A Behavior Genetic Study of Peer Groups and Alcohol Use in Adolescence

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Abstract

Peer relationships are heralded as an influential social domain in adolescence and may surpass parenting as the dominant influence on adolescent alcohol use. Selection and influence processes co-occur, but the specific extent of peer influence, primary influencing agents, and mechanisms of action are unclear. The current study addresses these concerns using data from the National Longitudinal Study of Adolescent Health. First, we consider the diversity in peer networks by examining structural and behavioral aspects of these networks. Second, as peers represent different social contexts throughout development, we examine the developmental course of alcohol use from early adolescence to early adulthood. Third, we use family designs to consider potential genetic and environmental confounds to identify true causal relationships. This is the first study to combine multiple dimensions of the peer environment with the rigor of family designs to differentiate risk indicators from causal mechanisms.

Results indicated that greater peer substance use was related to greater overall alcohol use, a greater increase into mid and late adolescence, and less of a decline into early adulthood. These effects were greatest when an adolescent was close to his or her peer group. While genetic confounds moderated the relationship between peers and adolescent alcohol use, there remained a quasi-causal path providing strong support for the causal role of peer group substance use on alcohol use throughout adolescence, particularly in the context of high quality friendships. These findings are consistent with a model involving selection and influence processes and implicate indirect peer effects. Implications regarding future research and interventions to reduce alcohol use and other problem behaviors in adolescence are discussed.

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To Alejandro,

my best friend and loving husband,

who steadies and inspires me.

—J. E. C

Acknowledgments

As the theme of this dissertation is the importance of interpersonal systems in individual outcomes, I would like to begin by acknowledging some of those individuals in my system who have contributed to my life through this journey.

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A Behavior Genetic Study of Peer Groups and Alcohol Use in Adolescence

Problem behaviors, including alcohol use, in adolescence are associated with enduring, negative outcomes for the individual and lead to strain on relationships and society. Although studies have demonstrated predispositions to engage in problem behaviors, social influences also contribute to the emergence and severity of the behavior (e.g., Rhee & Waldman, 2002). Peer relationships are heralded as a particularly influential social domain in adolescence and may surpass parenting as the dominant influence on adolescent problem behavior (e.g., Crosnoe & McNeely, 2008; Dishion & Patterson, 2006). The presumed strength of peer influence either directly through peer pressure or indirectly by setting normative standards for behavior has permeated cultural beliefs. "Running with a bad crowd" is commonly cited as the impetus for an adolescent's problem behaviors and adolescents. Social norms campaigns on college campuses inform students that "Fewer than one in five college students get drunk at parties" and adolescents are encouraged to "Just Say No to Drugs" by a wide-reaching campaign to increase the social desirability of deflecting peer pressure to engage in drug and alcohol use.

However, despite this colloquial belief of the importance of peers, empirical support is far from clear. As adolescents cannot be assigned to friends or families, peer research suffers from falling within a busy intersection of confounding processes that make identification of causal processes difficult. Best friends have received greater attention than peer groups in the literature and have been vetted by more rigorous tests of causality, including longitudinal and family designs, leading to continually dampening estimates of the effect of a best friend on alcohol use. Despite this focus, promotion and

prevention of alcohol use more likely lies in the complex and dynamic intricacies within the peer system and individual differences between adolescents. Recent reviews resonate the importance of the peer system, and call for consideration of these complexities to identify true causal pathways (Arnett, 2007; Crosnoe & McNeely, 2008). Recent studies have begun to consider multiple dimensions within the peer system and have validated that the complexity of the peer environment has implications for adolescent outcomes (Ennett et al., 2008). Failure to consider the complete peer system and individual differences oversimplifies an interactive environment and may inhibit the development of effective interventions (Arnett, 2007). In fact, concentrating only on best friendships may lead to the unlikely conclusion that friends do not have an effect on problem behaviors. Yet, overestimation of peer influence can occur as peers are not selected at random. Friends may select one another based on problem behaviors or confounds (genetic or environmental) may lead to both selection of peer groups and engagement in problem behavior. Both complexity of the peer system and consideration of the processes that may create that system are important in accurately identifying peer influences.

We review the research on best friends to demonstrate the importance of considering confounding processes in the association between peers and problem behavior, generally, and alcohol use, specifically. Although alcohol use is the focus of the current study, research involving peers and all problem behaviors are seen as highly relevant. While problem behaviors are heterogeneous in nature, they reflect similar liabilities and outcomes (e.g., Krueger et al., 2002). We then review the promising research on peer groups that suggests that groups may provide powerful contexts for the

development of problem behavior. We then propose the use of longitudinal and family designs as an efficient method to identify causal mechanisms and consider the numerous potential confounds in the relationship between peer groups and alcohol use in adolescence.

Overestimation of the Influence of Close Friends

Close friendships with adolescents who engage in problem behaviors are one of the strongest correlates of problem behavior in adolescence. This relationship is stable across gender, race (Laird, Pettit, Dodge, & Bates, 2005), and culture (Brook, Morojele, Zhang, & Brook, 2006; Cornelius, Clark, Reynolds, Kirisci, & Tarter, 2007; Kliewer & Murrelle, 2007; Kokkevi et al., 2007; Morash & Moon, 2007; Smith, Phongsavan, Bauman, Havea, & Chey, 2007). Friendships with adolescents engaging in problem behavior are associated with a variety of problem behaviors including alcohol and cigarette use (e.g., Audrain-McGovern, Rodriguez, Tercyak, Neuner, & Moss, 2006; Barnes, Hoffman, Welte, Farrell, & Dintcheff, 2006; Simons-Morton & Chen, 2006; Urberg, Degirmencioglu, & Pilgrim, 1997), illicit drug use (Barnes et al., 2006), aggression (Cairns et al., 1988), antisocial behavior (Dishion, Andrews, & Crosby, 1995; Kiesner, Cadinu, Poulin, & Bucci, 2002), early sexual behavior (Metzler, Noell, Biglan, & Ary, 1994), externalizing behavior (Reitz, Dekovic, Meijer, & Engels, 2006), and risk taking behavior (Michael & Ben-Zur, 2007).

Several mechanisms may be reflected in the strength of the association between problem behavior and deviant friendships including 1) selection based on problem behavior, 2) other confounds influencing both selection and problem behavior, 3) individual differences in susceptibility to peer influence, and 4) a causal role for peers

(Bauman & Ennett, 1996; Hill, Emery, Harden, Mendle, & Turkheimer, 2008; Jaccard, Blanton, & Dodge, 2005; Poelen, Engels, Vorst, Scholte, & Vermulst, 2007; Urberg, Luo, Pilgrim, & Degirmencioglu, 2003). Similarity between friends likely owes to a combination of influence and selection processes whereby adolescents choose and are chosen by friends who engage, or are likely to engage, in similar behaviors (e.g., Crosnoe & McNeely, 2008).

Friend Selection Based on Problem Behavior. Cross-sectional associations between adolescents and their peers as indications of peer influence have long been identified as severe overestimates (Bauman & Ennett, 1996). The past decade of research on deviant peer affiliation has confirmed this overestimation (e.g., Arnett, 2007; Jaccard et al., 2005; Poelen et al., 2007; Urberg et al., 2003). Selection may owe directly to the problem behavior as most adolescents become friends with adolescents who engage in similar behaviors (Allen, Porter, & McFarland, 2006; Urberg et al., 2003). Selection may also owe indirectly to the problem behavior as other children may initially reject children engaging in deviant behaviors, but rejected children may become friends out of a shared status in adolescence and may further support problem behavior through reinforcement of deviant talk and actions (e.g., Dishion & Owen, 2002; Granic & Dishion, 2003). There is also evidence for continuous selection processes. Adolescents change friends relatively often. These changes may reflect the tendency for adolescents to spend more time with friends engaging in similar levels of deviant behavior (Dishion & Medici Skaggs, 2000) and to nominate best friends with more similar expressions of problem behaviors (Poelen et al., 2007).

Other Influences on Friend Selection. Consideration of selection based on problem behaviors alone is insufficient in accurately estimating peer influence. Adolescents do not always select friends with similar behaviors (Urberg et al., 2003) and friends do become more similar over time (Reitz et al., 2006; Urberg et al., 2003). Yet, other factors influencing selection of friends may affect subsequent changes in alcohol use for both friends without the independent influence of each friend on the other (Hill et al., 2008; Jaccard et al., 2005). Convergence owing to a confound may manifest through a process such as early pubertal development that influences selection of similarly physically mature friends and has likewise been associated with increased problem behaviors (Harden, Hill, Turkheimer, & Emery, 2008; Jaccard et al., 2005). Confounds may exist at the context level, such as socioeconomic status, neighborhoods, schools (Miles & Carey, 1997), life transitions, and stressful life experiences (Fergusson, Wanner, Vitaro, Horwood, & Swain-Campbell, 2003); the family level, such as maternal attitudes toward risk behavior, perceived parental control (Jaccard et al., 2005); parental attachment (Allen, Moore, Kuperminc, & Bell, 1998; Allen, Porter, McFarland, McElhaney, & Marsh, 2007); and parental monitoring of peer interactions (Padilla-Walker, 2006), or the individual level such as adolescent rebelliousness (Curran, Stice, & Chassin, 1997), physical development, romantic relationship involvement, history of hyperactivity (Young, Heptinstall, Sonuga-Barke, Chadwick, & Taylor, 2005), and history of problem behavior (Jaccard et al., 2005).

Longitudinal designs have highlighted the importance of considering the confounding processes mentioned above. However, longitudinal designs are limited to finite and measurable confounds. Confounds may be innumerable, immeasurable, or

simply unmeasured. Family designs permit consideration of many more confounds than traditional designs, which may result in a spurious association between affiliation with deviant peers and deviant behavior. Family designs have generally indicated family confounds, both environmental and genetic, in the relationship between adolescent and friend deviance (Hill et al., 2008; Kendler et al., 2007; Poelen et al., 2007; Rowe & Osgood, 1984; Walden, McGue, lacono, Burt, & Elkins, 2004). Genetic influences affecting perception of peer group delinquency increase over time with corresponding decreases in shared environmental influences (Kendler et al., 2007). The relationship between adolescent alcohol use and perceptions of friends' alcohol use appear to be mediated largely by environmental confounds (Hill et al., 2008; Walden et al., 2004) while the relationship between adolescent alcohol use and peer report of substance use is completely mediated by genetic confounds (Hill et al., 2008). Family designs examining perceptions of friend alcohol use provide limited support for peer influence with friend alcohol use predicting less then 5% of the variance in adolescent alcohol use (Hill et al., 2008; Poelen et al., 2007) with younger adolescents demonstrating a greater peer influence effect than older adolescents (Poelen et al., 2007).

Individual Differences in Susceptibility. While consideration of selection based on problem behavior and selection based on confounds severely reduces estimates of peer influence, many of these studies assume that all adolescents are at an equal likelihood of being influenced by peers. It is more likely that adolescents differ in their susceptibility to peer influence and that factors related to susceptibility may likewise be related to problem behavior (e.g., Allen et al., 2006). In fact, susceptibility may be the determining factor in whether adolescents, initially discordant for problem behavior, trend toward the

more deviant friend, the less deviant friend, or converge (e.g., Allen et al., 2006; Urberg et al., 2003).

Susceptibility may differ due to environmental or genetic influences. Allowing for differences in susceptibility owing to genetic influences yields identification of a trio of risk factors for drinking: at risk adolescents were initially predisposed to drink alcohol, more likely to select friends who drank, and more likely to be influenced by these friends (Harden et al., 2008). Specific neural pathways may be responsible for this increased susceptibility as adolescents considered more susceptible to peers' influence have different neural responses to emotional environmental cues (Grosbras et al., 2007). While it is unlikely that there is a single gene controlling susceptibility, genes that affect personality characteristics, such as propensity to take risks, may affect alcohol use, peer selection, and susceptibility.

Observable characteristics that affect susceptibility may include individual characteristics, the family environment, or peer relationship quality. Adolescents with a history of binge drinking appear to be at a greater risk for assimilating to their friend's behavior (Jaccard et al., 2005). Furthermore, autonomous adolescents are less likely to use drugs when their friend experiments with drugs, measure lower in depression and problem behaviors, and have more stable and high quality relationships than adolescents who lack autonomy (Allen et al., 2006). Parenting practices and social contexts may also influence susceptibility to peer influence. Adolescents who meet friends in unsupervised contexts and who spend unstructured time with peers are more delinquent and may be more susceptible to their peers (Dishion et al., 1995).

While affiliation with deviant friends is one of the strongest correlates of problem behavior in adolescents, this association reflects a combination of selection and influence processes. Consideration of selection based on problem behavior and confounds greatly reduce the estimated effect of affiliation with peers on problem behavior. Recent work on susceptibility to peer influence stresses the importance of considering individual differences among adolescents and supports earlier assertions regarding the importance of friends' behaviors. Adolescents vary in their susceptibility to peer pressure with adolescents at a high risk for problem behavior also being at a high risk for peer influence. Although friends may influence problem behavior through modeling or reinforcement of deviant behavior for susceptible adolescents, this influence is considerably less than originally estimated. Other peer relationships and the context within which the friendships exist provide a more complete understanding of peer effects on problem behavior.

Peer Groups

Peer group dynamics may exert a powerful influence on adolescent behavior. Peer groups may create a culture in which certain behaviors are normative and social success is dependent on adherence to these norms. The cultures created by peer groups are amorphous and difficult to define, however adolescents are aware of the cultural dynamics of different groups and the differences between them. Adolescents can reliably identify members of groups (Michell, 1997), recognize social hierarchies (Brown & Lohr, 1987; Michell, 1997; Rosenberg, McHenry, & Rosenberg, 1962), and accurately attribute attitudes and behaviors regarding drug use to specified groups (Michell, 1997).

The peer group may subsume effects of individual relationships. Comparison of dyadic relations to group relations revealed that individual relationship quality within dyads in the group did not predict additional substance use beyond that predicted by peer group qualities (Bauman, Faris, Ennett, Hussong, & Foshee, 2007). Furthermore, protective effects of quality relationships with peers on problem behavior were greater for adolescents who were members of peer groups then for those who had only high quality dyadic friendships (Lansford, Criss, Pettit, Dodge, & Bates, 2003). Comparisons between the role of best friends and groups indicate that groups are more important for younger adolescents whereas close friendships and romantic partners increase in importance with age (Brown, Dolcini, & Leventhal, 1997; Morgan & Grube, 1991; Urberg, Shyu, & Liang, 1990; Urberg, Cheng, & Shyu, 1991). Peer groups also appear to have influence over different types of behavior. While close friends are more influential than peer groups on initiation of alcohol and cigarette use, both close friends and peer groups equally influenced drinking until drunk (Urberg et al., 1997).

Group Types. Researchers have attempted to categorize types of groups formed in adolescence and have generally suggested between three and six group types. Glendinning and collegues (1995) identified three groups: "conventional, family and school oriented", "peer oriented", and "disaffected" adolescents. Drug use was associated with the latter two with the distinction that the peer oriented group used drugs to maintain social status while understanding health implications whereas the disaffected youth group disregarded health implications and engaged in drug use in conjunction with other delinquent behaviors (Glendinning, Hendry, & Shucksmith, 1995).

Michell & Amos (1997) proposed six groups: “top girls,” “top boys,” “middle pupils,” “low status pupils,” “trouble-makers,” and “loners”. Adolescents perceive that top girls, low status pupils, and troublemakers were most likely to smoke; adolescents perceive, however, that these groups smoke for different reasons. Top girls smoked to maintain a mature image, whereas low status pupils smoked to fit in with adolescents that were more popular. Troublemakers, like the “disaffected” adolescents above, smoked as part of a general disregard for rules. Adolescents in the middle of the hierarchy reported supportive relationships with family and friends and were not motivated to conform or enhance their image by smoking (Michell & Amos, 1997; Michell, 1997).

Mosbach and Leventhal (1988) identified four groups: “dirts,” “jocks,” “hotshots,” and “regulars.” Dirts and hotshots tended to smoke, although again for different reasons, while jocks and regulars did not. Dirts were comprised largely of males who were relatively unconcerned with health consequences of smoking, drank heavily, and engaged in risk taking behaviors. Their smoking did not appear to be related to difficulties in resisting peer pressure. Instead, their behavior reflected their personal motivations to smoke. Hotshot females smoked to maintain social status although they recognized the harmful consequences of smoking. For these youth, peer influence played a greater role in their smoking decisions (Mosbach & Leventhal, 1988).

Barber, Eccles, and Stone (2001), acknowledging the difficulty of science to perform that task of group characterization that adolescents perform readily, predicted behaviors from qualitatively derived peer groups used in the movie *The Breakfast Club (Hughes, 1985)*. Adolescents were asked to indicate which character they were most like (i.e., “criminal,” “princess,” “brain,” “basket case,” and “jock”) and their self-

identification was compared to their involvement with leisure activities, substance use, academic outcomes, psychological outcomes, family demographics, and job characteristics in young adulthood. Considerable differences in outcome based on group identification indicated that adolescents were adept at such categorizations. Criminals had the greatest marijuana use, and jocks and criminals shared high levels of alcohol use. However, jocks were less likely than criminals to be in a substance abuse rehabilitation facility. This may reflect the greater likelihood for jocks to be in a college setting where drinking norms are higher and societal consequences less severe. Criminals and basket cases had the lowest self-esteem, and brains and jocks had the most positive psychological outcomes (Barber et al., 2001). Further, the extent to which self-identification and peer-recognition into these groups are in agreement has consequences for adolescent outcomes including depression and anxiety (Brown et al., 2007).

