohol use was only found in School B. Assimilation on physical activity has been found in several previous studies (de la Haye et al., 2011; Shoham et al., 2012; Simpkins et al., 2013), and the current study lends additional support to the importance of assimilation processes in physical activity development, especially in light of the non-significant selection effect. For example, an adolescent who did not engage in any reported physical activity (0 on physical activity scale) whose friends all exercised at least once a week (one-unit increase on physical activity scale) had odds between 2.07 (i.e., School B:  $e^{0.73} = 2.07$ ) and 2.47 (i.e., School A:  $e^{0.90} = 2.47$ ) times higher to increase his or her physical activity level one unit in the next micro-step than remain at the current state. Again, despite School A and School B representing different types of U.S. high schools, findings regarding peer assimilation were consistent. Consequently, findings indicate that health interventions aimed at physical activity would benefit from peer-led strategies.

In addition, physical activity levels in the current study were low overall and decreased over time (Table 2-2), consistent with findings from previous research (de la Haye et al., 2011; Simpkins et al., 2013). Gender differences in School B indicate that females engaged in less physical activity than males, highlighting an important area for future research. In light of the decline in physical activity during adolescence, with girls especially likely to engage in low levels, a more nuanced investigation of gender differences in assimilation to friends' physical activity behaviors could highlight

particularly useful strategies for health interventions.

Turning to alcohol use, there was some evidence for assimilation to friends' behavior, but this effect was only significant in School B. This supports previous research in which assimilation did not emerge as a significant process (Mundt et al., 2012), or peer selection was relatively stronger than assimilation (Knecht et al., 2010) in adolescent alcohol use. Differences in alcohol assimilation between School A and School B may partially be explained by differing characteristics of the schools. Adolescents in School B reported fewer friends than adolescents in School A, potentially promoting closer, more intimate friendships, thereby increasing susceptibility to peer influence. Also, although race was not found to be significantly associated with either alcohol use or physical activity in School B, the current study did not investigate if assimilation to friends differed as a function of racial similarity. Future research should investigate if adolescents are more likely to assimilate to the behavior of friends if they share a racial identity.

In addition, gender differences were found with regard to alcohol use, with males preferring higher alcohol consumption than females in School A. Lastly, evidence of a concurrent relationship between alcohol use and physical activity was not found to be significant in either school. Although previous research has indicated that physical activity may provide a protective effect against the use of alcohol (Terry-McElrath & O'Malley, 2011) or may be associated with increased alcohol consumption (Bigelow et al., 2014), the current study found no significant relationship between level of alcohol use and physical activity behaviors.

## **Limitations and Conclusions**

Several limitations of the current study need mentioned. First, friendship nominations were limited to five of each gender and consisted of friends attending the same school. It is possible that larger friendship networks, particularly those composed of friends both inside and outside of school, may display different social processes. In addition, the included alcohol use and physical activity measures focused on frequency of both behaviors, rather than including dimensions related to quantity. Similarly, the scaling of both behavioral variables is such that the models do not test for differences in peer processes between adolescents who engage in higher levels of either behavior and those who are lower on the scale. Last, the Add Health dataset is older, and the proliferation of social networking sites since data collection has potentially added a new dimension to the scope of peer influence on health behavior. Thus, as new datasets become available in which the role of online friendships are evaluated in tandem with face-to-face friendships, research should reflect these dual influences.

Despite these limitations, the current study advances research in several ways. Whereas previous research focused on the intersection of adolescent social networks and either alcohol use or physical activity, the current study nests these behaviors within the social environment of two adolescent school networks, providing a framework to model the complex processes through which friendships and both behaviors develop over time. Distinct differences were found in the importance of peer selection and assimilation to the observed coevolution of friendships, alcohol use, and physical activity. Although the sample schools reflect vastly different types of U.S. high schools, largely similar results

were obtained across schools. In both School A and School B, adolescents selected friends based on similarity in alcohol use, but friendships did not form around similarities in physical activity. In contrast, adolescents changed their physical activity behaviors to match that of their friends, but assimilation to friends' alcohol use was only seen in one school. These findings have important implications for intervention and prevention design. Programs that focus on friend influence in changing health behavior may have particular success with adolescent physical activity, and programs aimed at alcohol use would benefit from including an emphasis on preventing negative friendships from forming.

### CHAPTER 3

## STUDY 2: PERCEIVED SOCIAL ACCEPTABILITY AND PEER INFLUENCE ON ADOLESCENT CIGARETTE SMOKING<sup>2</sup>

### Abstract

The current study uses methods from social network analysis to predict longitudinal trends in adolescent cigarette smoking based on perceived social acceptability from friends, in addition to typical measures of peer influence (e.g., self-reported cigarette use of friends). By concurrently investigating the role of perceived social acceptability of smoking and peer influence, the current study offers new insight into the mechanisms through which peers influence adolescent smoking. Two waves of data from five high schools within one U.S. school district ( $N = 1,563$ ) were used. Stochastic actor-based models simultaneously estimated changes in smoking predicted by perceived social acceptability and peer influence. Findings demonstrate that adolescents with higher perceived social acceptability of cigarette use increased cigarette smoking over time. Conversely, support for peer influence on smoking was not found after controlling for the effects of perceived social acceptability. The results suggest that perceived social acceptability regarding cigarette smoking, rather than self-report of cigarette use among friends, is predictive of future smoking behavior. Consequently, the findings highlight the need for prevention efforts to take into account the multifaceted dynamics between adolescent smoking and friendships. Programs that address peer influence alone, without considering peer mechanisms such as perceived social

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acceptability, are at risk of ignoring critical avenues for prevention.

*Keywords: social networks, smoking, perceived social acceptability*

## **Introduction**

Cigarette smoking is primarily initiated and established during adolescence (Orlando, Tucker, Ellickson, & Klein, 2004; USDHHS, 2012), and despite declines in adolescent smoking in recent years, over 3,200 youth aged 18 or younger begin smoking daily (Centers for Disease Control and Prevention [CDC], 2017). Cigarette smoking remains the leading preventable cause of death in the U.S. (CDC, 2016), and as a result, remains a critical public health concern. Thus, the identification of malleable targets for reducing overall rates of cigarette smoking is crucial for prevention efforts.

Peer relations are important socializing processes for many health behaviors (Burk et al., 2007; Umberson & Montez, 2010), and adolescence marks a particularly vulnerable developmental stage for social influences (Brechwald & Prinstein, 2011; Steinberg & Monahan, 2007). In addition, developmental theories (Bronfenbrenner & Morris, 2006) suggest that the socio-contextual environment shapes adolescent development, such that there is a continuous, bidirectional interaction between individual characteristics and socio-contextual factors. Adolescent friendships are one of the most salient relationships during adolescence (Parker et al., 2006), and are thus uniquely situated to impact adolescent health behavior.

Although a myriad of factors contribute to adolescent smoking, previous research has consistently demonstrated that adolescents are influenced by the cigarette use of their



friends (see Simon-Morton & Farhat, 2010 for a review). Adolescents have been shown to form friendships based around shared smoking habits (Green et al., 2013; Wang, Butts, Jose, & Lakon, 2016), and alter their smoking based on their friends' actual (Schaefer, Haas, & Bishop, 2012; Wang et al., 2016) or perceived (Fujimoto & Valente, 2012; Hoffman, Monge, Chou, Valente, 2007) smoking patterns.

However, it is also known that some substances are perceived as more socially acceptable (Kulesza et al., 2013), particularly during adolescence (Eisenberg et al., 2014). Cigarette smoking, specifically, has shown overall declines in social acceptability in recent decades (Cummings & Proctor, 2014). In addition, low levels of perceived social acceptability of smoking has been shown to predict success in smoking cessation interventions for adolescents (Bricker et al., 2010). Further, perceived sibling approval of smoking is associated with future smoking in adolescents (Brown et al., 2010). Yet, no research to date has considered the role of perceived acceptability of smoking when examining social influence from friends on cigarette smoking.