The differences in categories across context may be in response to methodological considerations or may reflect cultural differences. Using similar methodology Mosbach and Leventhal (1988) and Sussman and collegues (1990) found different numbers of groups in different regions of the country. However, a striking similarity between these categorizations is that among high drug use groups there seem to be two primary types. There are groups where adolescents use drugs as part of a general disregard for rules (e.g., criminals, dirts, disaffected, and troublemakers) and groups where adolescents use drugs to assimilate into the normative expectations of the group (e.g., peer-oriented, top girls, hotshots, and jocks).

Popularity. An important aspect of friendship groups is where the group exists in the social hierarchy (i.e., how popular the group is) and where an individual exists within

the hierarchy of a particular group (i.e., how popular the individual is within the group). Adolescents commonly seek popularity. Research into childhood friendships has suggested that popularity is generally an indicator of adjustment such that popular children are well liked by their peers, socially competent, engage in prosocial behaviors, and have lower levels of depression (Nangle, Erdley, Newman, Mason, & Carpenter, 2003). Yet, popularity appears to have a more heterogeneous effect on adolescent problem behaviors. Several theories have developed to address the heterogeneity in outcomes associated with popularity.

Allen and collegues (2005) suggest that popularity is a marker of socialization. To become popular, adolescents must be adept at conforming to normative standards of the peer group. In childhood, these normative standards may be quite benign leading to the almost universally positive outcomes associated with popularity. In adolescence, however, minor delinquent acts become more normative as adolescents strive for independence, particularly from parents. As the normative level of delinquency increases, so do the expectations of the individuals in the peer group. Such normative behaviors can be subjectively grouped as positive (e.g., reduction in aggression toward others in the peer group) or negative (e.g., increase in minor delinquent behaviors).

Despite negative judgment by parents and authorities, increase in minor delinquent behaviors may be a measure of normal adjustment and functioning. The degree to which an adolescent is out of step with his or her peers may be an indication of poor socialization regardless of whether the incongruence is due to problem behavior by the peer group or the adolescent. For example, non-drinkers who are friends with drinkers have worse emotional and educational outcomes then other non-drinkers

whereas problems associated with drinking are worse when a drinking adolescent is friends with non-drinkers (Crosnoe & Needham, 2004). In addition, adolescents on the fringe of a peer group have increased risk for substance use compared to adolescents clearly belonging to a group of friends (Ennett & Bauman, 2006). Adolescents on the fringe of high status, substance-using groups may be at a particular risk. These adolescents may have greater motivation to change their behavior in order to comply with the standards of the popular group (Ennett & Bauman, 2006).

Engaging in minor problem behavior in order to comply with normative standards may fall into a normative level of delinquency in adolescence that is unlikely to continue into adulthood. Moffitt (1993 & 2003) describes delinquency as either life-course or adolescent limited. Adolescent limited delinquency may be in response to changing norms and may be adaptive. This same adaptation may lead to reduced delinquency during the transition to adulthood when rule-breaking behaviors are no longer normative (Allen et al., 2005).

Friendship Quality. Friendship quality may be an important factor in susceptibility to peer influence. Urberg et al. (2003) found that while affiliating with substance using friends was predictive of increased substance use, regardless of relationship quality, the effect was greatest for those with high quality relationships. In higher quality relationships, friends may spend more time with one another and provide greater opportunity for influence or the friend may be more influential due to the importance of the relationship (Urberg et al., 2003). Other research considering multiple dimensions of peer characteristics on adolescent smoking has indicated that having high quality relationships with many smokers predicts less smoking, after accounting for

group level smoking. This may reflect a level of social success wherein adolescents can diverge from their friends without social consequence (Ennett et al., 2008).

The subtype of problem behavior (e.g., delinquency or drug use) may affect the role of friendship quality on susceptibility to peer influence. Lansford et al. (2003) examined antisocial behavior and found that low quality relationships were associated with greater susceptibility and high quality relationships promoted resilience. Antisocial behaviors may hamper development of high quality relationships while normative behaviors, such as cigarette use and alcohol use, do not limit and may even promote the development of high quality friendships. Qualitative investigation of friends influence on alcohol use behavior indicated that adolescents with high quality friends might have reduced harm when using substances. For example, friends may ensure a friend does not drink too much, is in a safe environment, and makes good choices (Jorgensen, Curtis, Christensen, & Gronbæk, 2007).

Despite normative increases in alcohol and cigarette use, having high quality relationships appears to increase resiliency in adolescents and reduce development of more severe problem behaviors. When friendships lack in quality or friends lack prosocial skills, these relationships may reinforce and encourage antisocial behaviors (Lansford et al., 2003). Friendships poor in quality or with other socially deficient adolescents may be particularly damaging if the dyad is not part of a larger social network. The friends may exert greater influence over one another as maintaining the friendship may be more important than when there are other friends available. In addition, when other friends are present, they may act as competition for influencing the targeted friend (Jaccard et al., 2005).

Friendship quality may also affect adolescent susceptibility to other risk factors for problem behaviors. Adolescents with high quality friendships have greater resilience to family adversity than those that do not. Lansford et al. (2003) found that adolescents with high quality friendships, regardless of friends' antisocial behavior, demonstrated greater resilience to parenting practices associated with adolescent externalizing behavior. Low quality relationships do not protect, but rather seem to worsen the effects of family adversity. While this is true for adolescents whose peers are not antisocial, low quality relationships are particularly damaging when friends exhibit antisocial behaviors (Lansford et al., 2003). One explanation for this is that an individual's first opportunity to learn prosocial skills arises in the family environment and the peer context serves as a back-up when socialization is deficient (Bolger, Patterson, & Kupersmidt, 1998; Cooper & Cooper, 1992; Criss, Pettit, Bates, Dodge, & Lapp, 2002; Price, 1996). For adolescents whose home environment did not support development of prosocial behaviors, peers may fill this void by providing a context for socialization (Hartup, 1996; Ladd, 1999).

Cultural Norms and Problem Behavior. Within some groups of adolescents, the normative level of problem behavior is greater then in others. Becker & Luther (2007) found that, overall, adolescents who used high levels of substances perceived greater admiration by their peers than those who used lower levels of substances. However, they found that urban boys with high levels of substance use perceived greater admiration by peers then boys in affluent-suburban settings or girls in either urban or suburban settings. When comparing Latino to African-American adolescents in the urban setting, Latino adolescents in the high substance use group perceived a higher level of admiration by

their peers than did African-American adolescents (Becker & Luthar, 2007). Pearson and collegues (2006) found that although social status was unrelated to smoking, alcohol, and other drug use generally, differences emerged when considering the socioeconomic status of the school. For students in high SES schools, smoking rates were high for popular students while for students in low SES schools, smoking rates were low for popular students (Pearson et al., 2006).

Gangs represent a cultural context in which the normative behavior is problematic and persistent. Gang involvement has an enhancement effect on problem behavior in adolescence. While adolescents who select into gangs are more delinquent then those who do not, when compared to adolescents at the same level of delinquency, adolescents who select into gangs become more delinquent through their involvement in the gang than adolescents who do not select into gangs (Craig, Vitaro, Gagnon, & Tremblay, 2002; Thornberry, Krohn, Lizotte, & Chard-Wierschem, 1993). These differences are eliminiated if the gang member becomes inactive (Hill, Howell, Hawkins, & Battin-Pearson, 1999). The gang context is one that consistently requires delinquent and aggressive acts because maintenance of the individual's reputation in the gang and the gang's reputation in a community requires that adolescents respond to conflict aggressively (Gatti, Tremblay, Vitaro, & McDuff, 2005; Thornberry et al., 1993).

Depending on the peer group, conforming to the normative standards of the peer group may represent different levels of risk. In some contexts, supports may exist within the environment that will phase out delinquent behaviors as adolescents transition into adulthood. However, other contexts may lack the support to aid this transition allowing delinquent behaviors to continue into adulthood when these behaviors are no longer

indicators of socialization and adjustment. In peer groups that fail to adopt different normative standards, the problem behaviors may persist or worsen through the transition.

Conclusions on Peer Groups. Peer groups may have considerable influence on adolescent problem behavior by defining normative behaviors within the peer culture. However, the contributions of groups to social behavior have received considerably less attention than dyadic relationships. While research in dyadic relations has begun to consider the process by which adolescents come to be similar to their peers, similar work is limited with groups. Affiliation with a crowd that engages in a particular problem behavior is highly associated with engaging in the behavior. However, longitudinal studies in this area are lacking, which prevents parsing the degree to which this relationship is a manifestation of peer selection or group influence. Furthermore, it is difficult to parse whether any influence is the result of one or two good friends in the crowd or the crowd as a whole. Consideration of the structure of the group, the quality of the relationships, and cultural context in which the group exists are important in understanding the effects of peer groups.

Using Family Designs to Identify Causal Mechanisms

Peer relationships encompass many possible confounds that may affect peer selection and susceptibility to peer influence. Family designs are an advantageous way to untangle such factors that are usually confounded. Differences between unrelated individuals are confounded by all the environmental and genetic factors that differ between families, but differences between siblings are only confounded by influences that vary systematically within sibling pairs. The majority of variation in adolescent behavior is a product of the environment unshared by siblings (Daniels & Plomin, 1985).

Siblings experience substantial differences in peer environments and as such, peer relationships may be an important source of unique environmental context for siblings within a family (Daniels & Plomin, 1985). To date, family designs have not been applied to the relationship between adolescent behavior and characteristics of adolescent peer groups. Results from studies relating to best friends repeatedly indicate confounds in the relationship between friend behavior and adolescent behavior warranting examination of peer groups (Harden et al., 2008; Hill et al., 2008; Poelen et al., 2007; Walden et al., 2004).

Goals of Current Research

Although research has suggested that the influence of best friends on problem behaviors is overestimated, this does not imply that the peer environment is inconsequential to the development of problem behavior. Accurate identification of the specific mechanisms of influence by peers will focus attention on the particular aspects of the peer environment that may respond to interventions targeting problem behavior by reducing harmful peer interactions and increasing supportive relationships.

To this end, this study has the following goals:

1. We will focus on alcohol use as a behavior that has been commonly implicated as being susceptible to peer influence. Problem behaviors share some common processes, yet are heterogeneous. While other problem behaviors may reflect common mechanisms, examination of this claim is beyond the scope of the current study.
2. Because alcohol use changes dramatically between childhood and adulthood, we will consider the course of alcohol use from early adolescence to early adulthood

as peers likely have different effects on behaviors throughout this developmental period.

3. We will consider the peer system holistically by exploring the structure of the peer group and characteristics of the members. The structures we will focus on include peer groups and the more diffuse peer network made up of all individuals with whom an adolescent shares a tie. The primary characteristics we will focus on include peer substance use and the adolescent's quality of friendships in the group. Although this is an incomplete list of peer group characteristics and structures, it is impossible to include every peer group characteristic. Targeting these important characteristics, examining their potential causal roles, and identifying interactions between them is integral to understanding how the social context affects behavior in adolescence.
4. Many of the dynamic and confounding processes inherent in studies of friendship dyads exist or are magnified in peer groups. We will use longitudinal and behavior genetic designs that consider genetic and environmental confounds to identify true causal relations between peers and adolescent alcohol use.

Hypotheses

Alcohol Use in Adolescence. Consistent with other research that finds a normative increase of alcohol use in adolescence and decline in adulthood, we expect a nonlinear change in alcohol use over time. Alcohol use will increase through early and mid adolescence and decline into late adolescence and early adulthood. We further anticipate that genetic, shared environmental, and non-shared environmental processes will be involved in both levels and changes in alcohol use.

Relationship between Peer Groups and Alcohol Use. Characteristics and structures of peer groups (e.g., substance use and friendship quality) will be related to the extent of alcohol use and changes in alcohol use over time. Interactions between these characteristics and the relationship to alcohol use are expected.

For example, while we expect greater substance use in peer groups to be associated with greater adolescent alcohol use overall and greater friendship quality to be generally associated with greater alcohol use, we expect an interaction between these indicators. High friendship quality will be associated with lower alcohol use when the identified peer group is low in alcohol use but will be associated with greater alcohol use when the peer group is high in problem behavior. This is consistent with a socialization mechanism of peer influence whereby adolescents change their behaviors to become more typical of the group, and by so doing, are more central in the group.

Differentiating Risk Indicators and Risk Mechanisms. As identified in the relationship between best friend behavior and adolescent behavior, we expect genetic and shared environmental confounds to be involved in the associations between peer characteristics and alcohol use. However, we anticipate that there will be an additional unique effect of peer groups on the overall level and changes in adolescent alcohol use.

Overall, we expect that although there are confounding processes influencing selection and alcohol use, there is a causal role for peer groups. Outside of family relationships, peer groups are the primary social context for adolescents; we expect that examination of the peer system will identify true mechanisms involved in the development of adolescent alcohol use.

Method

Participants

Data were obtained from the National Longitudinal Study of Adolescent Health (Add Health), which was designed to investigate adolescent health and risk behaviors with a special focus on the social contexts in which they occur (Udry, 2003). Sampling for Add Health began with identification of all high schools in the United States that had at least 30 enrollees (N=26,666). Schools were stratified according to geographic region, urbanicity, school size or type, racial composition, and grade span. From these strata, a random sample of schools was selected, some of which ranged from Grades 7-12 and some from Grades 9-12 (Table 1). If the school did not include seventh or eighth grade, the study recruited students from the feeder middle school sending students to that high school. Overall, 79% of the schools selected agreed to participate (final sample N = 134 schools). School population ranged from under 100 students to over 3000 students.

Table 1

School Characteristics

	School Characteristics (*n* = 172)			
	Urban	**Suburban**	**Rural**	
Urbanicity	56 *32.56%*	94 *54.65%*	22 *12.79%*	
	West	**Midwest**	**South**	**Northwest**
Region	32 *18.60%*	43 *25.00%*	69 *40.12%*	28 *16.28%*
	Public	**Private**		
Type	155 *90.12%*	17 *9.88%*		
	Small	**Medium**	**Large**	
	<400	***401-1,000***	***1001-4000***	
School Size	39 *22.67%*	78 *45.35%*	55 *31.98%*	

In-school interviews. Study design included an in-school survey and three waves of in-home interviews. The confidential in-school survey (n = 90,118), administered during the 1994-1995 school year, included peer nominations and identification of adolescent siblings who may or may not have been included in the in-school survey. A sub-sample of eligible students, with deliberate oversampling of ethnic minorities, disabled students, and students with adolescent siblings, was selected to participate in a follow-up home interview (78.9% of the selected sample consented to participate). Adolescents who did not participate in the in-school portion were eligible for in-home interviews if they were siblings of respondents who completed the in-school questionnaire.

In-home interviews. The Wave I in-home, ninety-minute interview took place between April and December of 1995 and included 20,745 respondents (10,480 female, 10,264 male) between 11 and 21 years of age (M = 16 years, 25th percentile = 14 years, 75th = 17 years). In 85.6% of the cases, a parent (generally the mother) also completed a half-hour interview. The Wave II in-home interview, completed the following year, included 14,738 adolescents (7,556 female, 7,182 male) between 11 and 23 years of age (M = 16 yrs, 25th percentile = 15 yrs, 75th = 17 yrs). The Wave III in-home interview, designed to measure factors involved in the transition from adolescence to young adulthood, included 15,170 respondents (8,030 female, 7,167 male) and took place between August 2001 and April 2002. Participants were between 18 and 28 years of age at Wave III (M = 22 years, 25th = 21 yrs, 75th percentile = 23 yrs).

Siblings and twins. Information on whether adolescents reported living with another adolescent between 11 and 20 years of age (twin, biological sibling, cousins, or

unrelated sibling) was gathered from school rosters. Twin zygosity was determined primarily based on self-report and responses to four questionnaire items concerning similarity of appearance and frequency of being confused for one's twin. Similar questionnaires have been utilized widely in twin research and have been repeatedly cross-validated with zygosity determinations based on DNA (Loehlin & Nichols, 1976; Spitz et al., 1996). Congruence between siblings' reports of physical similarity was necessary to assign zygosity definitively. For 89 twin pairs of indeterminate zygosity, assignments were made based on similarity in five genetic markers (see Jacobson & Rowe, 1999 for more details). Overall, the sibling pairs sample consisted of 3,193 sibling pairs. Of these pairs, 43 were excluded because their biological relatedness was indeterminate even after genotyping, and 53 pairs were excluded because their social or biological relationship was not appropriate for a sibling comparison (aunt/uncle-niece/nephew pairs, cohabitating romantic partners, “in-laws,” and non-related pairs living together in a group home). There remained 3,043 pairs of known biological relatedness: 289 monozygotic (MZ) twin pairs, 451 dizygotic (DZ) pairs, 1,252 full sibling (FS) pairs, 442 half siblings (HS) pairs, 201 cousins (CO), and 408 non-related (NR) adolescents raised together. NR pairs were comprised of pairs in which both siblings were adopted (31); one sibling was adopted and the other biological (49); both siblings were in foster care (27); step-siblings (150); and non-related adolescents living together for other or unspecified reasons (151). Jacobson and Rowe (1999) compared the sociodemographic composition of the sibling pairs sample to the full Add Health sample and found negligible differences with regard to age, ethnicity, or maternal education. For the following behavior genetic analyses, only same-sex dyads are used. Previous research has suggested that using opposite sex

pairs may spuriously inflate genetic effects since monozygotic twins are always concordant for gender (Walden et al., 2004). Overall, there were 284 MZ pairs, 247 DZ pairs, 715 FS pairs, 225 HS pairs, and 216 NR same sex pairs for a total of 1,846 (subsequently referred to as the *sibling sample*).

Peer nominations. On the In-School Questionnaire, respondents identified up to five male and five female friends starting with their closest friend. Full social network data is available for respondents attending schools where over 50% of students participated which includes 91.69% (n = 82,629) of respondents. While most of these respondents were nominatable by other respondents in the sample, 8.18% (n = 6,758) of these respondents were not on their schools roster so other students could not identify them as friends. Table 2 provides information regarding the availability of nomination data. There were 540,639 total nominees from the 82,629 respondents with an average of 6.54 nominations per respondent. Of the 540,639 nominees, 509,943 (94.32%) had available data. There were two primary reasons for unavailability of nominee data; either the nominated friend was not on the roster of the respondent's school or sister school (n = 137,363, 66.57%), or the nominated friend was not included in the study (n = 68,976, 33.43%). There were 75,871 respondents (84.19%) with identifiable friendship nominations. These nominations permit identification of peer groups and characteristics of the group.

Table 2

Proportions of nominatable respondents and valid nominations.

		Nominee Data Available *N* = 334,300 (61.83%)		**Nominee Data Not Available** *N* = 206,339 (38.17%)		
		Same School	**Sister School**	**Not on Either Roster**	**Not Included in Study**	**Total Nominations**
Nominatable Respondents	*N*	314,938	5,481	124,689	64,835	**509,943**
N = 75,871 (91.82%)	% Total Nominees	*61.76%*	*1.07%*	*24.45%*	*12.71%*	*100.00%*
Non-Nominatable Respondents	*N*	13,527	354	12,674	4,141	**30,696**
N = 6,758 (8.18%)	% Total Nominees	*44.07%*	*1.15%*	*41.29%*	*13.49%*	*100.00%*
Total Respondants	***N***	**328,465**	**5,835**	**137,363**	**68,976**	**540,639**
N = 82,629	**% Total Nominees**	***60.75%***	***1.08%***	***25.41%***	***12.76%***	***100.00%***

Note: Respondents are considered "Nominateable" if they appear on their school's roster (91.82% of Respondents). "Non-Nominatable" respondants filled out questionnaires but are not on the roster provided by the school so other respondants cannot nominate them as friends. Nominee data is available only when the nominated friend is on the roster of either the respondant's school or sister school and the nominee completed a questionnaire. Data is available for 61.83% of Nominees.

As siblings select friends out of similar pools, in some situations adolescents nominated the same friend as their sibling. Throughout analyses, we treat a pair nominating the same peer as equivalent to a pair nominating different peers who have the same level of problem behavior. MZ pairs nominated the same closest friend significantly more often than DZ pairs ($\chi 2 = 104.095$, df = 1, $p < 0.0001$) and twins (MZ and DZ pairs) nominated the same closest friend significantly more often than non-twins ($\chi 2 = 88.825$, df = 1, $p < 0.0001$). In addition to sharing the closest friend more frequently, twins also overlapped more frequently with extended friends than other sibling types. One explanation for the greater likelihood of same-peer nomination by twins as compared to siblings may be differences within sibling pairs in age. To account for differences in ages among siblings that do not exist in twin pairs, age will be included as a covariate in twin and sibling analyses. Age is unlikely the only factor responsible for

same-peer nominations as MZ pairs nominated the same closest friend more often then DZ pairs. This greater likelihood may also be attributable to the greater similarity between MZ twin pairs in personality and appearance than DZ pairs, which may lead to a greater likelihood of selecting the same peers due to these similarities.

Measures

The Add Health interviews measured a broad array of health domains, including current mental, physical, emotional, and sexual health; exercise and diet; drug, tobacco, and alcohol use; family patterns of illness and disease; family relationships; peer influences; criminal and delinquent activity; school policies; and access to community services. The survey and its components were adapted from numerous sources (see Udry, 2003), but no intact scales from the literature were included in the survey. Questionnaire items were extensively pilot tested before use.

Sibling sample alcohol use measures. Alcohol use for the sibling sample was measured by a series of questions from the three waves of in-home interviews. Adolescents were asked at all three waves at what age they first drank alcohol and how often in the past twelve months they drank alcohol, got drunk, and had at least five drinks in a row: Every day or almost every day (1), 3 to 5 days a week (2), 1 or 2 days a week (3), 2 or 3 days a month (4), once a month or less (5), 1 or 2 days in the past 12 months (6), or Never (7). They were also asked how often in the past twelve months, due to drinking alcohol, they had sex or did something they later regretted, had a fight, were hung over, were sick, got in trouble with their parents, friends, someone they were dating, or at school: Never (0), once (1), twice (2), 3-4 times (3), 5 or more times.

Peer sample substance use measures. Although siblings were targeted from the in-school sample to be included in the in-home data collection, sibling peers were not. Therefore, too few nominated peers were included in the in-home interviews, and the in-school data were used to measure peer risk behavior. Peer risk behaviors were assessed in the in-school questionnaire using seven items that ask how often in the past 12 months respondents smoked cigarettes, drank alcohol, got drunk, did something dangerous because they were dared to, raced on a skateboard, roller-blades, or in a car, skipped class, and lied to their parents: Never (0), once or twice (1), once a month or less (2), 2 or 3 days a month (3), once a week (4), 3-5 days a week (5), and nearly everyday (6).

Friendship Quality. In addition to nominating friends, adolescents marked for each friend whether (1) or not (0) in the past week they went to the friend's house, met after school to hang out, spent time together over the weekend, talked with the friend about a problem, or spoke to the friend on the phone. These items were included as weights on each friendship nomination for subsequent analyses to account for friendship quality between the adolescent and both nominated and nominating peers.

Statistical Analyses

Statistical analyses included three main parts: 1) social network analysis to identify structure and characteristics of the peer network, 2) modeling of alcohol use from early adolescents to early adulthood, and 3) twin and sibling models to account for potential genetic and shared environmental confounds in the relationship between peer characteristics and alcohol use.

Exploratory Social Network Analysis

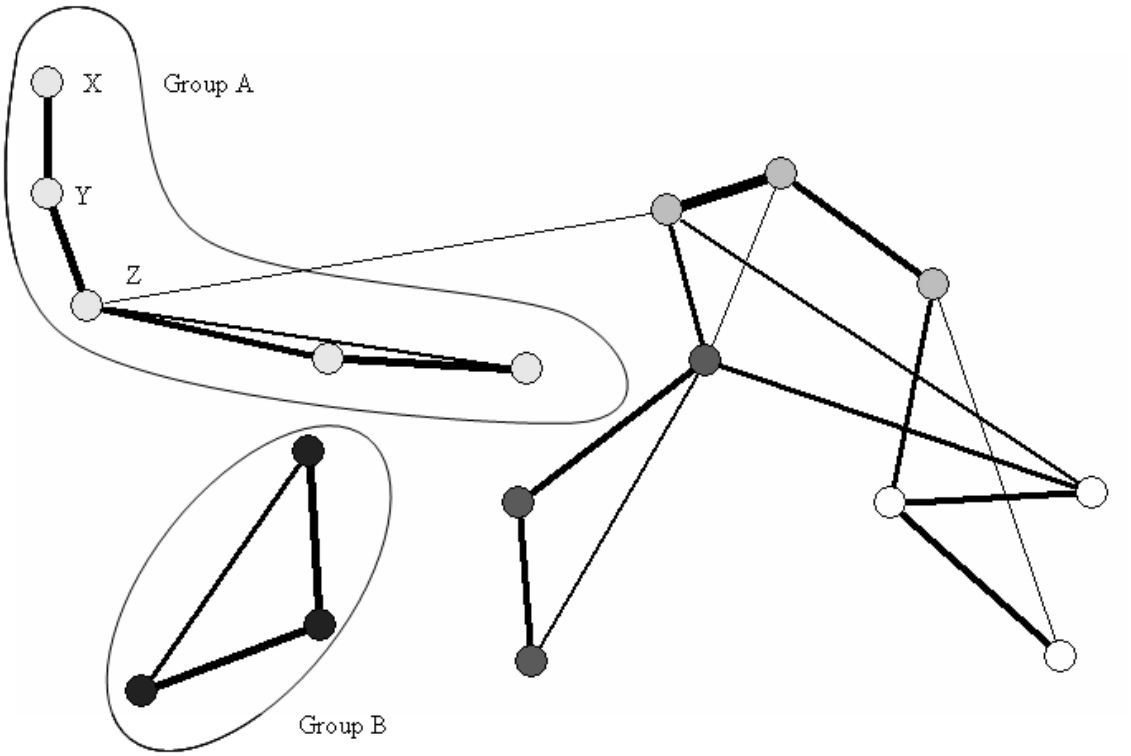
To address the ways in which peer groups may affect adolescent problem behavior, we examined the structure and characteristics of the peer groups. Comprehensive sampling in a number of schools permitted social network analysis based on friendship nominations (Bearman & Moody, 1997). Exploratory social network analysis was employed to describe adolescents' relationships within a system of individuals (de Nooy Mrvar, & Batagelj, 2005). Specifically, the goals of the social network analysis were to identify peer groups, extended peer networks, and closeness of ties to peers (see Appendix A for further description of social network analysis).

Add Health includes pre-constructed social network variables, however, the variables provided are constructed using distances based on rank order of the peers (i.e., the first friend nominated is given a distance of one). Using this system, the first ranked same sex and opposite sex friend are given the same weight although representing different relationships. Subsequent analyses weigh the distances between individuals by the friendship quality for each of these relationships. Previous research has indicated that high quality relationships are the strongest domains for peer influence (Urberg et al., 2003), as such, it is important to consider relationships in which the friends actually spend time together when assessing potential influence.

Identifying Peer Groups. School networks were partitioned into subnetworks using the *island* algorithm in *Pajek,* subsequently referred to as 'peer groups'. Although this partitioning device has not been used previously in Add Health, it has recently shown utility identifying important subnetworks within large networks in other fields including physics, history, and biology (e.g., Tzekina, Danthi, and Rockmore 2008, Batagelj,

Kejzar, Korenjak-Cerne, and Zaversnik, 2006, Schlicht and Stuckenschmidt 2007). Other more commonly used partitioning devices, such as components, are less effective as they often identify one giant component that includes the majority of the school and fails to differentiate subgroups (Moody, 2001). Islands are connected parts of a network where the vertices included in the island have greater connections within the island than with vertices outside the island. Such a division works well for the model of peer networks and socialization as it weights relationships where peers spend more time with one another more heavily. Islands were defined as groups larger than three and smaller than 25. Using larger maximum values resulted in few islands identified in each school, providing low discrimination, and using smaller maximum values resulted in large numbers of adolescents falling outside of groups. Within this framework, vertices not falling in an island were subsequently included in their *influence partition*, that is, the island with which they shared the greatest relationship. Characteristics of the peer groups can be identified qualitatively (see Appendix B) or quantitatively (e.g., mean substance use of the group). Figure 1 provides visualization of a selection of four peer groups in a school of 205 students.

Figure 1. Selection of seventeen adolescents belonging to four peer groups.



Notes: Each vertex represents an adolescent. Different colored vertices indicate membership to separate peer groups. Geodesic distance from vertex X to Y = 1 and from Y to Z = 2. The thickness of the line represents the strength of the relationship (i.e., thicker lines indicate greater relationship quality). Actual distance between vertices also is scaled relative to relationship quality, although does not reflect actual values as limited by two-dimensional visualization.

Extended social network. As an alternative to the partitioning approach, the extended social network including all adolescents reachable by the target adolescent was also examined. Reachable adolescents need not be directly connected to the target, but may be connected through other friends' nominations (e.g., a friend of a friend). The number of degrees of separation is the geodesic distance. A directly nominated friend has a geodesic distance of one, whereas if target *X* nominates friend *Y* who nominates friend *Z*, then the distance from *X* to *Z* would be two (Figure 1). Using the matrix

including these distances, we calculated a weighted mean of alcohol use such that adolescents *n* steps away were weighted 1/*n*.

Closeness centrality. Closeness centrality was calculated for each adolescent and is a ratio of the distance of reachable peers to the number of reachable peers (see Appendix C for complete description of closeness centrality). The distances were weighted by the inverse of friendship quality such that the greater the friendship quality, the shorter the distance. For example, if an adolescent has only a few friends, but the friends spend lots of time together and report high quality friendships, centrality would be greater than for an adolescent who can reach many peers, but only through indirect, or poor quality connections. As processes such as socialization may affect alcohol use, the degree to which an adolescent spends time with those peers in his or her immediate network may be an important moderator of the effect of those peers on the individual.

Alcohol Use for Siblings and Twins

Measurement models. To develop latent multivariate models of relevant constructs for later use in structural equation models, Exploratory Factor Analysis (EFA), and subsequent Confirmatory Factor Analysis (CFA) were conducted on the observed indicators of alcohol use. An approximation of the EFA solution at Wave I was tested using CFA in the full Add Health data set for the in-home alcohol use items with zeros substituted for estimated loadings less than 0.40. Alcohol use behaviors change from adolescence into adulthood, and although many items were repeated between waves, other behaviors were not assessed at all waves. For example, driving while drunk and being drunk at work were only assessed during adulthood, whereas having problems due to drinking at school was only assessed in adolescence. To evaluate whether items

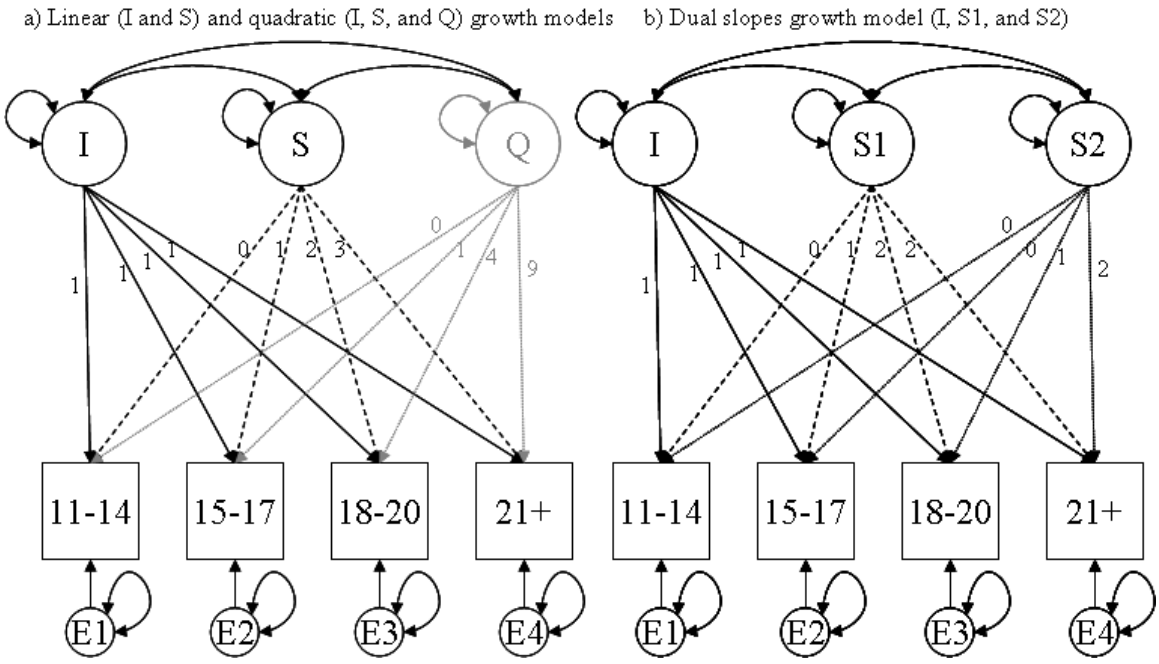
measured the same construct across the three waves, a restricted model in which the factor loadings of items in common between waves were constrained to be equal across waves was compared to a less restricted model in which the factor loadings were allowed to differ across waves.

The most restricted CFA (strong partial factorial invariance; Meredith, 1993) was specified as follows: items in common across multiple waves were constrained to load onto the same factor for all waves in which they were used; factor loadings for items in common across waves were constrained to be equal for all waves in which they were used; and item thresholds (intercepts) for the categorical items were constrained to be equal for items in common across waves. When strong partial invariance holds across waves, it can be inferred that the same latent construct is being measured at each wave based on common items, even though other items vary from wave to wave. The term partial invariance refers to invariance for only those items in common between waves (Byrne, Shavelson, & Muthén, 1989). This restricted model was compared to a series of less-restricted models, in which factor loadings, thresholds, or both were allowed to differ across waves. Factor scores based on the structures defined by the CFA were calculated and are used in subsequent analyses.