Advances in the field of social network analysis allow researchers to explicitly examine the extent to which adolescent friendships influence smoking behavior by overcoming important limitations of alternative methodologies. For example, friendship network data are inherently interdependent, thus violating assumptions of independence underlying conventional statistical methods. Further, methods focused on dyadic relationships neglect to control for effects of the social network in which these dyadic relationships are embedded (Snijders et al., 2007; Snijders, van de Bunt, & Steglich, 2010). Social network methods specifically incorporate the structure and interdependence

of social network data into the statistical modeling process, thus providing a detailed account of the mechanisms shaping both social and behavioral outcomes.

Social network data utilize friendship nominations, wherein adolescents are asked to identify peers from their school whom they consider to be a friend. Subsequently, friend influence is as the predicted probability of an adolescent changing his or her smoking behavior dependent on the level of smoking reported among his or her friends. Friend influence, therefore, is conceptualized as the actual smoking behavior among an adolescents' friends and obtained from the obtained friendship nominations (Ripley et al., 2018). Though empirical research supports peer influence occurring in this manner (Schaefer et al., 2012; Wang et al., 2016), it is currently unknown if this relationship is moderated by an adolescent's perceived social acceptability of smoking.

Therefore, the main goal of the current study is to concurrently investigate the role of perceived social acceptability and peer influence (e.g., level of smoking among an adolescent's friends) on longitudinal patterns in cigarette use within a large sample of U.S. high school adolescents. Using recent advances in social network analysis, the study explicitly examines the extent to which perceived social acceptability and smoking behavior within adolescent peer groups (e.g., peer influence) independently contribute to changes in smoking. Although peer influence from a social network perspective is widely researched (Simon-Morton & Farhat, 2010), the current study is novel in that it examines the impact of perceived social acceptability alongside the typical measure of peer influence. By illuminating the peer mechanisms associated with smoking, the study offers valuable insight into effective design of prevention programs. For example, perceived

social acceptability as predictive of smoking behavior suggests prevention strategies focused on altering beliefs about smoking and the idea that peers approve of this behavior.

## **Method**

### **Participants and Procedure**

The current study uses data from students within five high schools in one school district in Los Angeles, CA. The data come from the Social Network Study (Valente, Fujimoto, Soto, Ritt-Olson, & Unger, 2013), a longitudinal social network study aimed at examining the relationship between social networks and health behaviors. The sample consists of all five high schools in the district and is composed of 10<sup>th</sup> grade students interviewed in October 2010 and again in May 2011. The sample is a predominately Hispanic/Latino school district with 75-90% of students qualifying for free or reduced lunch. Of the total eligible 10<sup>th</sup> grade students, 88% returned valid parental consent forms. The proposed study is based on 1563 students who completed the survey at Wave I and Wave II. Models were run separately for each school and then combined using recommended meta-analysis techniques (Snijders et al., 2007).

### **Measures**

**Friendship ties.** Sociometric data (i.e., friendship nominations) collected at Wave I and Wave II compose the friendship measure. Adolescents were asked to identify up to seven close friends from a provided roster of students in 10<sup>th</sup> grade. ID codes were used to link adolescents to nominated friends, thus creating grade-level friendship networks, as

well as allowing for behavioral data to be collected directly from adolescents.

**Cigarette smoking.** Cigarette smoking was assessed through four items measuring self-reported use of cigarettes. A composite ordinal smoking score (0 = not susceptible, 1 = susceptible, 2 = ever smoker, 3 = past-month smoker, 4 = daily smoker) was created in order to meet modeling requirements (Ripley et al., 2018) and remain consistent with previous use of this data (Huang, Soto, Fujimoto, & Valente, 2014).

**Perceived social acceptability.** Perceived social acceptability of cigarette smoking was measured through three questions. Adolescents were asked to indicate how many of their five best friends would (a) think it is ok for someone their age to smoke, (b) be unfriendly toward them if they smoked, and (c) ever offer them a cigarette. Responses ranged from 0 (none of them) to 4 (all of them). Individual items were recoded into dichotomous indicators based on at least one friend endorsing acceptability of smoking. Items were summed, creating a social acceptability variable ranging from 0-3 that represents the perceived social acceptability of smoking among one's peer group. The composite ordinal scale of 0-3 was created to meet statistical modeling requirements (Ripley et al., 2018).

**Demographic control variables.** In order to provide accurate estimates of associations between adolescent friendships and cigarette smoking, potential predictors associated with friendship formation and smoking were controlled (Steglich et al., 2010). Friendships typically form based around shared demographic characteristics (McPherson et al., 2001), and thus gender and Hispanic ethnicity were included as control variables for friendship formation. Gender was also used as a basic demographic control variable

for cigarette smoking. Research has identified academic grades, adolescent drinking, and parental smoking as common predictors of adolescent smoking (Wellman et al., 2016), and thus each was tested as potential control variables in the current study. Established forward model selection procedures (described in Burk et al., 2007; Snijders et al., 2010) using Neyman-Rao score tests (Schweinberger, 2012) were used to test all parameters and build the final models.

### **Analysis**

Stochastic actor-based models (SABs; Snijders et al., 2010) specified using SIENA version 4.0 (Ripley et al., 2018) were used to capture the dynamics between adolescent friendships and cigarette smoking. SABs incorporate into the modeling process the interdependencies present in network data and the dynamic, constantly evolving nature of friendship and behavioral change. SABs are particularly useful for analyzing social network data due to their ability to model these dynamic processes while simultaneously accounting for the effects of friendship network structure and individual and dyadic attributes (Snijders et al., 2010). For example, several structures of network formation (i.e., the way individuals within a social network are connected) are known to play in role in subsequent relationship ties (Snijders et al., 2007). Conventional statistical methods fail to account for these tendencies, thereby biasing parameter estimates (Snijders et al., 2010; Steglich et al., 2010).

**Overview of the modeling process.** Estimation in SABs is accomplished through a continuous-time Markov process, which uses intensive computer simulations to repeatedly impute likely change trajectories, called micro-steps, occurring between

measurement periods. The overall modeling process determines the probabilities associated with an individual making changes to their social ties or behavior, given its current state. Friendship ties and behavior observed at the first measurement occasion are treated as exogenous in the model, and an iterative, simulation-based algorithm is carried out until simulated data adequately represent observed data at later waves (Snijders et al., 2007; Snijders et al., 2010). Separate friendship network evolution and behavior evolution models are integrated, as the current state for the continuously changing friendship network is the dynamic constraint for the behavioral changes, and vice versa. By repeatedly simulating these micro-steps, the models allow for differentiation of the strengths of multiple contributing mechanisms to the observed longitudinal data.

**Model specification and model selection procedures.** In the current study, theoretical considerations and established forward model selection procedures (Snijders et al., 2010) using Neyman-Rao score tests (Schweinberger, 2012) were used in model building. Separate friendship and smoking models were tested and then combined in order to create a final model in which friendships and smoking coevolve. Endogenous network effects, or basic tendencies known to influence friendship formation (Snijders, 2001; van de Bunt et al., 1999), were included as structural control variables in the friendship evolution model. Given the priority of peer relations during adolescence, two prototypical effects related to social status were included as control variables for friendship formation. Peer influence was tested in the smoking evolution model through the average similarity effect, or the tendency of adolescents to adopt levels of cigarette smoking similar to their friends. The effect of perceived social acceptability on smoking

was also tested in the smoking evolution model, thereby controlling each effect for the other. A complete list of all parameters retained in the final models is presented in Table 3-1.