Latent growth curve modeling. Figure 2 shows the Latent Growth Model (LGM) used to evaluate changes in alcohol use from early adolescents through early adulthood. The entire in-home sample with alcohol use scores for at least one wave was used for this analysis (n = 20,770). As the data was collected in waves that included a range of ages from early adolescents to early adulthood, it was inappropriate to use the waves as the units of time rather than the ages. However, as data were collected over a period of about

five years, individuals did not have data available at both ends of the range (e.g., 11 years and 23 years), and it was necessary to collapse the measurements into the following four ordinal age categories: early adolescence (A1 = 11-14 years, *n* = 12,938), mid-adolescence (A2 = 15-17 years, *n* =13,419), late adolescence (A3 = 18-20 years, *n* = 9,523), and early adulthood (A4 = 21 years and older, *n* = 11,615) to provide appropriate coverage across the time points. While collapsing the ages has the benefit of permitting an age-based analysis, one notable consequence is that adolescents may have been measured more than once in a given age category. When this occurred, the mean of the alcohol use scores within that age category was used to describe the average alcohol use during that period of adolescence. Overall there were 7,309 individuals (35.19%) with had two measurements in one age category and 1,296 individuals (6.24%) with all three measurements in one category (in the twin and sibling sample, no individuals had all three measurements in one category). As there are three waves of data collection and four age categories, there are a maximum of three measurements per person. The overlapping nature of the data and missing data analysis using ML under the MAR assumption (see *Software and Missing Data Analysis)* permit estimation of the latent growth parameters for all individuals with any data present.

Figure 2. Linear, quadratic, and dual slopes latent growth models.



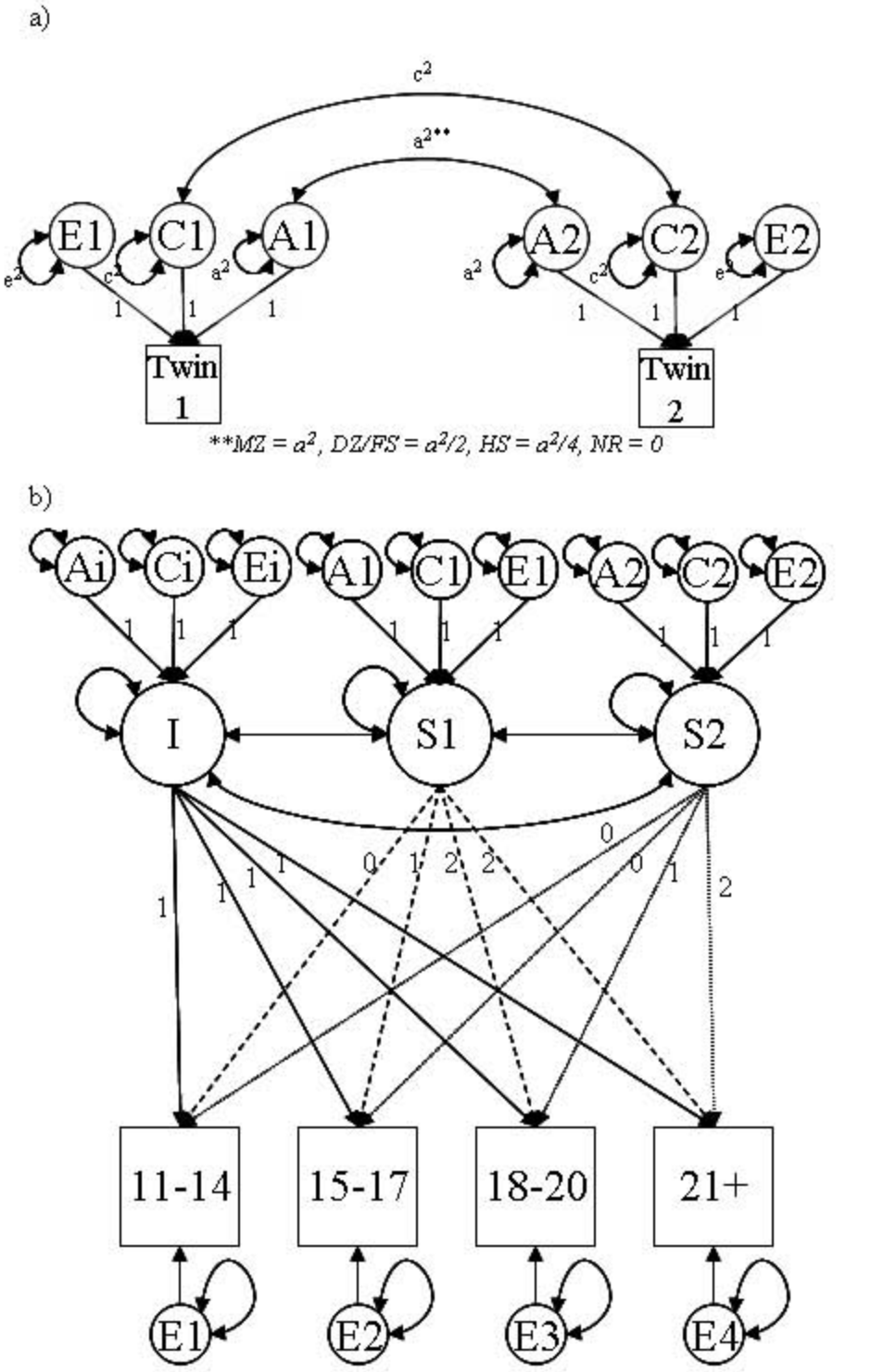
A linear model was compared to a quadratic models and a dual slopes model permitting different slopes at different developmental periods. For the linear model (Figure 2a), an intercept, the average level of alcohol use, and a linear slope, reflecting linear change over time were estimated. For the linear slope, the loadings on A1 to A4 were 0, 1, 2, and 3, respectively. For the quadratic model (Figure 2a), in addition to the intercept and linear slope, a quadratic term was estimated by setting the loadings on A1 to A4 to 0, 1, 4, and 9, respectively. For the dual slopes model (Figure 2b), the intercept remains the same as the linear and quadratic models, but two slopes were estimated that are connected at a mid point, in this case the mid-point occurs between mid and late adolescence. This method allows more clear interpretation of potential peer influences than a quadratic model as environmental contributions to alcohol use may differ in early

adolescence and early adulthood. For the first slope, the loadings on A1 to A4 are set to 0, 1, 2, and 2, respectively, modeling earlier change. For the second slope, the loadings on A1 to A4 are set to 0, 0, 1, and 2, respectively, modeling later change. The growth factors were permitted to covary as it was expected that the change in alcohol use would be related to the initial alcohol use level. Peer factors were regressed on the growth factors for alcohol use and alcohol problems.

Twin and Sibling Designs

Univariate ACE Decomposition. The covariance between same-sex sibling pairs (n = 1,669) for the growth factors and peer variables were decomposed into additive genetic influences (A), environmental influences shared by siblings (C), and environmental influences unique to siblings (E). The E component also includes residual error variance. Decomposition into ACE components was achieved by considering the different proportions of segregating genes shared by twin and sibling dyads (MZ=100%, DZ/FS=50%, HS=25%, NR=0%). Twin and sibling models depend on several assumptions, including random mating in the parental generation, similar environments for sibling and twin types (MZ environment is assumed to not differ systematically from DZ environment), and no gene-environment interaction. The models we employed to decompose the variances of the growth components and peer group problem behavior are in Figure 3. The paths from the latent genetic and environmental variables are fixed to one and the variances of the A, C, and E components are estimated. For more detailed information about the logic and methodology of behavior genetic modeling, see Neale and Cardon (1992).

Figure 3. Univariate ACE decomposition for peer variables (a) and growth factors (b).



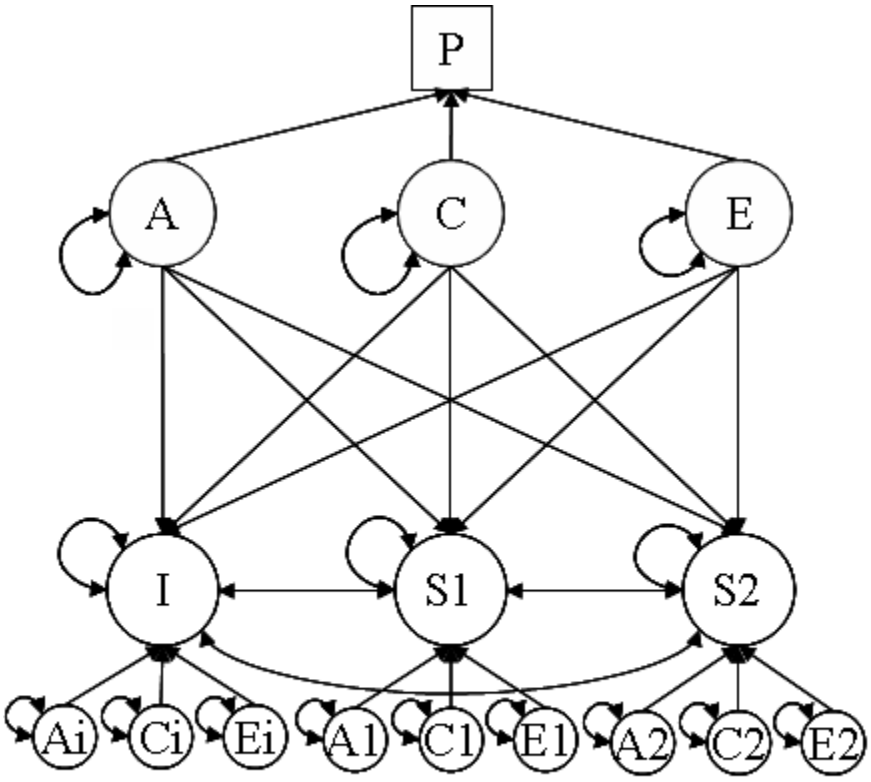
One twin shown for clarity. Covariance structures are replicated for ACE components of I, S1, and S2.

Multivariate Twin and Sibling Model. Peer group alcohol use, extended peer network alcohol use, and centrality will be modeled as risk indicators for adolescent alcohol use. The associations between peer and target behavior will be analyzed as a combination of genetic confounds, environmental confounds, and quasi-causal pathways. Peer characteristics will be modeled as the risks, and the growth model of adolescent alcohol use will constitute the outcome. Figure 4 shows an example using a generic peer construct (*P)*. Age and gender were used as covariates and missing data analysis was included. On occasion, variance estimates for *C* were negative for either the outcome or risk. This pattern may be the result of sampling error, or may suggest that there are dominance or epistatic processes at work. Negative variance estimates are not interpretable, and in each case, a negative variance estimate was fixed to zero and the change in model fit was assessed.

Software and missing data analysis. Social networking analyses were conducted using Pajek (Batagelj & Mrvar, 1996), a matrix program freely available on the internet that analalyzes the connections and relationships in large networks. All other analyses were conducted in Mplus (Muthen & Muthen, 1998-2004). Missing data was considered using maximum likelihood (ML) under the assumption that data was missing at random (MAR). The MAR assumption permits missingness in peer data to be a function of measured covariates and target delinquency. However, MAR assumes that missingness of peer data is unrelated to the level of the peer characteristic of interest after controlling for the level of target delinquency and measured covariates. If measured covariates and the target delinquency explain the relationship between missingness and peer characteristics, missingness is considered a function of the covariates and target alcohol

use rather then peer characteristics. MAR cannot be tested; it is impossible to know the true value of missing data. However, ML is robust to minor violations of this assumption. Maximum likelihood integrates over all possible values of missing peer data, and gives more weight to values that are more likely (Allison, 2002; Little & Rubin, 1989).

Figure 4. Multivariate twin and sibling model regressing growth factors on ACE components of peer factors.



For clarity, one twin is shown. The growth structure and age and gender (included as covariates) are not shown here.

Results

Exploratory Social Network Analysis

Partitioning networks into peer groups. Partitioning the school networks into groups of adolescents using the island algorithm reveals 5,077 groups ranging in size from three to 90. There are 76,926 adolescents included in peer groups of the 82,629 (93.09%) for whom social network data was gathered. The mean group size is 13.596 (SD = 10.849), the median is ten, and the modal group sizes are four (n = 381) and five (n = 381). While less than 10% of the groups are larger than 25, they contain larger proportions of students and it is not rare for an adolescent to belong to a larger group. About a third (32.62%) of adolescents belong to groups larger than 25, yet membership to a group larger than 50 remains infrequent with only 6.26% of adolescents falling in these groups.

Peer group substance use is calculated as the mean of the adolescents' substance use in the group, excepting the target's own substance use. The mean group substance use is 0.950 (SD = 0.637, n = 76,926). Peer group means are moderately correlated with target substance use (r = 0.459, df = 74,701, $p < 0.001$) with greater peer group substance use associated with greater target substance use. The relative likelihood that an adolescent will nominate someone within their group instead of someone in another group, and the degree to which groups of adolescents share characteristics compared to the school network at large are assessed. The groups appear to be cohesive and meaningful (see Appendix D for evaluation and further group details).

Extended peer network. The extended peer network reflects all individuals in the peer network with whom an adolescent can reach directly and indirectly, regardless of

friendship quality. The substance use of the extended peer network (EPN) is the average of all the reachable peers' substance use weighted by the inverse of geodesic distance of each pair from the target. Adolescents closer to the target adolescent are weighted greater than are adolescents indirectly connected. The average number of peers in an adolescent's EPN is 746.721 (SD = 469.201, n = 72,216), but ranges from one to 1,793 with a mean distance to peers of 5.703 (SD = 1.715). As the sizes of the schools vary greatly, it is easier to interpret these numbers as a function of the size of the school. The mean extended network includes 76.703% of students in the school (SD = 18.69). Despite the large proportion of students in each of these EPNs, they represent distinct values from the school level means as they are weighted based on the distance of the peer from the target adolescent. Substance use in the EPN is moderately related to the target's substance use (r = 0.246, df = 72,216, $p < 0.0001$, 95% CI = (0.24, 0.26)) and notably more weakly related to target substance use than is peer group substance use (r = 0.459). However, given the large proportion of the school included in the extended peer network, this construct may have limited utility in differentiating between sibling environments.

Closeness centrality. Closeness centrality is a ratio of the reachable nominations to the target to the distances to these nominations (here, weighted by the inverse of friendship quality such that greater friendship quality corresponds to closer friendships). The mean centrality was 0.510 (SD = 0.255, n = 70,862). Centrality reflected a moderate correlation with substance use overall with adolescents who are more central to their peers reporting greater substance use (r = 0.190, n = 70,396, $p < 0.001$).

Substance Use Measurement Models

Target alcohol use. Table 3 summarizes alcohol use items from the three waves of the full in-home sample submitted to EFAs. The EFA of alcohol use items for Wave I yields two eigenvalues greater than one (7.435 and 1.562), and a scree plot suggests two factors. The two-factor solution fits well (*RMSEA* = 0.038), whereas the one-factor solution does not (*RMSEA* = 0.160). The two factor model suggests one factor representing frequency of alcohol use, including items assessing the number of times the adolescent drank in the past year and how many drinks they had each time, and one factor representing problems due to alcohol use, including items assessing physical symptoms of drinking and problems in a variety of social contexts due to alcohol use.

The measurement models for alcohol use developed for Wave I are applied to the Wave II and III data, fixing the loadings for the items in common with Wave I to be equal across the three waves (see Tables 3). The strong partial invariance model fits well for the alcohol use factors (*RMSEA* = 0.039, *CFI/TLI* = 0.991/0.996) and the factors have high internal reliability (Cronbach's alpha > 0.80 for all factors). As previously indicated, the data was collected in waves that included a range of ages without sufficient coverage to examine scores at each age. Factor scores are estimated for each wave and matched to the appropriate age category (early adolescence, mid adolescence, late adolescence, and early adulthood) given the adolescent's age at each measurement yielding the following eight factor scores: frequency of alcohol use at each age category (AU-1, AU-2, AU-3, AU-4), and problems relating to drinking alcohol (AP-1, AP-2, AP-3, and AP-4).

Table 3

Items and factor loadings used to estimate factor scores

	In-Home Wave		
Factor 1: Alcohol Use	I	II	III
How many days did you drink alcohol?	1	1	1
How many days did you drink five or more drinks in a row?	1.04	1.04	1.04
How many days have you gotten drunk on alcohol?	1.05	1.05	1.05
Factor 2: Alcohol Problems			
Trouble w/parents b/c drinking.	1	1	1
Problems at school b/c drinking	0.98	0.98	
Problems w/friends b/c drinking	1.05	1.05	1.05
Problems w/dating b/c drinking	1.02	1.02	1.02
Did smtg later regretted b/c drinking	1.15	1.15	
Were Hung-over	1.2	1.2	1.2
Threw up b/c of drinking	1.12	1.12	1.12
Sexual situation later regret b/c drinking	1.02	1.03	1.03
Physical fight b/c drinking	1.01	1.01	1.01
Driven while drunk			1.06
Drunk at school or work			0.91

Note: Loadings for common items are fixed across wave specifying strong partial invariance. Loadings on first item of each factor fixed to one.

Peer and target substance use. Using the full in-school sample, an EFA of the six externalizing items reveals two eigenvalues greater than one (2.707 and 1.188), and the scree plot suggests two factors. The two factor solution fits well (*RMSEA*=0.019), whereas the one factor solution fit is poor (*RMSEA*=0.109). The two-factor solution yields a substance use factor and a rule-breaking factor which are moderately correlated ($r = 0.477$). Using the factor structure suggested by the EFA, a CFA is fit where items with loadings less than 0.40 are set to zero. The CFA fits well (*RMSEA* = 0.037, *CFI/TLI* = 0.959/ 0.938), with moderate correlation between the factors ($r = 0.548$). Given the

focus of the current paper, the substance use factor will be used for subsequent analyses. The loadings on the smoking, drinking and getting drunk items are 1.00, 0.99, and 1.05, respectively, and setting these to be equal does not result in a significant loss in fit. Therefore, for subsequent analyses the mean of these items represents substance use. In addition to reflecting target substance use, this factor is used to calculate the mean peer group substance use (Peer Group), and the weighted mean of substance use in the extended peer network (EPN).

Latent growth curve modeling. For the alcohol use and problem factors, the dual slopes model fits better than the linear and quadratic model (See Table 4, n = 20,770). As such, we allow for nonlinear change by estimating the average level of alcohol use, the intercept (*I*), and two slopes: the first reflecting earlier change from early adolescence into late adolescence (*S1*) and the second reflecting later change from mid adolescence to early adulthood (*S2*).

Table 4

Latent growth model fit and comparative fit indices.

		χ^2	*df*	*CFI*	*TLI*	*RMSEA*	*Linear* $\Delta\chi^2$	Δdf	*p*
Alcohol Use	Linear	7,062.347	5	0.875	0.850	0.261		--	
	Quadratic	129.489	1	0.998	0.986	0.079	6,932.858	4	< 0.0001
	2 Slopes	101.949	1	0.998	0.989	0.070	6,960.398	4	< 0.0001
Alcohol Problmes	Linear	6,533.154	5	0.880	0.856	0.251		--	
	Quadratic	110.911	1	0.998	0.988	0.073	6,422.243	4	< 0.0001
	2 Slopes	83.202	1	0.998	0.991	0.063	6,449.952	4	< 0.0001

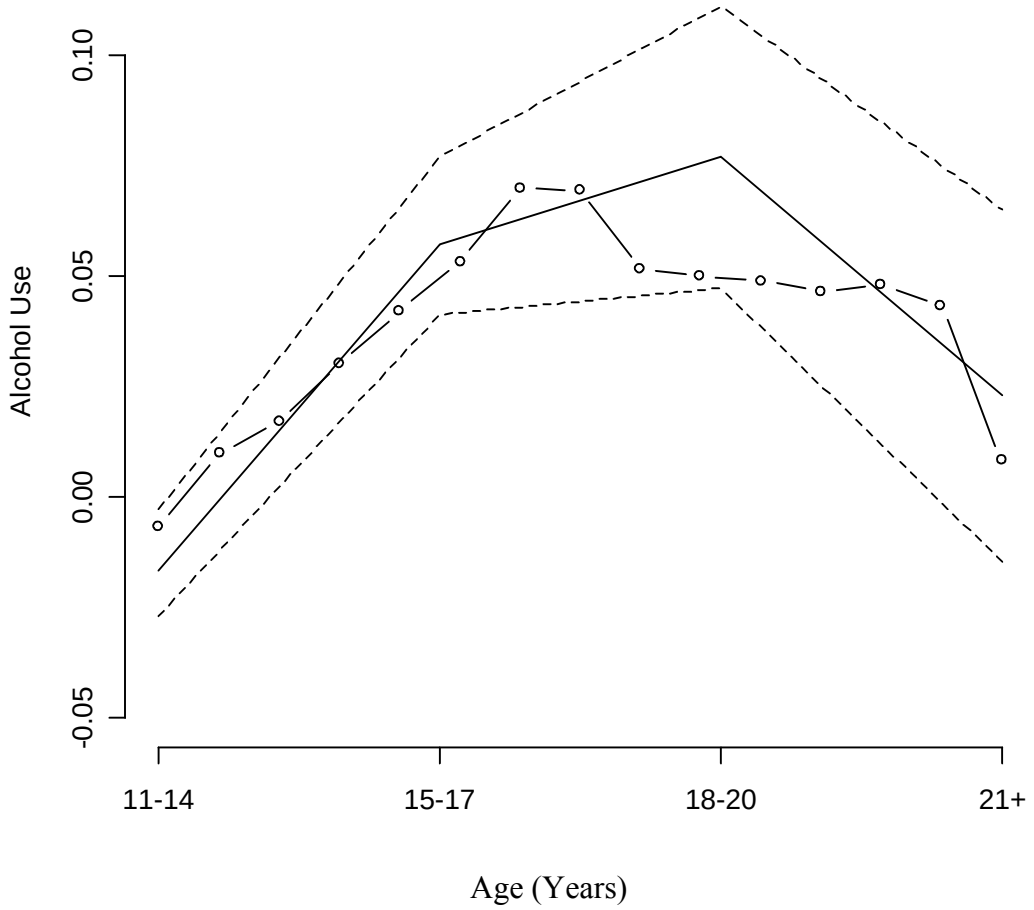
The dual slope growth models fit the data well for alcohol use (*RMSEA* = 0.055, *CFI/TLI* = 0.999/0.992), and alcohol problems (*RMSEA* = 0.071, *CFI/TLI* = 0.998/0.987). The model indicates that both alcohol use and alcohol problems increase from early to mid and late adolescence and decrease from mid and late adolescence to early adulthood (See Table 5). Figure 5 shows the estimated and actual means during each developmental period for alcohol use. The overall shape of the observed means is consistent with previous work suggesting an "adolescent-limited" increase in problem behaviors (e.g., Chassin et al., 2004; Moffitt, 1993; Moffit, 2003), peaking mid-late adolescence and tapering into early adulthood. The actual means are not significantly different from those means estimated using the growth model ($p > 0.05$).

Table 5

Estimates of growth factors for dual slope growth models.

		Means	SE	Correlations				Means	SE	Correlations	
				I	*S1*					*I*	*S1*
Alcohol Use	I	-0.017	0.005	--	--	Alcohol Problems	I	-0.018	0.005	--	--
	S1	0.074	0.003	0.237	--		S1	0.061	0.003	0.218	--
	S2	-0.054	0.004	-0.593	-0.434		S2	-0.039	0.004	-0.522	-0.398

Figure 5. Predicted (line) and actual (points) estimates of alcohol use from early adolescence to early adulthood.



Note: Dotted lines represent 95% confidence interval.

Relationship between Target and Peer Behavior

The intercept and slopes from the measurement model of adolescent alcohol use and alcohol problems are regressed on 1) the peer group substance use, closeness centrality and their interaction, and 2) on the substance use of the extended peer network, closeness centrality, and their interaction using the full in-home sample with peer data available (n = 13,464). Age and gender are included as covariates and these models fit

well (*CFI/TLI* > 0.99 for all models). Peer factors accounted for between 9-12% of the variance in alcohol use and problems overall and between 3-6% of the changes in alcohol use and problems over time. Patterns of relatedness are similar for alcohol use and alcohol problems, full parameter estimates are available in Table 6.

Table 6

Standardized regression coefficients for growth factors on peer values for alcohol use and problems using full sample.

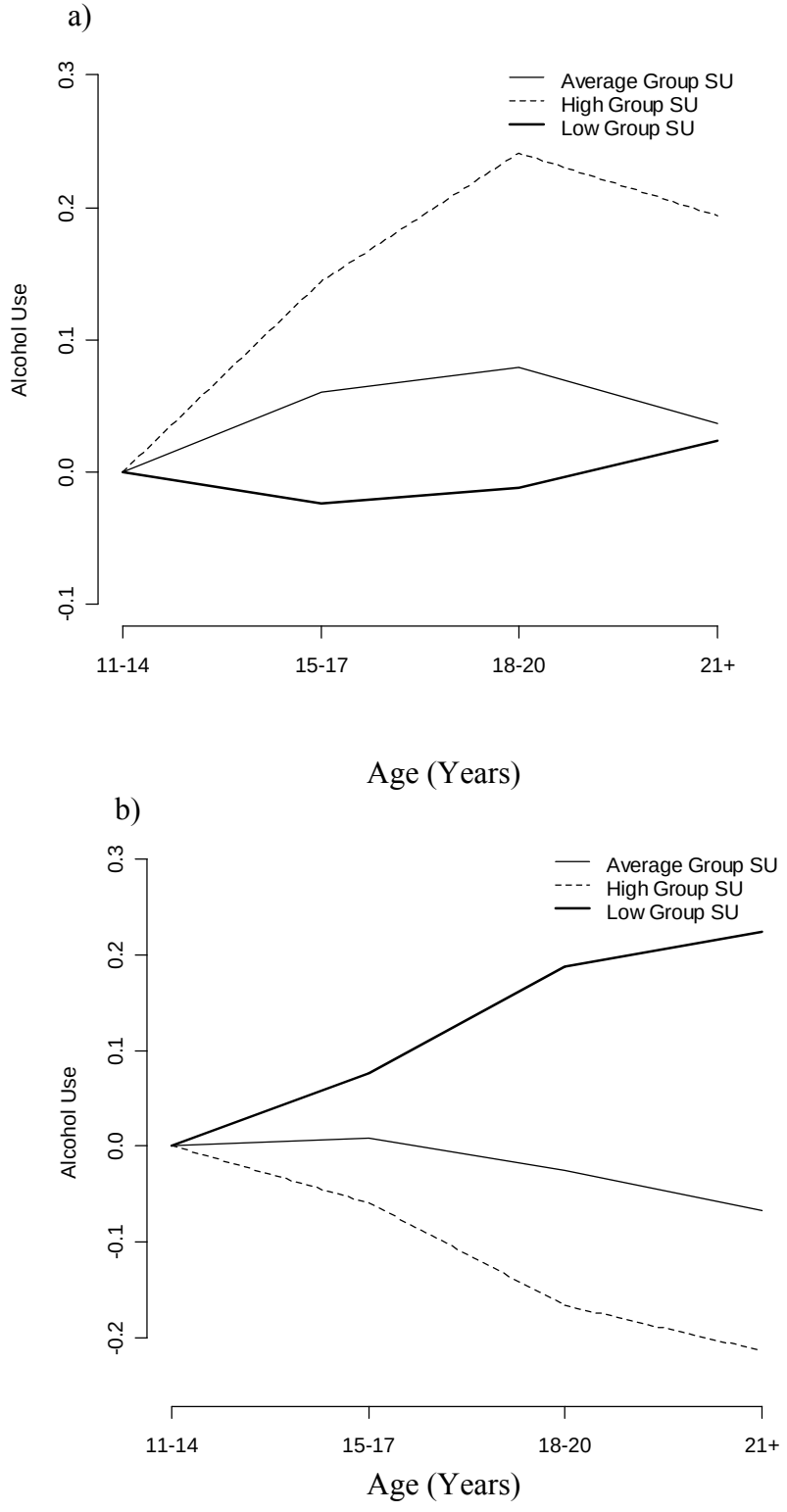
		Use	Problems			Use	Problems
Peer Group	I	**0.306**	**0.311**	EPN	I	**0.151**	**0.120**
	S1	**-0.097**	**-0.144**		S1	*0.030*	*-0.022*
	S2	**0.108**	**0.106**		S2	*-0.013*	*0.045*
Close	I	**0.034**	**0.035**	Close	I	**0.140**	**0.140**
	S1	**0.027**	**0.056**		S1	*0.077*	**0.103**
	S2	**0.014**	**0.048**		S2	*-0.025*	*-0.029*
Group x Close	I	*0.001*	*-0.001*	EPN x Close	I	**0.073**	**0.086**
	S1	**0.204**	**0.173**		S1	*-0.005*	*-0.051*
	S2	**-0.090**	**-0.108**		S2	*0.012*	*0.043*

Estimates in italics are not significantly different from zero p > .05

Greater substance use in peer groups is related to greater overall alcohol use and problems. Although centrality is related to the intercept and slopes independently, when including group substance use and the interaction term, centrality is only weakly related to the growth factors and no longer predicts meaningful portions of the variance in the slopes (R^2 < 1%). The effect of centrality on changes over time depends more on the substance use in the group. For adolescents who are close to their peers, high substance using peer groups are associated with an increase from early adolescence to late

adolescence and a slight decrease into early adulthood, while low substance use predicts negligible increases in alcohol use into early adulthood (Figure 6a). For adolescents who are not close to their peers, those in high substance using groups steadily decrease over time while those in low substance using groups steadily increase over time (Figure 6b). Despite the convergence in these low friendship quality groups, adolescents in high substance using peer groups have overall greater alcohol use throughout development. It is possible that adolescents who are not close to their peer groups may be more likely to select into other peer groups over time or, alternatively, this convergence may reflect regression to the mean in the absence of high quality relationships. However, as substance use within the peer group is only available at one time point, changes in peer groups cannot be evaluated.

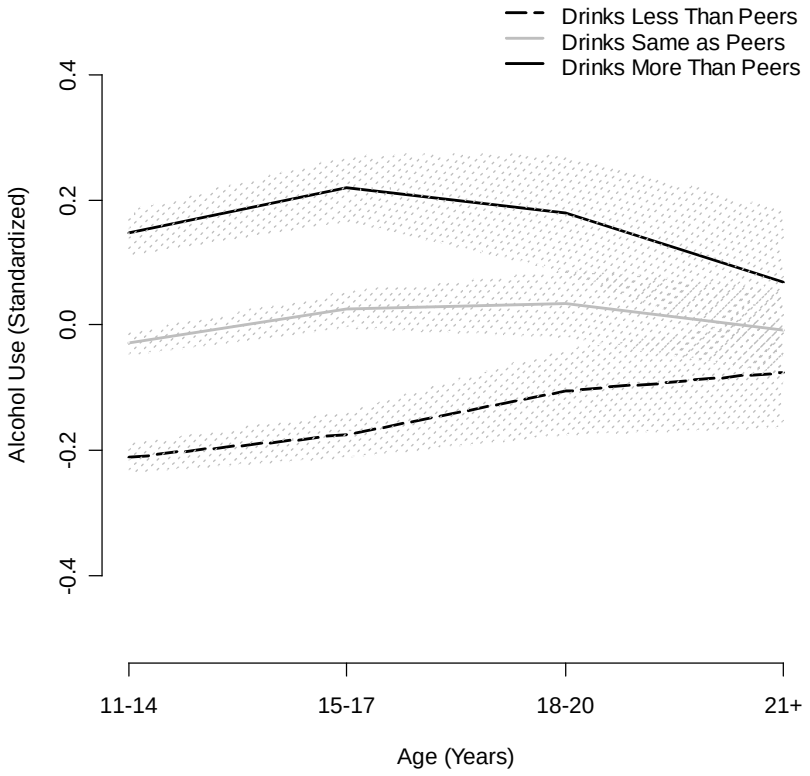
Figure 6. Projected trajectories for adolescents with (a) high closeness centrality and (b) low closeness centrality.
*Note**:** Intercept not modeled to show differences in trajectory. High group substance use predicts greater overall alcohol use than low group substance use across development for all levels of closeness centrality.*



In contrast to the effect of peer group substance use on the trajectory, the substance use of the extended peer network predicts minimal change over time. Overall, greater substance use in the EPN and greater friendship quality is related to greater substance use. There are additional effects on overall alcohol use for the interaction between the EPN and closeness centrality; there are stronger relationships between EPN substance use and target alcohol behavior for adolescents close to their peers. The potential effects of the immediate peer group are not only more robust, but also seem to have greater ties to change processes over time. This suggests potentially a special role for these peer groups over the more diffuse peer culture.

To evaluate the effects of peer groups on adolescent alcohol use and problems over time, it is helpful to examine the changes over time for those adolescents initially discordant for substance use with their peer group. Figure 7 shows the trajectories for those adolescents discordant with their peer group compared to those who are concordant with their peer groups. For both adolescents with initially less and more substance use than their peers, there is an initial increase in alcohol use; however, these groups follow different paths following mid adolescence. For adolescents who initially have less substance use then their peers, their alcohol use continues to increases into adulthood. For adolescents who have greater substance use initially, their alcohol use decreases into early adulthood. However, it is difficult to identify whether these reflect causal processes as convergance over time may also reflect normative developmental processes, regression to the mean, or selection and confounding processes. Subsequent analyses will examine these alternative explanations.

Figure 7. Adolescent alcohol use over time for adolescents concordant and discordant with initial peer substance use. Note: Shaded region represents 95% confidence interval.