Table 3-1

*Interpretation of Parameters in Final Models*

Parameter	Interpretation
Friendship network dynamics	
Outdegree	Tendency to have outgoing ties
Reciprocity	Tendency to reciprocate friendship choices
Transitive triplets	Tendency of adolescents to become friends with adolescents their friends are already connected to
3-cycles	Tendency to form ties with a friendship nominator's nominator
Indegree popularity squared	Tendency to nominate individuals with high in-degrees
Outdegree popularity squared	Tendency to nominate individuals with high outdegrees
Gender similarity	Preference for friendships with individuals of same gender
Hispanic similarity	Tendency to become friends with individuals of your same ethnicity
Smoking ego	Effect of smoking on number of friends chosen
Smoking alter	Effect of smoking on number of incoming friend nominations
Smoking similarity ( <i>peer selection</i> )	Friend selection based on similarity in smoking
Behavior dynamics	
Linear shape	Overall tendency of weight control
Quadratic shape	Quadratic shape of weight control
Average similarity on smoking ( <i>peer influence</i> )	Tendency to adopt level of smoking of friends
Effect from perceived social acceptability	Effect of level of perceived social acceptability on adolescent smoking
Effect from academic grades	Effect of grades on smoking
Effect from gender	Effect of gender on smoking
Effect from alcohol use	Comorbid alcohol use and smoking
Effect from parental smoking	Effect of parental smoking on adolescent smoking

Convergence criterion of  $t < 0.1$  was applied to all models, reflecting deviations of estimates from observed, or target, values (Ripley et al., 2017). Models were estimated separately for each school, and results were then combined via meta-analysis techniques in order to test parameter means and variances across the sample (Snijders et al., 2007). Following recommendations (Ripley et al., 2018), two different tests were used to measure the significance of effects (1) a likelihood method using the t-ratio under iterative weighted least square modification (Snijders & Baerveldt, 2003), and (2) a Fisher-type combination of one-sided p-values (Hedges & Olkin, 1985). Differences in parameter estimates between the sample schools were calculated with an approximate chi-square test of parameter variances by the Snijders and Baerveldt (2003) method.

**Missing data.** Missing data due to item nonresponse was imputed by the SIENA software, but treated as noninformative in parameter estimation (Huisman & Steglich, 2008). In this method, missingness in dependent behavioral variables is treated with imputation of previously observed values if missingness occurs at Wave II, and imputation of values from Wave II if missingness occurs at the first observation. Missingness in both observations results in imputation of the observation-wise mode of the variable. Missing covariate data is treated by using the sample mean. Due to relatively small sample size per school, adolescents were excluded from the sample if they did not participate in both Wave I and Wave II.

## Results

Friendship, smoking, and covariate characteristics of the sample are presented in



Table 3-2. The sample was evenly split on gender, with an average age of 15. Nearly 65% of the sample reported Hispanic ethnicity. Cigarette smoking levels remained largely stable from Wave I to Wave II. Average perceived social acceptability of smoking was low (1.21), with scores dispersed relatively evenly across the scale. Adolescents

Table 3-2

*Sample Characteristics*

Characteristic	<i>N</i>	%	Mean	<i>SD</i>
Female		48.8		
Hispanic		64.2		
Academic grades			3.14	0.77
Parental smoking		26.9		
Adolescent alcohol use			1.53	1.47
Perceived social acceptability			1.21	0.98
0 No acceptability	352	22.5		
1 Low acceptability	418	26.7		
2 Moderate acceptability	326	20.9		
3 High acceptability	140	10.0		
Missing	327	20.9		
Cigarette smoking Wave I			0.76	1.11
0 Not susceptible	877	56.1		
1 Susceptible	143	9.1		
2 Ever smoker	217	13.9		
3 Past month smoker	89	5.7		
4 Daily smoker	35	2.2		
Missing	202	12.9		
Cigarette smoking Wave 2			0.76	1.08
0 Not susceptible	957	61.2		
1 Susceptible	138	8.8		
2 Ever smoker	253	16.2		
3 Past month smoker	84	5.4		
4 Daily smoker	37	2.4		
Missing	97	6.2		
Friendship network				
Wave I average number of friends		3.50		
Wave II average number of friends		3.58		
Jaccard Index, average stability coefficient		0.29		

*N* = 1,563.

reported approximately 3.5 friends at both measurement occasions, and the Jaccard Index, a measure of stability in friendships, ranged from 0.27 to 0.32. Indices above 0.2 are recommended to accurately estimate effects (Snijders et al., 2010).

Table 3-3 presents results from the final model. Results from both sets of meta-analyses are displayed, however, given that the sample schools represent the entire population of schools within the district, outcomes from the Fisher 1-sided test ( $\alpha/2 - 0.025$ ) are described (Ripley et al., 2018). A chi-square test with 4 degrees of freedom ( $N-1$ ) was used to test for parameter variances between schools. Schools were comparable across all included parameters, with the exception of two endogenous network parameters.

**Effects predicting friendship formation.** As expected, the endogenous network effects included in the model significantly predicted friendship formation ( $p < .001$ ). Specifically, adolescents were likely to form reciprocated friendships, become friends with adolescents their friends are already connected to (transitive triplets, i.e., friends of my friends become my friends), and form ties with a friendship nominator's nominator (3-cycles). In addition, both effects representing social status were significant ( $p < 0.001$ ), demonstrating that adolescents tended to nominate popular peers as friends (indegree popularity squared), as well as adolescents with many outgoing friendship nominations (outdegree popularity squared). In terms of effects related to cigarette smoking, adolescents with higher levels of smoking received marginally more friendship nominations ( $X^2 = 16.66, p = 0.08$ ) than adolescents with lower levels of smoking.

Table 3-3  
*Friendship and Smoking Evolution*

Parameter	Snijders-Baerveldt method			Fisher's combination method		
	$\beta$	SE	Between school difference	$\chi^2$ (Left Side)	$\chi^2$ (right Side)	p value
<b>Network dynamics</b>						
Outdegree	-2.55	0.11***	0.23	1420.67	0	< .001
Reciprocity	3.02	0.11***	0.28***	0	2663.09	> .999
Transitive triplets	0.77	0.05***	0.11***	0	1267.64	> .001
3-cycles	-0.35	0.07**	0.16	84.02	0.10	> .999
Indegree popularity sq	0.32	0.03***	0.07	0	218.96	< .001
Outdegree popularity sq	-0.54	0.02***	0.04	238.49	0	> .999
Gender similarity	0.03	0.02	0.04	4.93	12.96	0.23
Hispanic similarity	0.01	0.03	0.08	7.83	7.81	0.65
Smoke alter	0.04	0.01**	0.02	2.27	16.66	0.08
Smoke ego	0.04	0.01*	0.02	3.18	15.07	0.12
Smoke similarity	0.12	0.05	0.10	4.21	12.04	0.28
<b>Behavior dynamics</b>						
Smoking linear	-1.12	0.06***	0.17	332.51	0	< .001
Smoking quadratic	0.14	0.03*	0.07	0.98	40.35	> .999
Smoking influence	0.17	0.16	0.35	4.89	15.03	0.13
Effect from gender	0.20	0.08	0.19	2.60	19.88	0.03
Effect from grades	-0.15	0.09	0.21	22.40	5.10	0.89
Effect from perceived acceptability	0.25	0.05**	0.11	1.26	37.36	< .001
Effect from parental smoking	0.11	0.09	0.19	4.91	13.85	0.18
Effect from alcohol	0.13	0.06	0.13	3.10	30.53	< .001

\*  $p < 0.05$ .

\*\*  $p < 0.01$ .

\*\*\*  $p < 0.001$ .

Smoking did not significantly predict outgoing friendships, nor was similarity in smoking predictive of friendship formation.

**Effects predicting cigarette smoking.** Longitudinal trends in cigarette smoking were explained by multiple parameters, including both distributional shape effects (e.g., linear, quadratic). The significant and negative linear shape parameter indicates that adolescents reported low levels of smoking overall. The positive quadratic shape parameter demonstrates that changes in smoking differed as a function of initial levels, with higher levels predicting further increases. The focal parameter of perceived social acceptability significantly predicted adolescent smoking ( $X^2 = 37.36, p < .001$ ), while peer influence did not emerge as significant ( $X^2 = 15.03, p < 0.13$ ). In addition, gender predicted an increase in smoking ( $X^2 = 19.88, p < .03$ ), with males displaying a higher tendency to smoke. Of the additional control variables tested, adolescent drinking predicted cigarette smoking ( $X^2 = 30.53, p < .001$ ), while academic grades and parental smoking did not.