Twin and Sibling Designs

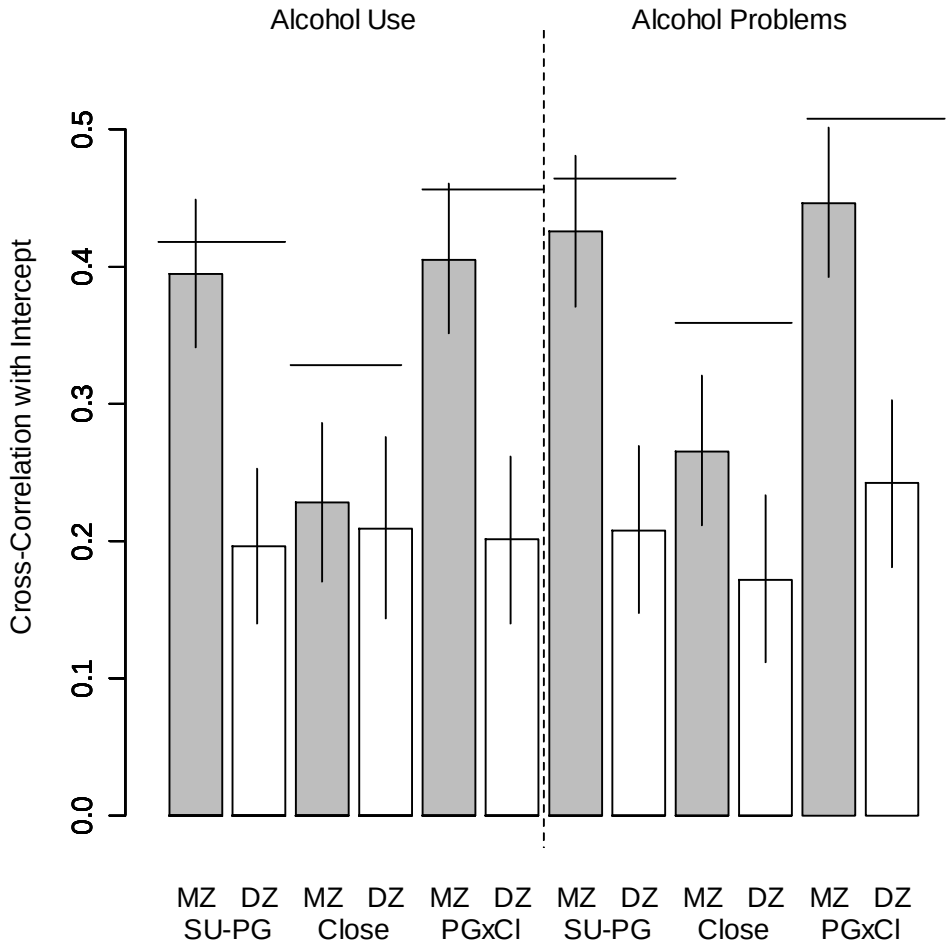
Cross-Correlations between Target Delinquency and the Twin's Peer Group

The relationship between adolescent alcohol use and peer group problem behavior presented above is confounded by genetic and environmental factors. To begin to explore potential confounds, we examine the correlations between the target behavior and the peer group of the target's twin, known as *cross correlations*, for the intercept of target alcohol use and alcohol problems. Although not a formal examination of potential

genetic and environmental confounds, examination of cross correlations provides an intuitive illustration of effects identified through structural equation modeling.

Figure 8. Cross correlations for peer variables with alcohol growth estimates.

Note: Horizontal lines represent traditional correlations (i.e., a target's relationship with his or her own peer).



The patterns of cross correlations involving peer group substance use, closeness centrality, and the interaction of these variables are generally suggestive of genetic and shared environmental confounds mediating the relationship between these peer measures

and target behavior (Figure 8). Genetic confounds may be particularly salient for peer group substance use and the interaction term as MZ cross correlations are significantly greater than DZ cross correlations for both alcohol use and alcohol problems. Shared environmental confounds are implicated across relationships as DZ cross correlations are greater than half MZ cross correlations. In particular, MZ and DZ cross correlations are most similar for closeness centrality indicating a potential role for shared environmental confounds in the relationship between target alcohol use and problems and closeness centrality.

Univariate ACE Decomposition

Table 7 provides proportion of variance and accounted for by A, C, and E components for target substance use, alcohol use and problem growth factors, peer group substance use, extended peer network substance use, and closeness centrality. All models fit well (CFI/TLI > 0.950). All peer constructs and almost all growth factors have variance attributable to genetic, shared environmental, and non-shared environmental factors. Only S1 for alcohol problems does not reflect shared environmental variance. Similar to findings regarding best friends (Hill et al., 2008), peer group alcohol use reflects large proportions of genetic variance. This does not indicate that there are genes 'for' peer selection and does not shed light on the specific genetic mechanisms. Variance attributable to genetic factors may manifest because of genes that affect factors such as personality traits or behaviors, which may direct selection of and being selected by certain friends. Closeness centrality reflects large proportions of shared environmental variance, which may reflect parenting practices such as involving their adolescents in sports or clubs, making time for their adolescents to socialize, or promoting skills that

maintain close friendships. For the extended peer network, the percent variance attributable to unique environmental factors is only 3.7%, which also includes error. Therefore, this measure does not differ enough between environments for twins and siblings to be used in subsequent multivariate twin and sibling models.

Table 7

P*roportions of variance in A, C, and E for peer and target factors.*

	Alcohol Use			Alcohol Problems			Peer Factors		
	I	*S1*	*S2*	*I*	*S1*	*S2*	*SU-PG*	*SU-EPN*	*Closeness*
A	0.150	0.371	0.092	0.277	0.402	0.127	0.744	0.402	0.180
C	0.192	0.056	0.023	0.132	0.000*	0.079	0.060	0.561	0.606
E	0.658	0.573	0.885	0.591	0.598	0.794	0.195	0.037	0.214

**For these variables, the estimates for C were negative which may be the result of sampling error or may suggest dominance or epistatic processes at work. Negative estimates are not interpretable and negative variance estimates were fixed to zero resulti*

Multivariate Twin and Sibling Model.

To test more formally the relationships suggested by the cross-correlations, the peer variables, peer group problem behavior, centrality, their interaction, and the growth factors are decomposed into their *ACE* variance components and the growth factors are regressed on to the *ACE* components of the peer variables. The models for both alcohol use and problems fit well (Alcohol Use: *CFI/TLI* = 0.978/0.977, *RMSEA* = 0.048 | Alcohol Problems: *CFI/TLI* = 0.974/0.973, *RMSEA* = 0.051).

Phenotypic regressions. The regression coefficients for the growth factors on the *ACE* components of the peer factors are constrained to be equal to test the equality of between- and within-family associations fit (see Table 8 for overall fit comparisons and Appendix E for path specific comparisons). When constrained to be equal, the estimated

regression parameter represents the phenotypic relationship between peer and target behavior. If the model fit does not worsen by fixing these values, then no confounds are suggested. When this occurs, the model is consistent with a causal model because the coefficients are not explained by factors that make families different (i.e., genetic or shared environmental factors).

Table 8

Comparative model fit of full model to phenotypic models for alcohol use and problems. See Appendix E for path specific comparisons.

	Alcohol Use				
	χ^2	*df*	$\Delta\chi^{2a}$	Δdf	*p*
Full Model	1321.166	457			
No *E* Regression	1495.201	466	174.035	9.00	<0.001
Phenotypic Model: All Paths Equal	1537.146	469	215.980	12.00	<0.001
	Alcohol Problems				
	χ^2	*df*	$\Delta\chi^{2a}$	Δdf	*p*
Full Model	1333.574	457			
No *E* Regression	1547.232	466	213.658	9	<0.001
Phenotypic Model: All Paths Equal	1602.482	469	268.908	12	<0.001

[a] Compared to Full Model

Unequal ACE regressions indicate selection effects and are inconsistent with assumed peer causal influences on substance use. For all but S2 on centrality (which itself is not significantly different from zero), fixing these paths results in a significant decrease in fit implicating genetic and shared environmental influences on the association between the peer variables and adolescent alcohol use. In Table 9, the estimated parameter in the phenotypic (or fixed parameter) model reflects the between-family association for alcohol use, and in the *ACE* (or free parameter) model, the within-family

association is reflected in the coefficient on *E.* See Appendix F for estimates for alcohol problems.

Table 9

Multivariate ACE fit estimates for alcohol use (see Appendix F for estimates for alcohol problems).

Variance Components [a]		***A***		***C***		***E***	
		Est.	*% Total*	*Est.*	*% Total*	*Est.*	*% Total*
	Group	0.844	80.08%		--	0.210	19.92%
	Centrality	0.182	17.45%	0.605	58.01%	0.256	24.54%
	Group x Centrality	14.589	81.05%		--	3.411	18.95%
Residual Variance Components [a]							
	I	0.151	29.43%	0.099	19.30%	0.263	51.27%
	S1	0.058	66.67%		--	0.029	33.33%
	S2	0.039	15.06%	0.053	20.46%	0.167	81.07%

Regression Coefficients [a]		***Phenotypic*** [b]	***A***	***C***	***E***
Group	I	0.206 (0.01)	0.121 (0.02)	--	0.641 (0.05)
	S1	-0.025 (0.01)	0.037 (0.01)	--	-0.159 (0.04)
	S2	0.049 (0.00)	0.031 (0.02)	--	0.421 (0.06)
Centrality	I	0.147 (0.01)	0.730 (0.26)	*0.056 (0.03)*	*0.036 (0.07)*
	S1	*0.006 (0.01)*	0.223 (0.11)	*0.004 (0.02)*	*-0.133 (0.07)*
	S2	*-0.007 (0.01)*	*-0.175 (0.15)*	*0.012 (0.02)*	*0.053 (0.05)*
Group x Centrality	I	0.087 (0.01)	0.030 (0.00)	--	0.150 (0.01)
	S1	0.015 (0.00)	0.009 (0.00)	--	-0.023 (0.01)
	S2	-0.020 (0.00)	-0.008 (0.00)	--	0.099 (0.01)

Effect sizes owing to peer variables		***Model Fit***	
	I	23.34%	CFI	0.978
	S1	6.12%	TLI	0.977
	S2	12.34%	RMSEA	0.048

Standard errors for estimates are in parantheses. Parameters in Italics not significantly different from zero $p > 0.05$

[a] Negative variance and residual variance estimates were set to zero.

[b] Peer group and the interaction term do not have reflect shared environmental variance (C), so the phenotypic models are defined by setting the regression coefficents on A and E equal (a = e).

Genetic confounds. Regressions on the *A* variance component estimate the extent to which genetics confound the relationship between affiliating with alcohol using peers and drinking alcohol. Genetic confounds mediate the relationship between peer group substance use, centrality, and the interaction term for the intercept and both slopes of alcohol use and alcohol problems (except for the regression of S2 on centrality, however, the phenotypic regression is not significantly different from zero).

Environmental confounds. Regressions on the *C* variance component estimate the extent to which shared environmental factors confound the relationship between target alcohol use and having substance using peer groups and closeness to the groups. The variance of the *C* component of peer group substance use and the interaction term are negative but are not significantly different from zero. Constraining the variance of *C* to be zero and estimating only the variances of *A* and *E* does not result in a significant loss of fit ($\Delta\chi^2 = 5.363$, $\Delta df = 2$, $p = .068$). For centrality, the regressions on *C* for alcohol use and alcohol problems are both not significantly different from zero indicating that shared environmental influences do not mediate the relationship between centrality and target alcohol use.

Quasi-Causal Relationships. Table 9 shows the regression coefficients for target estimates on the ACE components of peer behavior. For closeness centrality on the intercept of alcohol use, the phenotypic regression coefficients is larger than the the coefficient on the *E* component of closeness centrality indicating the relationship is explained by genetic and environmental confounds. The phenotypic regression of the intercept of target alcohol use on closeness centrality ($b = 0.147$, $p < 0.05$) exceeds the regression on the *E* component ($e = 0.035$, *ns*, $p > 0.05$) which reflects the relationship

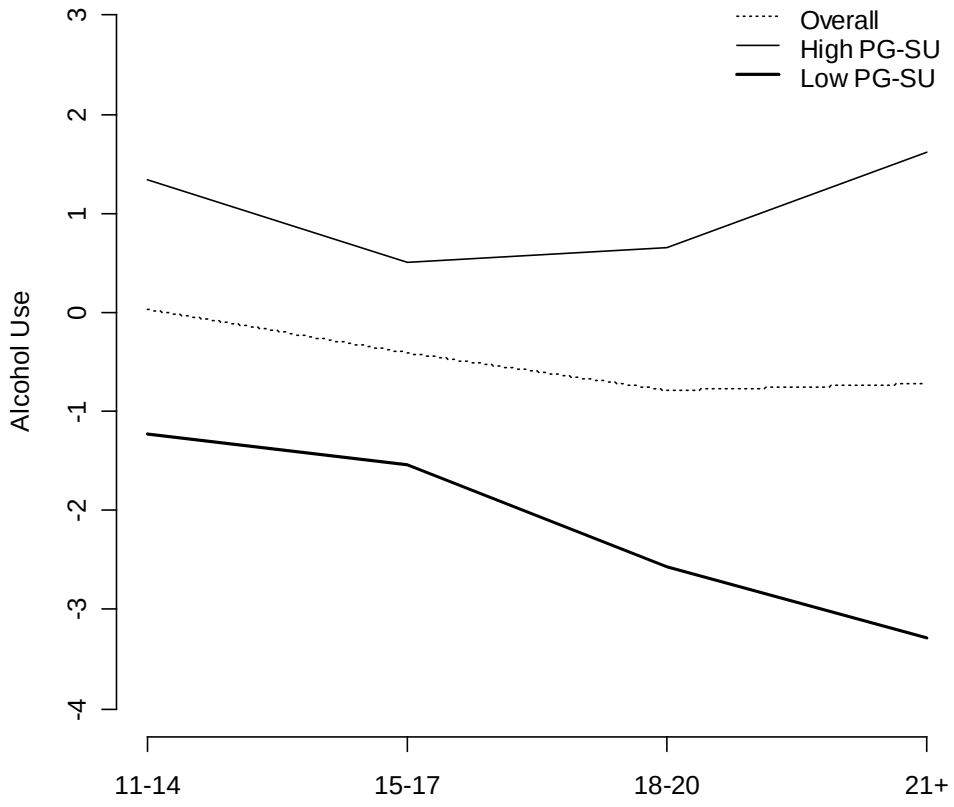
between target and peer behavior after considering genetic and environmental confounds. Closeness centrality does not explain additional variance after considering confounds and does not reflect causal processes.

For peer group substance use and the interaction between closeness centrality and peer group substance use, after considering genetic and shared environmental confounds, there remain significant paths on the *E* components of these peer factors for the intercept and both slopes of alcohol use and alcohol problems. To test whether this effect was driven by a single member of the group, rather than the group as a whole, post hoc analysis included best friend substance use as a covariate. Inclusion of best friend substance use did not affect the quasi-causal pathway, although inclusion did reduce the estimate of the genetic confounds. This suggests the quasi-causal effect is driven by the peer group. This is consistent with a potential role of peer group influence on overall adolescent alcohol use and problems and changes in alcohol use and problems over time. A regression on *E* indicates that after controlling for genetic and shared environmental confounds, the sibling who is exposed to more alcohol using peers will engage in more alcohol use than his or her co-sibling.

These effects indicate that overall, the sibling who is in a greater substance using peer group has greater overall alcohol use and problems than his or her co-sibling. This effect is amplified when the sibling reports close relationships with his or her peers. That is, for adolescents more central to their peer group, their behavior is more typical of that group overall. In addition to the effects on overall drinking, the regression of S1 and S2 on *E* are significant predicting differences in the trajectory after controlling for genetic and shared environmental confounds. Figure 9 shows the difference in change over time

for adolescents who have peer groups with substance use one standard deviation above and below the mean. Unlike the predicted phenotypic trajectory, which increased initially and decreased into adulthood for the high substance using peer group, the path on *E* suggests that after controlling for genetic and shared environmental confounds, greater peer substance use predicts a u-shaped trajectory, initially declining, but increasing into adulthood. Similarly, despite the monotonic increase predicted by low substance using peer groups in the phenotypic regression, the path on *E* suggests a decrease in alcohol use into adulthood. These effects are greater when adolescents spend more time with their peers (i.e., have greater closeness centrality).

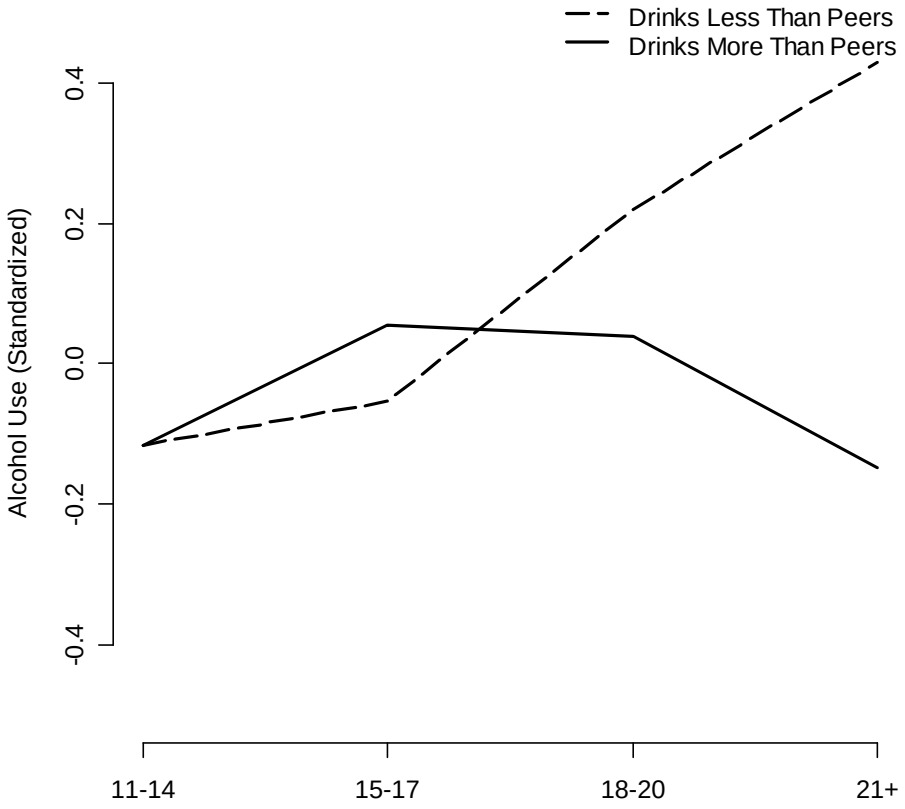
Figure 9. Alcohol use trajectories predicted by the regressions on E for high and low substance using peer groups.



The potential causal relationship is most evident in pairs of MZ twins who are discordant for risk, in this case peer group alcohol use. Figure 10 shows the trajectories for MZ twins who are initially concordant for alcohol use, but are discordant with their peer group. That is, neither twin drinks more than the other initially, but one twin is in a peer group with greater alcohol use and the other is in a peer group with less alcohol use. While this should be interpreted cautiously due to the small number of twin pairs for which this is true (n = 17 pairs), the twin who initially drinks less than his or peers increases alcohol use steadily into adulthood while the twin who initially drinks more than his or her peers slightly increases into mid adolescence but decreases into early adulthood. The difference in early adulthood reflects that the twin initially in a more risky environment has greater alcohol use than the twin initially in the less risky environment.

The within-family association is not free from confounds, rather, within-family associations are confounded by factors that vary systematically between siblings. For example, the twin who chooses to be in a peer group with greater substance use may engage in more conflict with his or her parents, and this conflict may cause the twin to engage in more alcohol use behavior than his co-twin. Nevertheless, it is important to stress that within-family associations have many fewer potential confounds than between-family associations and present a stronger case for causal peer influence.

Figure 10. *MZ twin pairs initially concordant for alcohol use, but discordant for peer group substance use (one peer group drinks more, the other peer group drinks less, n = 17 pairs, differences are not significant).*



Discussion

This study approaches the complex relationship between peer characteristics and adolescent alcohol use in three primary ways. First, we consider the diversity in peer networks by examining structural and behavioral aspects of these networks. Second, as peers represent different social contexts throughout development, we examine the developmental course of alcohol use from early adolescence to early adulthood. Third, we use family designs to consider the immeasurable and innumerable potential confounding processes between friendships and alcohol use to identify true causal

relationships. This is one of only a few studies to consider either effects of multiple dimensions of peer networks on adolescent problem behavior or peer effects on adolescent problem behavior using family designs, although both approaches have yielded important contributions. Further, this is the only study to combine these approaches to both consider the complexity of the peer system and the complexity of distinguishing risk indicators from risk mechanisms in the presence of genetic and environmental confounds.

Overall, the results presented here make a strong case for a combination of selection and influence mechanisms involving the relationship between the peer group and adolescent alcohol use. The results presented here may indicate that the primary mechanism through which peers may affect behavior is socialization. Here, we present the pieces of the puzzle that, when combined, make a strong case that there are processes within peer groups that affect alcohol behavior throughout adolescent development:

1. Alcohol use in adolescence reflects nonlinear change with an increase in alcohol use and problems in mid and late adolescence and a decline into early adulthood.
2. Overall adolescent alcohol use and peer group characteristics reflect genetic, shared environmental, and nonshared environmental variance. Changes in adolescent alcohol use only reflect genetic and nonshared environmental variance.
3. Peer group substance use is related to overall level of adolescent alcohol use and greater use over time. Greater peer substance use is related to greater overall alcohol use, a greater increase into mid and late adolescence, and less of a decline into early adulthood. These effects are greatest when an adolescent is close to his or her peers.

4. While genetic confounds moderated the relationship between peers and adolescent alcohol use, there remains a quasi-causal path providing strong support for the causal role of peer group substance use on alcohol use throughout adolescence. This role is particularly salient in the context of high quality friendships.

Developmental Course of Alcohol Use from Early Adolescence to Early Adulthood

As expected, the course of alcohol use from early adolescence to early adulthood reflects nonlinear change with an increase in mid and late adolescence and decrease into adulthood. This is consistent with previous research indicating a normative increase in alcohol use and other problem behaviors that occurs during adolescence (e.g., Moffitt 1993). Partitioning the variance into genetic, shared environmental, and nonshared environmental components reveals that overall levels of alcohol use have portions of genetic and shared environmental influences, but the majority of variation owes to nonshared environmental influences. Changes in alcohol use throughout adolescence reflected only genetic and nonshared environmental variance indicating that shared environmental factors did not contribute to changes in alcohol use throughout adolescence. The different proportions of variance owing to genetic and environmental factors do suggest different influences throughout development and are consistent with previous research (e.g., McGue and Iacono, 2008; Chassin et al., 2004).

While common environmental factors (e.g., parenting practices, socio-economic status) may affect alcohol use overall, changes in alcohol use and problems reflect little to no shared environmental variance. Previous research has indicated a reduced role for

the shared environment throughout adolescence (Rose & Dick, 2004) which may reflect growing independence from parents, greater involvement in individual activities, or a greater role of genetic influence. However, this also may reflect the fact that the environment shared by adolescence may not change substantially throughout adolescence. Socioeconomic status, parent characteristics, school characteristics, and other common environments are often consistent throughout adolescence and therefore may have a greater impact on overall alcohol use rather than changes in alcohol use.

The finding that there are genetic contributions to adolescent alcohol use is consistent with previous research (e.g., Rhee et al., 2003; Silberg et al., 2003), but does not indicate specific genes or the mechanism through which genes may influence alcohol use behaviors. Genes may, and likely do, influence alcohol use through a variety of mechanisms such as biological responses to alcohol use or personality characteristics that encourage adolescents to act in certain ways and seek out certain environments.

Nonshared environmental variance indicates that there are aspects of the environment that differ for twins and siblings within families and that these differences are related to overall alcohol use and changes in alcohol use over time. There is a particularly large role for the nonshared environment on the changes in alcohol use as individuals enter adulthood. This may reflect greater physical separation of twins and siblings who move out of their homes and begin to select into different environments.

Genetic and Environmental Influences on Peer Characteristics

Peer group substance use reflected predominately genetic and nonshared influence, with a small proportion of shared environmental contribution. This is largely consistent with previous research, which has indicated exclusively genetic and nonshared

environmental contributions to best friend substance use (Hill et al., 2008; Cleveland et al., 2005). As with an adolescent's own alcohol use, this finding does not indicate the specific genetic mechanisms that may influence the selection of peers. Likely, genes that influence personality characteristics, physical characteristics, and behaviors influence selection of peers with certain characteristics rather than a gene, or set of genes, specifically influencing the selection of peers.

Friendship quality reflects a majority of variance (60%) attributable to shared environmental factors and relatively smaller proportions of genetic and nonshared environmental influences. While this again does not specify the environmental factors that may be influencing the formation of close friendships, factors such as parenting practices, access to school clubs and organizations, or cultural expectations for socializing may encourage the development of high quality friends. For example, studies have repeatedly indicated that parent-adolescent relationships affect the quality of relationships between adolescents and their peers (e.g., Allen et al., 2007; Lansford et al., 2003; Franco & Levitt, 1998; Schneider, Atkinson, & Tardif, 2001).

Despite genetic and shared environmental influences on both peer substance use and friendship quality, a considerable portion of the variance of these risk indicators is attributable to nonshared environmental factors, or those components of the environment that vary within twin and sibling pairs. To identify whether either of these risk indicators represent causal mechanisms, we test to what degree differences in friendship quality or peer group substance use predict differences in alcohol use outcomes for adolescents.

Phenotypic Relationships

Greater peer group substance use predicts greater overall alcohol use and problems, a greater increase in alcohol use and problems in early and mid adolescence, and a less dramatic decline into late adolescence. More specifically, greater peer group substance use is not only related to greater overall alcohol use, but the peak in alcohol use during mid and late adolescence is greater and is more sustained into adulthood. These effects are amplified for adolescents who are close to their peer groups. By examining the relationship between peer characteristics and the developmental course of alcohol use, a stronger case is made for the concurrence of selection and causation mechanisms within peer groups.

Within peer groups, the strength of the association with group substance use is greatest when an adolescent is close to his or her friends. That is, for adolescents spending a lot of time with those he or she nominates or is nominated by, their behaviors are more typical of the group. This is consistent with previous research that has found for adolescents with higher relationship quality associations between individuals and friends are stronger (Urberg et al. 2003). This may indicate that the more time an adolescent spends with his or her peer group, the more typical of the group the adolescent's behavior is; adolescents whose behavior is typical of the group, spend more time with these peers; or a combination of these processes. For adolescents who spend lots of time with a high substance using peer group, the increase of alcohol use into mid and late adolescence is more dramatic than for adolescents in low quality or low substance using peer groups. For adolescents in high quality, low substance using groups, there is little change in alcohol use as it remains low from early adolescence to early adulthood. For these high

quality friendships, the direction of the effect depends on the characteristics of the friends. Being close to substance peers predicts greater and more persistent alcohol use while being close to low substance using peers predicts persistently low alcohol use.

The implications regarding the findings for adolescents who are not close to their peer group are less intuitive. While the main effect of having a high substance using peer group on overall alcohol use remains, the changes over time are in the opposite direction of the peer group (i.e., adolescents in high substance using groups decrease over time and those in low substance using groups increase over time). It is possible that adolescents who were not close their peer groups may have been more likely to select into other peer groups over time, perhaps groups that had more or less substance use. Alternatively, for adolescents in low quality relationships, this may reflect regression to the mean; friendships may have limited effect when they are low quality and these adolescents converge to more normative alcohol use levels over time. As peer group substance use is only available at the initial time point, these hypotheses cannot be evaluated.

Taken together, the interactive effects of friendship quality and peer group substance use contribute another piece of the puzzle and are consistent with a combination of selection and socialization processes. Adolescents engaging in greater alcohol use are in greater substance using peer groups, reflecting possible selection processes, and adolescents change in the direction of their peer groups over time, reflecting possible causal processes. These changes are greater when friendship quality is high, that is, most likely to occur for adolescents exposed to the risk more than for adolescents who are exposed to the risk less. The effect of friendship quality suggests that time spent with

peers may be an integral component in the mechanism through which peers influence behavior.

Genetic Confounds

Applying the quasi-causal model to these phenotypic relationships demonstrated both support for confounding processes and causal peer influence. While shared environmental confounds were not prevalent, genetic confounds were implicated in the relationship between peer variables and both overall alcohol use and changes over time. Genes may influence the correlation between two observed variables in several ways. Two mechanisms through which gene-environment correlations (rGE) may be at work in the current association are active and evocative rGE (Plomin, DeFries, & Loehlin., 1977). Active rGE suggests that an individual is influenced by his or genes to seek out certain environments. For example, an individual genetically predisposed to drink alcohol may seek out other individuals predisposed to drink alcohol. Evocative rGE suggests that an individual's genes cause others to act in a certain way toward him or her. For example, an adolescent who is predisposed to drink alcohol will attract peers who drink alcohol. In this case, as peer selection is a reciprocal process in which adolescents and peers select each other, it is likely both active and evocative rGE processes may be at work. With regard to the moderation of the effect on the trajectory of alcohol use, similarly, the 'type' of adolescents to select in or out of substance using groups may also be the 'type' of adolescents to demonstrate the normative increase in mid to late adolescence, or may be the 'type' to abstain altogether.

The finding that genes play a role for both peer selection and alcohol use behavior does not imply that genes determine these characteristics. The majority of variance in

alcohol use was attributable to environmental factors and further, did not completely explain the covariance between alcohol use and peer factors. This finding does not suggest which genes are responsible for this association, nor does it shed light on the specific mechanisms that are at work. There may be genes for alcohol use and peer selection directly, or more indirectly, genes for personality traits such as risk taking or sociability which may affect both selection of peers and alcohol use.

Support for Peer Influence

Unlike the finding for best friends, where genetic confounds completely accounted for the covariance between alcohol use and best friend substance use (Hill et al., 2008), for peer groups there remained an additional quasi-causal effect suggesting that after considering selection based on genetic and shared environmental factors, peer group substance use is related to overall alcohol use and changes over time. Specifically, after considering genetic and environmental confounds and controlling for best friend substance use, greater peer group substance use predicts greater overall alcohol use and more persistent alcohol use over time.

To best understand the quasi-causal effect, consider monozygotic twins who are discordant for levels of risk. MZ twins share the same genes and shared environment, so the obvious question is as follows: do differences in the level of risk they are exposed to predict these differences in behavior? In this case, the answer is yes. The twin exposed to greater peer substance use has greater overall substance use and more persistent alcohol use over time than the twin exposed to less peer substance use.

Despite the strong support gleaned from accounting for the numerous potential confounds that vary between families, both genetic and environmental in nature, we call

these quasi-causal relationships as they are not free from within-family confounds (e.g., belonging to a peer group with greater substance use may lead to greater parental conflict and in turn lead to greater alcohol use). However, combined with the findings from the longitudinal data and enhanced effects for adolescents with close relationships, these results make a strong case for the causal role for peers. The most parsimonious explanation finds a role for both selection and causation in relation to peer groups and alcohol use behavior.

Potential Mechanisms and Implications

Importance of peer groups. Whereas dyadic relationships reflected potential causal processes for only a select group of high-risk adolescents (Harden et al., 2008), peer groups reflect a more robust mechanism for influence that persisted after controlling for genes, shared environment and best friend substance use. This may suggest a greater role for norm setting and socialization mechanisms rather than "peer pressure" where a deviant adolescent promotes problem behavior in an otherwise "good kid." Rather, peer groups may create a culture that rewards certain behaviors and discourages others. The results indicate a dynamic system where peer groups are formed based on similarity for a host of behaviors, including substance use behaviors. To the extent that adolescents differ from their group, adolescents change in the direction of the group over time. The group may set normative standards for behavior; these behaviors seem to be fostered most within close friendships where the adolescents spend time with one another. The importance of peer groups is supported by previous research that has suggested potential influence of dyadic relationships is generally subsumed by the peer group (Bauman et al., 2007).

The use of social network analysis permits identification of groups within adolescence, and suggest that the concept of a 'peer group' is both individualized and highly relevant. For some adolescents, a peer group includes large numbers of twenty and thirty peers or more, while for many adolescents, the peer group includes only a few friends. By defining the peer group structure individually, rather than assigning an arbitrary size, this more closely reflects the heterogeneity within the peer system. This individual variation may account for previous difficulty in identifying peer groups, a task that adolescents perform with relative ease (Michell, 1997). These peer groups describe contexts that are highly relevant to exploring peer processes. Individuals within peer groups are more similar to one another for a number of characteristics (i.e., academic achievement, substance use, and involvement in school activities) than are individuals within dyadic relationships or the school culture more generally.

Most relevantly, the substance use among members within the peer groups demonstrates a greater degree of relatedness than any other identified peer subnetwork including the best friend, the weighted mean of the extended peer network, and the mean of the school at large. In the current study, substance use among peer groups accounts for twice as much variance as is accounted for by the same-sex best friend's substance use, often considered the most powerful predictor of alcohol use in adolescence. This high degree of relatedness strongly suggests that these groups identify meaningful social contexts within the peer network within which important selection and influence processes may be at work.

Social success and alcohol use. Although the overall effect of friendship quality is negligible when considered in combination with group substance use, the moderate,

positive relationship between substance use and friendship quality indicates that the closer adolescents are to their peers, the greater their alcohol use. While this is inconsistent with findings examining other problem behaviors that are considered "antisocial" where greater friendship quality was a protective factor against the development of delinquent behaviors that more acutely violate social norms (Lansford et al, 2003), this may indicate that moderate substance use is normative and generally greater among socially engaged adolescents (Allen et al., 2006).

The importance of friendship quality may explain why a popular intervention to curb binge drinking on college campuses by educating students regarding normative levels of drinking on campus (which are generally considerably below the expectations of college students) has found little to no support (Wechsler et. al., 2003), while iatrogenic effects of congregating antisocial youth for treatment have found increases in substance use (Dishion and Dodge, 2005). Time spent with peers seems to be a key factor in the effect of socialization on adolescent problem behavior as indicated by the current study and others (Urberg et al., 2003, Ennett et al., 2006; Crosnoe and Needham, 2004); effects are most salient in groups where adolescents spend time with one another. The school-based interventions that do not expose adolescents to the socializing agents (the "normal" college students promoted by the campaign) do not have an effect on alcohol use behaviors. However, because adolescents spend time with their peers in the treatment groups, socialization processes in these contexts do seem to affect behavior.

Notably, adhering to social expectations is not an inherently negative behavior. In groups where normative behaviors are seen as problematic, such adherence may lead to negative outcomes (Dishion & Dodge, 2005). However, the current study extends

socialization processes to include the potential for positive socialization processes. The current study finds that peer groups are neither inherently "good" nor "bad" influences; for adolescents with initially high alcohol use who select into low substance using groups, there is a decrease in alcohol use over time.

Peer environments are both potentially protective and potentially risky. Parenting practices and interventions aimed at decreasing alcohol use in adolescence may foster positive peer relationships by exposing adolescents to opportunities to meet peers and the skills to develop high quality relationships.

Peers and problem behavior trajectories. For the quasi-causal paths on the changes into mid and late adolescence, we see projected changes that differ from the phenotypic effect. For the phenotypic effect, greater peer group substance use predicts a greater increase in alcohol use during mid and late adolescence, but for the quasi-causal path, greater peer group substance use predicts a less dramatic increase in mid and late adolescence. That is, the quasi-causal path flattens the spike in mid and late adolescence for high substance using groups, but enhances the spike for low substance using groups. This may indicate that having high substance using peer group early in adolescence predicts more persistent drinking over time. Studies have often differentiated between "adolescent-limited" and "life-course persistent" trajectories of alcohol use and other problem behaviors. The "adolescent-limited" trajectory generally reflects a more normative increase in problem behavior that decreases in adulthood and is generally less indicative of long-term negative outcomes. "Life-course persistent" trajectories generally are associated with earlier involvement in the problem behavior and more persistent negative outcomes into adulthood when the behaviors cease to be normative (Chassin et

al., 2004; Moffitt, 1993). Belonging to a high substance using peer group may sustain problematic alcohol use behavior. It is possible that early involvement in such groups may influence the way adolescents conceptualize social relationships and normative behavior that encourage and sustain alcohol use behaviors.