## Discussion

Cigarette smoking among adolescents remains a critical health concern, and developmental theories (Bronfenbrenner & Morris, 2006) suggest that the socio-contextual environment shapes adolescent development. Given the increased priority of peer relationships during adolescence (Parker et al., 2006), a clear representation of the mechanisms through which peers impact smoking habits is crucial for prevention design. Further, schools are frequently used as intervention settings for programs addressing

health behaviors (Stigler et al., 2011; Valente, Hoffman, Ritt-Olson, Lichtman, & Johnson, 2003), and growing evidence indicates that peers can be effectively engaged in behavioral interventions (Osgood et al., 2013; Valente, 2012). Although previous research suggests that perceived social acceptability of smoking impacts adolescent smoking habits (Bricker et al., 2010; Brown et al., 2010), social network research has exclusively focused on the impact of the level of smoking among an adolescent's direct peer group (e.g., peer influence; Simon-Morton & Farhat, 2010). Consequently, the main goal of the present study was to simultaneously investigate the extent to which perceived social acceptability and peer influence predict longitudinal patterns in cigarette smoking among a network of school-based adolescent friends. The study uses rigorous SAB models to concurrently investigate these processes, and therefore offers new insight into the mechanisms through which peers impact cigarette use.

*Friendship evolution.* Consistent with previous social network research, adolescent friendship formation followed basic network properties, such that adolescents formed reciprocated and triadic friendships (Burk et al., 2007; Snijders et al., 2007). In addition, social status was predictive of friendships, in that adolescents tended to nominate popular peers as friends, and also preferred adolescents who were active in the network (e.g., sending many outgoing friendship nominations) as friends. In terms of the impact of cigarette smoking on friendship, adolescents with higher levels of smoking showed marginal increases in popularity. Popularity of adolescent smokers has been documented elsewhere (Lakon, Hipp, Timberlake, 2010; Schaefer et al., 2012; Valente, Unger, & Johnson, 2005) and suggests that although cigarette use continues to decline

nationally (CDC, 2017), social benefits within the adolescent context remain. In contrast to several previous studies (DeLay, Laursen, Kiuru, Salmela-Aro, & Nurmi, 2013; Green et al., 2013; Mercken, Snijders, Steglich, Vartiainen, & de Vries, 2010), support for friendship formation based on similarity in smoking was not found in the present study. This difference could be attributed to the restriction of friendship to seven ‘close friends’ versus more loosely defined friendship. Shared smoking habits may promote friendship in less intimate, more casual relationships, while this similarity is less relevant in the context of close friendships.

**Smoking evolution.** Of prominent interest to the goals of the study, evidence was found for the effect of perceived social acceptability of smoking on future adolescent smoking, while support for peer influence was insignificant. This suggests that adolescents were more likely to change their smoking behaviors in response to how they perceived their friends to feel about smoking, versus the smoking behavior of their friends. For example, for every one-unit increase in the social acceptability scale, an adolescent had odds 1.28 times higher (i.e.,  $e^{0.25} = 1.28$ ) to increase his or her smoking by Wave II. While previous research has found mixed support for peer influence on smoking (Simons-Morton & Farhat, 2010), findings from the current study suggest that this relationship is tempered by accounting for perceived social acceptability of smoking. As a result, prevention programs that aim to reduce adolescent cigarette use should address perceptions of adolescent smoking and beliefs that peers approve of this behavior.

Adolescents also engaged in comorbid alcohol use and smoking, such that adolescents who ranked higher on the alcohol use scale also had an increased likelihood

of smoking. In addition, males were more likely than females to smoke, suggesting important gender differences to consider when designing prevention efforts. Lastly, the significant quadratic shape effect demonstrates that smoking was self-reinforcing, in that adolescents with high smoking levels at Wave I were likely to continue their use at Wave II, indicating the addictive nature of cigarettes. Overall, the current study demonstrates that peers play an important role in shaping adolescent smoking behaviors, but this impact stems from perceptions of peer approval rather than the level of smoking among an adolescent's friendship group. Thus, findings from the current study highlight the need for prevention efforts to take into account the multifaceted dynamics between adolescent smoking and friendships.

Although the present study offers considerable strengths, several limitations need to be mentioned. First, the sample represents one high school district in Southern California. Results of the study may not generalize to adolescent populations in different geographic locations or composed of varying demographics. Second, the current study focused on grade level school friendships, and therefore did not account for mechanisms of peer influence occurring outside of the school context. Larger friendship networks, particularly those composed of students within all grades and outside of school, may display different social processes. Nevertheless, measures of friendship, friend influence, and perceived social acceptability in the current study all represent close adolescent friendships and are thus most relevant to the research questions at hand. Lastly, although the study is longitudinal in nature, the results are limited to two waves of data collection and therefore capture behavioral change over the course of one academic year. Future

research is needed to investigate these processes across larger measurement occasions. Despite these limitations, findings from the current study offer valuable insight into the dynamic between adolescent friendships and cigarette smoking, and consequently, the appropriate design of prevention efforts.



**CHAPTER 4**

**STUDY 3: USING SOCIAL NETWORK ANALYSIS TO UNRAVEL THE  
RELATIONSHIP BETWEEN CHRONIC ILLNESS AND  
ADOLESCENT FRIENDSHIP<sup>3</sup>**

**Abstract**

*Background* The current study uses methods from social network analysis to examine the relationship between chronic illness and adolescent friendships. Particular attention is given to the processes of peer marginalization, peer withdrawal, and homophily related to chronic illness.

*Methods* Exponential random graph models were used to investigate the effect of chronic illness on friendship selection processes, while controlling for important social network properties and covariates. The study uses cross-sectional data from six small high schools ( $N = 461$ ) within the National Longitudinal Study of Adolescent to Adult Health. *Results* Findings demonstrate no significant differences between adolescents with chronic illness and adolescents without chronic illness in the likelihood of receiving friendship nominations or sending friendship nominations. In addition, similarity in chronic illness did not significantly predict friendship formation between two individuals. *Conclusions* Adolescent chronic illness was not significantly associated with friendship formation processes, including peer marginalization, peer withdrawal, and homophily related to chronic illness, after controlling for alternative peer selection processes.

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<sup>3</sup> Coauthors: Tyson Barrett and Ginger Lockhart. Author release letter for Tyson Barrett is found in Appendix B.

Although previous literature suggests that adolescents with chronic illness experience negative social consequences, the current findings demonstrate that the social network structure of adolescents with chronic illness did not differ significantly from that of their peers without chronic illness.

*Keywords: social networks, chronic illness, friendships, marginalization, withdrawal*

## **Introduction**

Developmental research highlights the importance of peer relationships to adolescent wellbeing and healthy development (Prinstein & Dodge, 2008; Rubin, Bukowski, & Parker, 2006). Increased autonomy and time with peers contribute to the salience of friendships during this developmental period (Crosnoe & Johnson, 2011; Rubin et al., 2006). Consequently, a lack of friends is associated with increased depression and decreased self-worth in adolescents (Prinstein & Dodge, 2008; Rubin et al., 2006). According to developmental theories (Bronfenbrenner & Morris, 2006), adolescent friendships and health are interrelated, such that health impacts social outcomes (e.g., friendships), and vice versa. Empirical research supports this relationship and adolescent friendships have been shown to form around health indicators such as obesity (Schaefer & Simpkins, 2014), mental health (Baggio, Luisier, & Vladescu, 2017), and substance use (Wang, Hipp, Butts, Jose, & Lakon, 2016). Given the interdependence of friendships and health, in tandem with the critical role of friendships during adolescence, there is a critical need to investigate the impact of health on social outcomes.

Recent advances in the field of social network analysis allow for the complex mechanisms driving friendship formation to be explicitly modeled, including the impact of health indicators on social connections. Social network methods embed adolescents within the social structure of their environment (e.g., typically the school peer context) and estimate the impact of individual attributes (e.g., health indicators) on friendship formation. The primary strength of social network designs rests in the ability to model the ways through which individual attributes shape social outcomes, while also controlling for features of the social network itself. For example, friendships form around shared sociodemographic attributes such as gender and race (McPherson et al., 2001), shared social connections (i.e., transitivity), and have a tendency toward reciprocity (i.e., “If you are my friend, I’m also your friend”; Steglich et al., 2010). Further, adolescents differ in sociability and popularity, often driven by particular health attributes. Specifically, adolescents who are obese (Schaefer & Simpkins, 2014) or have poor mental health (Baggio et al., 2016) are socially marginalized and isolated, while adolescents who use substances, particularly alcohol, are often popular (Ali, Amialchuk, & Nikaj, 2014).

Findings demonstrate that adolescents with chronic illness experience feelings of social isolation (Manning et al., 2013; Taylor, Gibson, & Frank, 2008; Yeo & Sawyer, 2005) and engage in increased levels of health risk behaviors (Barnes et al., 2010; Suris et al., 2008). This suggests that adolescents with chronic illness are particularly vulnerable to the negative repercussions of social isolation, compounded by engagement in health risk behavior. Despite this considerable vulnerability, no study to date has examined the relationship between chronic illness and friendship patterns in adolescents.

Knowledge of the social consequences of chronic illness would allow researchers to better design effective intervention strategies to support and enhance the wellbeing of this vulnerable population. Thus, the current study employs a novel social network design to uncover the objective mechanisms through which chronic illness shapes adolescent friendships.

Nearly one out of four youth aged 17 years or younger in the U.S. suffers from a chronic health problem (Van Cleave, Gortmaker, & Perrin, 2010; van der Lee, Mokkink, Grootenhuis, Heymans, & Offringa, 2007). Although definitions vary (van der Lee et al., 2007), chronic illness typically involves a health problem that does not resolve within three months, affects a youth's normal activities, and requires prolonged or frequent treatment from a medical provider. Chronic illness impacts adolescent development in multiple domains, and research demonstrates that adolescents with chronic illness experience social consequences, such as reported difficulty developing and maintaining friendships and feelings of social isolation (see Taylor et al., 2008 for a review). In addition, chronic illness has been associated with poorer quality peer relationships and increased levels of social anxiety (McCarroll, Lindsey, MacKinnon-Lewis, Chambers, & Frabutt, 2009). Though previous research has highlighted negative social consequences of chronic illness, the current study is the first known effort to parse apart the underlying social mechanisms linking chronic illness and friendship.

Social network methods are particularly well-suited to investigate the intersection of chronic illness and adolescent friendships due to their ability to deconstruct adolescent social networks in three critically important ways. Social network data utilize friendship

nominations, wherein adolescents are asked to identify peers from their school whom they consider to be a friend. These nominations are subsequently separated into incoming and outgoing friendship ties, thereby allowing researchers to examine the specific associations between chronic illness and adolescent friendship. First, social marginalization of adolescents with chronic illness can be tested by comparing the likelihood of friendship ties directed toward adolescents with chronic illness, versus ties directed toward adolescents without chronic illness. Second, social withdrawal can be tested by comparing differences in the likelihood of sending friendship nominations according to whether the adolescent has a chronic illness. Last, homophily, or similarity in chronic illness status, can be tested in order to determine if friendships are more likely between two individuals with similar chronic illness status (e.g., either both with or without chronic illness) than friendship between adolescents without this in common.

Although previous literature suggests that adolescents with chronic illness experience feelings of social isolation, the current study uses a novel social network approach to examine if the objective social network structure of adolescents with chronic illness differs from that of their peers without chronic illness. Specifically, the current study asks the following research questions: (1) Do adolescents with chronic illness receive fewer friendship ties (i.e., social marginalization) than adolescents without chronic illness? (2) Do adolescents with chronic illness send fewer friendship ties (i.e., social withdrawal) than adolescents without chronic illness? (3) Do adolescent friendships form around similarity in chronic illness status (i.e., homophily)? By illuminating the processes linking chronic illness and friendship, the current study offers

valuable insight into effective strategies to support the social wellbeing of adolescents with chronic illness.

## **Method**

### **Participants and Procedure**

The current study is based on students within The National Longitudinal Study of Adolescent to Adult Health (Add Health; Harris et al., 2009), a nationally representative multi-wave panel study of adolescents in grades 7-12 at the onset of the study in 1994. Add Health consists of a sample of 80 high schools and 52 middle schools from the U.S., selected with unequal probability of selection, stratified by region of country, urbanicity, school size, school type, and ethnicity ( $N = 90,118$ ). Wave I in-school interviews were conducted with 132 schools in 1994, and a sub-sample of students underwent more comprehensive Wave I in-home interviews approximately 6 months later. The current study uses data obtained during the Wave I in-home interviews, as chronic illness questions were limited to this measurement occasion. 16 schools administered complete friendship surveys as part of the Wave I in-home interviews, a requirement of the present analyses. Of these schools, two were eliminated for large sample size ( $n = \sim 1,000$ ), which adds computational challenges to the analyses (An, 2016), and seven were eliminated for being designated as middle schools (i.e., grades 6-8) or special education schools. One additional school was excluded due to issues with model convergence. As a result, the current study is based on students within six high schools (i.e., grades 9-12) in the Wave I in-home sample of Add Health ( $N = 461$ ). Models were run separately by

school and then aggregated across schools via the meta-analysis technique of Snijders & Baerveldt (2003).

## **Measures**

**Friendship ties.** Adolescents were asked to identify their five closest female and five closest male friends from a provided roster of students within their school. ID codes were used to link adolescents to nominated friends, thus creating friendship ties.

Nominations for out-of-school friends were not considered, as data was not collected on these individuals. In this way, friendships were restricted to those occurring within the school in which the adolescent is enrolled, allowing for the formation of multiple complete networks of adolescents, a requirement of the analyses.

**Chronic illness.** Chronic illness is measured through three questions on various forms of chronic illness, including asthma, migraine headaches, and diabetes. A binary indicator of chronic illness was created, such that adolescents with no chronic illnesses were given a score of 0, and adolescents with one or more chronic illnesses were given a score of 1. Data on chronic illness was obtained from the parent questionnaire administered as part of Wave I in-home survey.

**Demographic control variables.** In order to provide accurate estimates of associations between adolescent friendships and chronic illness, other potential predictors must be controlled (Steglich et al., 2010, Veenstra & Steglich, 2012). Therefore, the proposed study controlled for important variables related to friendship formation or chronic illness, including grade level, gender, ethnicity, and depression. Grade level was coded as grade at Wave I and ranged from 9-12. Gender was coded dichotomously as

male or female. Ethnicity was measured through a binary indicator of Hispanic self-identification (0 = no, 1 = yes). Depression was measured with an 18 item, 3-point Likert scale from the Center for Epidemiologic Studies Depression Scale included in Add Health (Cronbach's alpha: 0.84).

**Missing data.** Variables within the current study displayed relatively low rates of missing data (3.5% on average). As a result, the school mean was imputed for continuous variables and the school mode was imputed for categorical variables. Methods for treating both attribute and friendship tie missingness within the ERGM framework are underdeveloped (Koskinen, Robins, & Pattison, 2010; Wang, Butts, Hipp, Jose, & Lakon, 2016), and the use of school-wise mean and mode imputation is commonly used with small rates of missing data in ERGM studies (Goodreau, Kitts, & Morris, 2009; Schaefer & Simpkins, 2014).

## **Analysis**

The current study investigated the relationship between chronic illness and adolescent friendships using cross-sectional exponential random graph models (ERGMs; Robins, Pattison, Kalish, & Lusher, 2007) carried out in the “ergm” package (Hunter, Handcock, Butts, Goodreau, & Morris, 2008) in R Language and Environment for Statistical Computing (R Core Team, 2017). Friendships in social network models are auto-correlated and therefore violate assumptions of independence, thus precluding the use of conventional statistical techniques. The ERGM statistical framework, however, takes dependencies between friendship partners into account and predicts the likelihood of friendship formation based on individual, dyadic, and structural features of the



network (i.e., the way individuals within a social network are connected). ERGMs produce parameter estimates that can be interpreted as the log odds of a friendship tie conditional on all other ties. ERGMs have recently been used to examine how adolescent friendships form around health indicators such as obesity (Schaefer & Simpkins, 2014) and mental health (Baggio et al., 2016), however the proposed study is the first known effort to apply a social network approach to the relationship between chronic illness and adolescent friendships.

**Overview of modeling process.** The outcome of an ERGM is dichotomous: the presence or absence of a friendship tie between all possible dyads within a social network. All models include an edges term, which represents the overall probability of a friendship tie. ERGMs represent social networks as graphs of nodes (i.e., individuals within a network) and edges (i.e., ties between friendship partners). For every ERGM, the number of nodes is fixed to the number of observed individuals within the network. The observed network is treated as one possible pattern of friendships out of a large set of possible patterns. The range of possible networks, and their probability of occurrence is represented by a probability distribution on the set of all possible graphs with the observed number of nodes.

Theoretically-driven model parameters are estimated in order to determine the attributes and social processes that most likely generated the observed friendship network. Thus, the assumption of ERGMs is that the social network is created through a stochastic process in which friendships are shaped by structural network properties as well as individual attributes (e.g., chronic illness). Markov chain Monte Carlo maximum

likelihood estimation (MCMCMLE) is used to test model parameters. Simulation of a distribution of random graphs is obtained from starting parameter values, and repeated to get refined values by comparing the simulated distribution of graphs to the observed network. MCMCMLE is the current recommended approach (Robins et al., 2007) and the default estimation technique in the “ERGM” package.

In the current study, models were estimated for each sample school separately, and then a meta-analysis technique (Snijders & Baerveldt, 2003) using the “metaphor” package (Viechtbauer, 2010) in R Language and Environment for Statistical Computing was conducted in order to combine results. In this method, estimates for each school are used to calculate a semi-weighted sample mean (Hedges & Olkin, 1985) for each effect, in which parameters are weighted inversely by their standard errors, thereby giving more weight to more precise estimates. The standard errors are used to calculate estimates of the sample variance for each effect, and the significance of effects is based on the t-value calculated from each estimated sample mean and variance. A more detailed account of this method can be found in Snijders & Baerveldt (2003) and Lubbers & Snijders (2007).

**Model specification and model selection procedures.** In order to explicitly model the relationship between chronic illness and adolescent friendships, several parameters must be tested. Chronic illness *indegree* measures how adolescent chronic illness affects the likelihood of being nominated as a friend by others. This effect represents the desirability, or popularity, of adolescents with chronic illness. A significant and negative coefficient would indicate that adolescents with chronic illness are socially marginalized. Chronic illness *outdegree* measures how adolescent chronic illness impacts

the likelihood of sending out friendship nominations. This effect represents reaching out for friendships, or level of sociability in the network. A significant and negative coefficient would indicate that adolescents with chronic illness are more socially withdrawn in comparison to adolescents without chronic illness. Lastly, chronic illness *nodematch* captures the effect of similarity, or homophily, in chronic illness on the likelihood of friendship formation. This effect indicates whether adolescents with chronic illness are more likely to form friendships with other adolescents who have a chronic illness, and vice versa.

The current study also controls for important demographic variables associated with friendship formation, including grade level, gender, parental education, depression, and ethnicity. Further, several endogenous features of the network, or structural properties known to predict friendship formation, were also included as control variables. For example, friendship reciprocity (e.g., mutuality in friendship nominations) and transitivity (e.g., friendship formation based around common others) contribute to the likelihood of friendship ties and were controlled. For all models, goodness of fit diagnostics were tested using AIC and BIC criteria, in addition to visual goodness of fit plots produced by the “ergm” package. In this way, all potential covariates were tested and nested models were compared to determine the best fitting model specification. Through this process, two potential covariates, ethnicity and depression, were excluded from the final model. A complete list of all parameters included in final model, in addition to their interpretation, is provided in Table 4-1.

Table 4-1

*Interpretation of Parameters in Final Models*

Parameter	Interpretation
Endogenous network properties	
Edges	Baseline number of ties within the network
Mutual	Likelihood of reciprocated friendship
Geometrically weighted edgewise shared partner	Likelihood of friendship based on the number of friendship partners linking two individuals
Geometrically weighted dyadwise shared partner	Likelihood of individuals without a friendship sharing multiple friendship partners
Geometrically weighted indegree	Tendency for some individuals to receive many nominations (e.g., popularity)
Geometrically weighted outdegree	Tendency for some individuals to send many nominations (e.g., sociability)
Basic covariates	
Gender similarity	Likelihood of friendships between individuals of the same biological sex
Grade similarity	Likelihood of friendship between individuals in the same grade
Parental education similarity	Likelihood of friendship between individuals with similar parental education
Chronic illness effects	
Chronic illness indegree (marginalization)	Difference in the likelihood of receiving friendship nominations based on whether the individual has chronic illness
Chronic illness outdegree (withdrawal)	Difference in the likelihood of nominating friends based on whether the individual has chronic illness
Chronic illness nodematch (homophily/similarity)	Likelihood of friendship based on whether both friendship sender and receiver have chronic illness

*Note.* Parameters represent only the effects included in the final model after following model fitting procedures. Hispanic ethnicity and depression, for example, were tested, but are excluded from the final model.

## Results

### Descriptive Statistics

Table 4-2 provides descriptive statistics for the sample. Adolescents were evenly split on gender (50.11% female) and across grade level. Only 3% of the sample identified as Hispanic. All control variables had relatively low rates of missing data (e.g., average

Table 4-2

*Descriptive Statistics of the Sample (N = 461)*

Characteristic	Percent	Mean	SD	<i>p</i> value
Female	50.11			0.68
Hispanic	3.04			0.98
Grade				0.94
9	25.16			
10	25.60			
11	26.68			
12	22.56			
Parental education				0.99
1 Less than high school	9.98			
2 High school	33.84			
3 Some college	27.55			
4 College degree	18.00			
Depression				0.98
1 Low	85.90			
2 Moderate	14.10			
3 High	0.00			
Chronic illness				0.94
0 No chronic illness	71.37			
1 Chronic illness	17.57			
Missing	11.06			
Friendship network				
Average number of incoming friendships		2.22	1.89	< .001
Average number of outgoing friendships		2.33	2.09	< .001

*Note.* *p* values represent chi-square tests for categorical variables. The average number of friends is calculated within the statnet package and between school differences tested with a one-way ANOVA.

of 2.1%); as a result, the school mean or mode was imputed, respectively. Approximately 17% of the sample reported having a chronic illness. Adolescents, on average, received 2.22 friendship nominations and sent out 2.33 nominations. Differences across schools in descriptive statistics were tested using chi-square tests for categorical variables (e.g., gender, parental education), and an ANOVA was used to test for differences in the continuous variables (e.g., average number of friendships). No significant differences

were found across the schools with regard to basic demographic variables, demonstrating a highly homogenous sample. Differences were found in the average number of incoming and outgoing friendship ties across schools, a common feature of social networks within schools (McPherson et al., 2001; Snijders, 2001).

### **Friendship Dynamics**

Results for the final ERGM model are displayed in Table 4-3. As expected, adolescent friendships formed based around several endogenous, or structural, features of social networks. Adolescents demonstrated a tendency toward reciprocated friendships (e.g., mutual effect;  $b = 2.70, p < .001$ ) and also transitivity (e.g., geometrically weighted edgewise shared partners and geometrically weighted dyadwise shared partners;  $b = 1.29, p < .001, b = -0.24, p < .001$ , respectively). For example, adolescents had 14.88 higher odds of forming reciprocated friendships (i.e.,  $e^{2.70} = 14.88$ ) than unilateral friendships. In the current sample, shared demographic features such as gender similarity, grade similarity, and parental education similarity did not significantly predict the likelihood of friendship.

Moving to the primary variables of interest, three parameters were included to capture the effect of chronic illness on adolescent friendship: chronic illness based marginalization (e.g., chronic illness indegree), chronic illness based withdrawal (e.g., chronic illness outdegree), and friendship based on chronic illness homophily (e.g., chronic illness nodematch). In the current sample, no significant evidence was found for marginalization ( $p = 0.10$ ), withdrawal ( $p = 0.44$ ), or homophily ( $p = 0.09$ ) based on chronic illness. The lack of significant findings for the impact

Table 4-3

*Parameter Estimates from Final Model*

Parameter	Coefficient	SE	Between school difference <i>p</i> value
Edges	-2.70	0.15***	0.08
Mutual	2.51	0.15***	0.28
Geometrically weighted edgewise shared partner	1.29	0.07***	< .01
Geometrically weighted dyadwise shared partner	-0.24	0.02***	0.24
Geometrically weighted indegree	-0.68	0.15***	0.29
Geometrically weighted outdegree	-0.80	0.15***	0.54
Gender similarity	0.01	0.06	0.05
Grade similarity	-0.04	0.03	0.65
Parental education similarity	0.05	0.03	0.49
Chronic illness indegree	0.10	0.08	0.10
Chronic illness outdegree	0.01	0.08	0.44
Chronic illness similarity	-0.03	0.08	0.09

\*\*\*  $p < 0.001$ .

of chronic illness on adolescent friendship formation patterns suggests that the social network structure of adolescents with chronic illness does not differ from that of their peers without chronic illness.

### Discussion

Peer relationships contribute to adolescent wellbeing and healthy development (Prinstein & Dodge, 2008; Rubin et al., 2006), and health indicators, such as obesity (Schaefer & Simpkins, 2014) and mental health (Baggio et al., 2016) have been shown to predict adolescent friendship formation patterns. Further, developmental theories (Bronfenbrenner & Morris, 2006) postulate a bidirectional relationship between social context and health, such that adolescent friendships and health are interdependent.

Previous research suggests that adolescents with chronic illness experience social isolation (Manning et al., 2013; Yeo & Sawyer, 2005), but no research to date has examined the ways through which chronic illness is related to friendship patterns in adolescence. Thus, the current study employed advanced social network methods to uncover the social mechanisms linking chronic illness and adolescent friendship in a sample of six U.S. high schools. Specifically, the study used objective social network measures of network structure to determine if adolescents with chronic illness were socially marginalized, socially withdrawn, or formed friendships with other adolescents who also have chronic illness.

The current study controlled for a number of alternative mechanisms through which adolescent friendships could form. Consistent with previous research (Snijders & Baerveldt, 2003; Steglich et al., 2010), adolescent friendships followed basic endogenous, or structural, properties of social networks. For example, friendships tended to be reciprocated (e.g., mutual effect) and associated with common others (e.g., geometrically weighted edgewise shared partner, geometrically weighted dyadwise shared partner). In the current sample, similarity in gender, grade, and parental education did not significantly contribute to the likelihood of friendship. Further, baseline measures of sociability (e.g., geometrically weighted outdegree) and popularity (e.g., geometrically weighted indegree) were not significant, suggesting comparability among adolescents in sending and receiving friendship nominations.

Turning to the theoretical variables of interest, the current study did not find significant evidence that adolescents with chronic illness were socially marginalized,



withdrawn, or formed friendships with others with chronic illness. Although previous research has found that adolescents with chronic illness experience social isolation (Manning et al., 2013; Taylor et al., 2008; Yeo & Sawyer, 2005), the current study found that the social network structure of adolescents with chronic illness did not differ from that of their peers without chronic illness. This difference could be due to the fact that previous research relied on adolescent self-report of isolation from peers, while the present study utilized objective social network measures of friendship connections, therefore suggesting an important distinction when examining the social consequences of chronic illness. Taken together, the results suggest that chronic illness does not impact adolescents through the quantity of their social connections, but rather through subjective quality. For example, although adolescents with chronic illness display the same social structure as their peers, they may experience social isolation as a result of reduced participation in extracurricular activities due to their chronic illness, missed school and social events due to doctor's appointments, or an inability to emotionally connect with their friends about their chronic illness.

Overall, the present study adds to the literature on adolescent development by examining the structure of adolescent social networks in relation to chronic illness and highlighting the objective comparability of friendship structure between adolescents with chronic illness and adolescents without chronic illness. The lack of a significant relationship between chronic illness and friendship patterns suggests that the negative social consequences of chronic illness reported in previous literature is specific to subjective feelings of social isolation and poor relationship quality, rather than the

quantity of social connections. Consequently, interventions aimed at enhancing the wellbeing of adolescents with chronic illness would benefit from promoting increased quality of friendships and reducing subjective feelings of isolation, rather than building skills related to forming friendships.

### **Limitations and Conclusions**

Several limitations of the current study need to be mentioned. Most notably, the study is limited to six schools within Add Health, each with a relatively small sample size. The sample is limited by available chronic illness data within the Add Health dataset and computational challenges associated with the use of ERGMs on large social networks (An, 2016; Robins et al., 2007). As a result, the findings generalize to schools of similar size, and differences in the generative mechanisms behind adolescent friendship connections may be present in larger schools. In addition, chronic illness is measured through parental report on three common chronic illnesses, and therefore does not necessarily reflect medically diagnosed conditions. Similarly, the chronic illnesses captured in the present study are treatable conditions, in contrast to more severe chronic illnesses, which could impact the extent to which adolescent social lives were affected. Lastly, analyses were run separately for each school and then combined via meta-analytic techniques (Snijders & Baerveldt, 2003; Viechtbauer, 2010), however this approach does not overcome power limitations of studying small social networks (An, 2016; Robins et al., 2007). Future research would benefit from replicating these results with schools of larger size.

Despite these limitations, the current study advances developmental research by

employing a novel social network design to explicitly examine the social mechanisms linking adolescent chronic illness and friendships. Building upon previous literature that highlighted the negative social consequences of chronic illness (Manning et al., 2013; Taylor et al., 2008; Yeo & Sawyer, 2005), the main goal of the present study was to determine if the social network structure of adolescents with chronic illness differs from that of their peers without chronic illness. Specifically, the study investigated the relationship between chronic illness and social marginalization and social withdrawal, in addition to homophily, or similarity in chronic illness status, as predictive of friendship. Findings demonstrate that the social network structure of adolescents with chronic illness did not differ significantly from that of their peers without chronic illness.

The lack of a significant relationship between chronic illness and friendship patterns in the current sample suggests that the negative social consequences of chronic illness reported in previous literature (e.g., feelings of social isolation) are distinct from the objective measures of social connections (e.g., social marginalization, social withdrawal, chronic illness homophily) captured in social network methods. Given the comparability in friendship structure of adolescents with chronic illness and adolescents without chronic illness, the results demonstrate that chronic illness does not impact adolescent development through objective reductions in social connections, but likely through creating feelings of social isolation from peers.

## CHAPTER 5

### SUMMARY

Adolescence is a critical developmental period for health behavior, and marks a particularly vulnerable developmental stage for social influences (Brechwald & Prinstein, 2011; Steinberg & Monahan, 2007). Consequently, the identification of sociocontextual factors associated with health behaviors is essential for efforts aimed at promoting healthy adolescent development. Friendships are one of the most salient relationships during adolescence (Parker et al., 2006), and as a result, there is a critical need to understand the relationship between health behavior and friendships. Further, developmental theories (Bronfenbrenner & Morris, 2006) posit a continuous, bidirectional interaction between individual characteristics and sociocontextual factors. Through this framework, adolescent health behavior results both from the adolescents themselves, as well as their surroundings. The current manuscript encompasses a series of three studies in which the interplay between adolescent friends and health is investigated using rigorous social network methodologies.

Social network analysis is uniquely positioned to answer critical questions regarding adolescent development due to the novel ability to embed adolescents within their social network of friends and predict both social and behavioral outcomes. Social network methods overcome statistical challenges associated with non-independence of individuals, and perhaps most notably different than conventional methods, control for important structural features of social networks. The use of social network analysis has grown rapidly in recent years, and a growing body of literature demonstrates the

relevance of adolescent friendships to health behavior development, including substance use (Wang et al., 2016), delinquency (Rulison et al., 2014), and aggression (Laninga-Wijnen et al., 2017). The three studies included in this dissertation capitalize on the rigorous statistical framework of SAB models and ERGMs, with integrate critical components of an adolescent's social network when predicting the development of friendships and health behavior. As such, the work within this dissertation expands upon previous research by investigating critical gaps in the literature with regard to the dynamics of adolescent friendships and health behavior.

Chapter 2 of the present manuscript seeks to advance our understanding of the relationship between friendships and adolescent health by investigating multiple behaviors at one time. Although adolescence is marked with simultaneous increases in health risk behavior and declines in health protective behavior (Kann et al., 2016), social network studies typically examine one behavior in isolation (Veenstra et al., 2013). Therefore, Chapter 2 examined two divergent health behaviors (i.e., alcohol use and physical activity) in conjunction in order to (1) model the differential impact of friendships on each behavior, and (2) investigate the relationship between the behaviors. Results demonstrated differing mechanisms linking adolescent friendships and alcohol use and physical activity. Specifically, adolescents formed friendships based on shared levels of alcohol use, but did not show this same preference with regard to forming friendship based around physical activity. Conversely, adolescents changed their level of physical activity over time to become more similar to their friends' physical activity patterns, but did not change their alcohol consumption over time. Last, no evidence was

found for a significant relationship between level of alcohol use and level of physical activity.

Results from Chapter 2 suggest that adolescent friendships differentially impact alcohol use and physical activity, thereby suggesting different mechanisms to target in behavioral interventions. In particular, interventions aimed at alcohol use would benefit from a focus on preventing negative friendships from forming based around shared alcohol use. In contrast, a strong emphasis on friend selection processes in physical activity interventions may be unwarranted. Findings also indicate that health interventions aimed at physical activity would benefit from peer-led strategies, while relying on peer assimilation or influence to change alcohol use patterns may be ineffective. Overall, Chapter 2 highlights the varying dynamics between adolescent friendships and health behavior dependent on the behavior in question. As a result, the study suggests that applying one comprehensive peer-based strategy in efforts to change maladaptive adolescent behavior (e.g., alcohol use) or promote healthy behavior (e.g., physical activity) is ill advised. Rather, prevention and intervention programs must take into account the complex relationship between adolescent friendships and health behavior and design strategies that best capitalize on the role of peers in shaping behavior.

Chapter 3 of the present manuscript builds upon the wide body of literature examining peer influence on adolescent smoking. Previous research has demonstrated that adolescents are influenced by the cigarette use of their friends (see Simon-Morton & Farhat, 2010, for a review). At the same time, it is known that some substances are perceived as more socially acceptable (Kulesza et al., 2013), and cigarette smoking,

specifically, has shown overall declines in social acceptability in recent decades (Cummings & Proctor, 2014). Therefore, the main goal of Chapter 3 was to examine the concurrent impact of peer influence and perceived social acceptability of smoking on longitudinal trends in adolescent cigarette use. Results from Chapter 3 demonstrate that adolescents were more likely to change their smoking behaviors in response to how they perceived their friends to feel about smoking, versus the smoking behavior of their friends.

While previous research found mixed support for peer influence on smoking (Simons-Morton & Farhat, 2012), findings from Chapter 3 suggest that this relationship is tempered by accounting for perceived social acceptability of smoking. The applied impact of Chapter 3 is twofold. First, the results demonstrate the need for future research to carefully consider all aspects of influence from friends on smoking, rather than simply focusing on the quantity of smoking among an adolescent's friends. By controlling for important sociocontextual factors such as perceived social acceptability, the study expands our understanding of the complex mechanisms through which aspects of the peer environment shape adolescent smoking. The findings from Chapter 3 also have practical implications for prevention and intervention design. In particular, programs that aim to reduce adolescent cigarette use should address perceptions of adolescent smoking and beliefs that peers approve of this behavior.

Chapter 4 switches perspectives and examines adolescent health from the framework of social outcomes. Developmental research highlights the importance of peer relationships to adolescent wellbeing and healthy development (Prinstein & Dodge, 2008;

Rubin et al., 2006), and a primary benefit of applying a social network approach to adolescent development is the ability to model the ways through which individual attributes shape social outcomes (e.g., friendship). Although previous research has demonstrated that adolescents with chronic illness experience feelings of social isolation (Manning et al., 2013; Taylor et al., 2008; Yeo & Sawyer, 2005), no study to date has parsed apart the social patterns linking friendships and chronic illness. As a result, Chapter 4 applied a novel social network design to examine if adolescents with chronic illness were socially marginalized, socially withdrawn, or formed friendships with other adolescents who also have chronic illness.

Results from Chapter 4 demonstrate that the social network structure of adolescents with chronic illness did not differ from that of their peers without chronic illness. That is, the study did not find significant evidence that adolescents with chronic illness were socially marginalized, withdrawn, or formed friendships with others with chronic illness. Findings from Chapter 4 suggest an important distinction when examining the social consequences of chronic illness. Whereas previous research relied on adolescent self-report of isolation from peers, Chapter 4 utilized objective social network measures of friendship connections. As a result, the lack of a significant relationship between chronic illness and friendship patterns suggests that the negative social consequences of chronic illness reported in previous literature is specific to subjective feelings of social isolation and poor relationship quality, rather than the quantity or structure of social connections. Consequently, interventions aimed at enhancing the wellbeing of adolescents with chronic illness would benefit from



promoting increased quality of friendships and reducing subjective feelings of isolation, rather than building skills related to forming friendships.

In sum, the three studies included in this dissertation apply advanced social network methodologies to answer critical questions regarding the relationship between adolescent friendships and health. Grounded in developmental theories (Bronfenbrenner & Morris, 2006), the studies capture the bidirectional relationship between adolescent friendships and varying aspects of health. Findings from all three studies inform developmental research through the identification of novel intervention targets from a social network perspective. The dissertation adds to the literature by applying rigorous models from social network analysis in order to expand our understanding of the sociocontextual factors impacting adolescent development.

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Appendix B

Coauthor Permission for Tyson Barrett

**Tyson Barrett**

Permission for Dissertation

To: Emily Long

March 26, 2018 at 12:16 PM

TB

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I give Emily Long permission to publish our jointly authored articles entitled "Network-behavior Dynamics of Adolescent Friendships, Alcohol Use, and Physical Activity" and "Using Social Network Analysis to Unravel the Relationship Between Chronic Illness and Adolescent Friendship" as part of her dissertation entitled "Using Social Network Analysis to Examine the Intersection of Adolescent Friendships and Health Behavior."

Tyson

Tyson S. Barrett, PhD  
Research Assistant Professor  
Managing Director of the Data Science & Discovery Unit  
Emma Eccles Jones Jones College of Education and Human Services  
Utah State University

Appendix C

Coauthor Permission for Thomas Valente

☆ Valente, Thomas 

March 25, 2018 at 6:48 PM



permission to use our data for your dissertation

To: Emily Long

---

Emily

I give Emily Long permission to publish our jointly authored article entitled "Perceived Social Acceptability and Peer Influence on Adolescent Cigarette Smoking" as part of her dissertation entitled "Using Social Network Analysis to Examine the Intersection of Adolescent Friendships and Health Behavior".

It is a pleasure working with you.

-Tom

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**EDUCATION**

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| 2009        | B.A.  | Psychology<br>University of Redlands, Redlands, CA<br>Emphasis: Research Methodology   |

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**PUBLICATIONS**

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Long, E. & Valente, T.W. (*under review*). Perceived social acceptability and longitudinal trends in adolescent cigarette smoking. *Prevention Science*.

Simone, M. & Long, E. (*in press*). The dynamic relationship between unhealthy weight control and adolescent friendships: a social network approach. *Journal of Youth and Adolescence*.

Long, E., Barrett, T., & Lockhart, G. (*manuscript in preparation*). Social consequences of adolescent chronic illness: evidence from an ERGM framework.

## RESEARCH PRESENTATIONS

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