Future Directions and Limitations

Twin models of the kind employed here assume that there is no gene-environment interaction (GxE) and include any GxE effects in the genetic confound thereby underestimating potential peer effects. As this paper identifies genetic confounds and GxE processes have been identified for best friends (Harden et al., 2008), future work might use emerging methods (Eaves et al., 2003; Harden et al, 2008) that may be able to examine GxE and rGE simultaneously for the association between peer groups and adolescent outcomes.

Missing data are another possible concern. Missing peer reports due to failure to nominate a peer or nominated peers who did not provide data were both treated as missing. Missing data analysis showed only minor differences between these groups on measured covariates and outcomes. However, it is possible that there were important unmeasured differences between groups. The proportion of missing data may also produce biased estimates as the limitations of the missing data analysis used in the current study have not been tested for complex genetic models and social network analyses. Evaluation of ML under MAR with simpler genetic models suggests that with samples of similar size and high rates of missing data (nearly 80%) ML under MAR performs adequately (Schafer and Graham, 2002).

The ages of the youth in this study spanned the entire range of adolescence. Due to low coverage for each age in this span, ages were collapsed into categories in order to facilitate developmentally sensitive analyses. While these categories attempted to take into account meaningful periods within adolescence, it is possible that specificity was lost in this aggregation.

Peer group identification, especially in large networks, is a notoriously complex task (Moody, 2001). Finding meaningful groups, and evaluating the validity of these groups is still more complicated. However, the island algorithm in *Pajek* demonstrated utility in identifying groups of meaningful size within the peer networks in Add Health. Often, group identification using large social networks can lead to groups that are too large to be meaningful (i.e., including most individuals in a system due to high connectedness), not including many individuals in a group at all (i.e., large numbers of isolates and dyads), or producing overlapping groups. The groups identified in the current study demonstrated validity in that members shared characteristics and were more likely to nominate members within the groups than to nominate adolescents in the system at large. However, due to limited previous use of this algorithm and the difficulty of identifying groups within large systems generally, further validation efforts are indicated.

Friendship quality was measured by using a ratio of time spent with peers to the number of peers nominated. Thus, an adolescent is less central if they nominate many peers with whom they do not spend much time. There are other factors, however, involved in friendship quality including supportiveness and affection that are not measured here. Further, adolescents with higher quality social relationships may have greater self-esteem and better relationships with their parents that may affect the degree

to which friends influence behavior (e.g., Lansford et al., 2003). Given the importance of friendship quality in the current study, exploring more factors related to this characteristic and potential mediating factors may be of further interest.

While alcohol use is an important problem behavior, it is one of a group of heterogeneous externalizing behaviors in adolescence. Generalization of these findings to other problem behaviors may not be appropriate. Studies have also indicated different mechanisms increasing risk for different types of alcohol users. This study treated variation in alcohol use continuously, but there may be differences in the way peers affect different types of drinkers in adolescence.

Conclusions

The rigorous combination of longitudinal and behavior genetic designs and consideration of multiple dimensions of the peer environment indicates the importance of considering selection and provides strong support for the causal role of peer group behavior and relationship dynamics on adolescent alcohol use. Peer groups with high relationship quality are highlighted as being a particularly important context for development of alcohol use behaviors. These analyses demonstrate the utility in considering diverse characteristics and structures within peer networks and in considering potential confounds using behavior genetic designs. By simplifying the peer system to dyadic relationships, we may underestimate potential peer effects. Similarly, by failing to consider confounding processes, effects may be overestimated. In addition to demonstrating the utility of these methodological approaches, identification of the causal role of behaviors within peer groups has implications for interventions targeting problem adolescent alcohol use. Interventions and parents should focus on increasing the quality

of relationships and providing opportunities to socialize with peer groups with low or normative levels of alcohol use. This may be accomplished by encouraging development of friendships within activities where the primary reason for aggregating is not drinking, ensuring adequate supervision or awareness of social gatherings, and by teaching skills that will promote deepening of friendships.

References

Allen, J. P., Moore, C., Kuperminc, G., & Bell, K. (1998). Attachment and adolescent psychosocial functioning. *Child development, 69*(5), 1406-1419.

Allen, J. P., Porter, M. P., & McFarland, C. F. (2006). Leaders and followers in adolescent close friendships: Susceptibility to peer influence as a predictor of risky behavior, friendship instability, and depression. *Development and psychopathology, 18*(1), 155-172.

Allen, J. P., Porter, M. R., McFarland, F. C., Marsh, P., & McElhaney, K. B. (2005). The two faces of adolescents' success with peers: Adolescent popularity, social adaptation, and deviant behavior. *Child development, 76*(3), 747-760.

Allen, J. P., Porter, M., McFarland, C., McElhaney, K. B., & Marsh, P. (2007). The relation of attachment security to adolescents' paternal and peer relationships, depression, and externalizing behavior. *Child development, 78*(4), 1222-1239.

Allison, P. D. (2002). *Missing Data.* London: Sage Publications.

Arnett J. J. (2007). The Myth of Peer Influence in Adolescent Smoking Initiation.

Audrain-McGovern, J., Rodriguez, D., Tercyak, K. P., Neuner, G., & Moss, H. B. (2006). The impact of self-control indices on peer smoking and adolescent smoking progression. *Journal of pediatric psychology, 31*(2), 139-151.

Barber, B., Eccles, J., Stone, M. R. (2001). Whatever happened to the jock, the brain, and the princess?: Young adult pathways linked to adolescent activity involvement and social identity. *Journal of Adolescent Research, 16 (5),* 429-455.

Barnes, G. M., Hoffman, J. H., Welte, J. W., Farrell, M. P., & Dintcheff, B. A. (2006). Effects of parental monitoring and peer deviance on substance use and delinquency. *Journal of Marriage and Family, 68*(4), 1084-1104.

Batagelj, V., Kejzar, N., Korenjak-Cerne, S., & Zaversnik, M. (2006). Studies in classification, data analysis, and knowledge organization. In Batagelj, V., Bock, H., Ferligoi, A., Iberna, A. (Eds.), *Data Science and Classification.* New York, NY, US: Springer.

Bauman, K. E., & Ennett, S. T. (1996). On the importance of peer influence for adolescent drug use: Commonly neglected considerations. *Addiction, 91*(2), 185-198.

Bauman, K. E., Faris, R., Ennett, S. T., Hussong, A., & Foshee, V. A. (2007). Adding valued data to social network measures: Does it add to associations with adolescent substance use? *Social Networks, 29*(1), 1-10.

Bearman P, Moody J, & Stovel K. (1997). The Add Health network variable codebook.

Becker, B. E., & Luthar, S. S. (2007). Peer-perceived admiration and social preference: Contextual correlates of positive peer regard among suburban and urban adolescents. *Journal of Research on Adolescence, 17*(1), 117-144.

Bolger, K. E., Patterson, C. J., & Kupersmidt, J. B. (1998). Peer relationships and self-esteem among children who have been maltreated. *Child development, 69*(4), 1171-1197.

Brook, D. W., Morojele, N. K., Zhang, C., & Brook, J. S. (2006). South African adolescents: Pathways to risky sexual behavior. *AIDS Education and Prevention, 18*(3), 259-272.

Brown, B. B., & Lohr, M. J. (1987). Peer-group affiliation and adolescent self-esteem: An integration of ego-identity and symbolic-interaction theories. *Journal of personality and social psychology, 52*(1), 47-55.

Brown, B. B., Dolcini, M. M., & Leventhal, A. (1997). In Schulenberg J., Maggs J. L. and Hurrelmann K. (Eds.), *Transformations in peer relationships at adolescence: Implications for health-related behavior*. New York, NY, US: Cambridge University Press.

Byrne, B. M., Shavelson, R. J., & Muthen, B. (1989). Testing for the equivalence of factor covariance and mean structures: The issue of partial measurement invariance. *Psychological Bullettin, 195*(3), 456-466.

Cairns, R. B., Cairns, B. D., Neckerman, H. J., Gest, S. D., & Gariépy, J. (1988). Social networks and aggressive behavior: Peer support or peer rejection? *Developmental psychology, 24*(6), 815-823.

Chassin, L., Flora, D. B., King, K. M. (2004). Trajectories of alcohol and drug use and dependence from adolescence to adulthood: The effects of familial alcoholism and personality. *Journal of Abnormal Psychology, 113 (4), 483-498.*

Cooper, C. R., & Cooper, R. G. J. (1992). In Parke R. D., Ladd G. W. (Eds.), *Links between adolescents' relationships with their parents and peers: Models, evidence, and mechanisms*. Hillsdale, NJ, England: Lawrence Erlbaum Associates, Inc.

Cornelius, J. R., Clark, D. B., Reynolds, M., Kirisci, L., & Tarter, R. (2007). Early age of first sexual intercourse and affiliation with deviant peers predict development of SUD: A prospective longitudinal study. *Addictive Behaviors, 32*(4), 850-854.

Craig, W. M., Vitaro, F., Gagnon, C., & Tremblay, R. E. (2002). The road to gang membership: Characteristics of male gang and nongang members from ages 10 to 14. *Social Development, 11*(1), 53-68.

Criss, M. M., Pettit, G. S., Bates, J. E., Dodge, K. A., & Lapp, A. L. (2002). Family adversity, positive peer relationships, and children's externalizing behavior: A longitudinal perspective on risk and resilience. *Child development, 73*(4), 1220-1237.

Crosnoe, R. & McNeely, C. (2008). Peer relations, adolescent behavior, and public health research and practice. Family and Community Health, 31, S71-S80.

Crosnoe, R., & Needham, B. (2004). Holism, contextual variability, and the study of friendships in adolescent development. *Child development, 75*(1), 264-279.

Curran, P. J., Stice, E., & Chassin, L. (1997). The relation between adolescent alcohol use and peer alcohol use: A longitudinal random coefficients model. *Journal of consulting and clinical psychology, 65*, 130-140.

Daniels, D., & Plomin, R. (1985). Differential experience of siblings in the same family. *Developmental psychology, 21*(5), 747-760.

de Nooy, W., Mrvar, A., & Batagelj, V. (2005). *Exploratory Social Network Analysis with Pajek.* New York: Cambridge University Press.

Dishion, T. J. & Dodge, K. A. (2005). Peer contagion in interventions for children and adolescents: Moving towards an understanding of the ecology and dynamics of change. *Journal of Abnormal Child Psychology, 33*(3), 395-400.

Dishion, T. J., & Medici Skaggs, N. (2000). An ecological analysis of monthly 'bursts' in early adolescent substance use. *Applied Developmental Science, 4*(2), 89-97.

Dishion, T. J., & Owen, L. D. (2002). A longitudinal analysis of friendships and substance use: Bidirectional influence from adolescence to adulthood. *Developmental psychology, 38*(4), 480-491.

Dishion, T. J., & Patterson, G. R. (2006). In Cicchetti D., Cohen D. J. (Eds.), *The development and ecology of antisocial behavior in children and adolescents*. Hoboken, NJ, US: John Wiley & Sons Inc.

Dishion, T. J., Andrews, D. W., & Crosby, L. (1995). Antisocial boys and their friends in early adolescence: Relationship characteristics, quality, and interact ional process. *Child development, 66*(1), 139-151.

Eaves, L., Silberg, J., & Erkanli, A. (2003). Resolving multiple epigenetic pathways to abstract adolescent depression. *Journal of Child Psychology and Psychiatry, 44*(7), 1006-1014.

Ennett, S. T., & Bauman, K. E. (2006). In Levine J. M., Moreland R. L. (Eds.), *The contribution of influence and selection to adolescent peer group homogeneity: The case of adolescent cigarette smoking*. New York, NY, US: Psychology Press.

Ennett, S. T., Faris, R., Hipp, J., Foshee, V. A., Bauman, K. E., Hussong, A., & Cai, L. (2008). Peer smoking, other peer attributes, and adolescent cigarette smoking: A social network analysis. *Prevention Science, 9,* 88-98.

Ennett, S. T., Faris, R., Hipp, J., Foshee, V. A., Bauman, K. E., Hussong, A., & Cai, L. (2008). Peer smoking, other peer attributes, and adolescent cigarette smoking: A social network analysis. *Prevention Science, 9*(2), 88-98.

Fergusson, D. M., Wanner, B., Vitaro, F., Horwood, L. J., & Swain-Campbell, N. (2003). Deviant peer affiliations and depression: Confounding or causation? *Journal of abnormal child psychology, 31*(6), 605-618.

Franco, N. & Levitt, M. J. (1998). The social ecology of middle childhood: Family support, friendship quality, and self-esteem. *Family Relations, 47*(4), 315-321.

Gatti, U., Tremblay, R. E., Vitaro, F., & McDuff, P. (2005). Youth gangs, delinquency and drug use: A test of the selection, facilitation, and enhancement hypotheses. *Journal of Child Psychology and Psychiatry, 46*(11), 1178-1190.

Glendinning, A., Hendry, L., & Shucksmith, J. (1995). Lifestyle, health and social class in adolescence. *Social science & medicine, 41*(2), 235-248.

Granic, I., & Dishion, T. J. (2003). Deviant talk in adolescent friendships: A step toward measuring a pathogenic attractor process. *Social Development, 12*(3), 314-334.

Grosbras, M., Jansen, M., Leonard, G., McIntosh, A., Osswald, K., Poulsen, C., Steinberg, L., Toro, R., & Paus, T. (2007). Neural mechanisms of resistance to peer influence in early adolescence. *Journal of Neurooscience, 27,* 8040-8045.

Harden, K. P., Hill, J. E., Turkheimer, E., Emery, R. E. (2008). Gene-environment correlation and interaction in peer effects on adolescent alcohol and tobacco use. *Behavior Genetics*, 38, 339-347.

Harden, K. P., Mendle, J., Hill, J. E., Turkheimer, E., & Emery, R. E. (2008). Rethinking timing of first sex and delinquency. *Journal of Youth and Adolescence, 37,* 373-385.

Hartup, W. W. (1996). The company they keep: Friendships and their developmental significance. *Child development, 67*(1), 1-13.

Health Education Behaviors, 34, 594-607.

Hill, J. E., Emery, R. E., Harden, K. P., Mendle, J., & Turkheimer, E. (2008). Alcohol use in adolescent twins and affiliation with substance using peers. *Journal of abnormal child psychology, 36*(1), 81-94.

Hill, K. G., Howell, J. C., Hawkins, J. D., & Battin-Pearson, S. R. (1999). Childhood risk factors for adolescent gang membership: Results from the Seattle social development project. *Journal of Research in Crime and Delinquency, 36*(3), 300-322.

Jaccard, J., Blanton, H., & Dodge, T. (2005). Peer influences on risk behavior: An analysis of the effects of a close friend. *Developmental psychology, 41*(1), 135-147.

Jacobson, K. C. & Rowe, D. C. (1999). Genetic and environmental influences on the relationships between family connectedness, school connectedness, and adolescent depressed mood: Sex differences. *Developmental Psychology, 35*(4), 926-939.

Jorgensen, M. H., Curtis, T., Christensen, P. H., & Gronbæk, M. (2007). Harm minimization among teenage drinkers: Findings from an ethnographic study on teenage alcohol use in a rural Danish community. *Addiction, 102*(4), 554-559.

Kendler, K. S., Jacobson, K. C., Gardner, C. O., Gillespie, N., Aggen, S. A., Prescott, C. A. (2007). Creating a social world: A developmental twin study of peer-group deviance. *Archives of General Psychiatry, 64*(8), 958-965.

Kiesner, J., Cadinu, M., Poulin, F., & Bucci, M. (2002). Group identification in early adolescence: Its relation with peer adjustment and its moderator effect on peer influence. *Child development, 73*(1), 196-208.

Kliewer, W., & Murrelle, L. (2007). Risk and protective factors for adolescent substance use: Findings from a study in selected central American countries. *Journal of Adolescent Health, 40*(5), 448-455.

Kokkevi, A. E., Arapaki, A. A., Richardson, C., Florescu, S., Kuzman, M., & Stergar, E. (2007). Further investigation of psychological and environmental correlates of substance use in adolescence in six European countries. *Drug and alcohol dependence, 88*(2), 308-312.

Krueger, R., Hicks, B., Patrick, C., Carlson, S., Iacono, W., & McGue, M. (2002). Etiologic connections among substance dependence, antisocial behavior and personality: Modeling the externalizing spectrum. *Journal of Abnormal Psychology*, *111*(3), 411-424.

Ladd, G. W. (1999). Peer relationships and social competence during early and middle childhood. *Annual Review of Psychology, 50*, 333-359.

Laird, R. D., Pettit, G. S., Dodge, K. A., & Bates, J. E. (2005). Peer relationship antecedents of delinquent behavior in late adolescence: Is there evidence of demographic group differences in developmental processes? *Development and psychopathology, 17*(1), 127-144.

Lansford, J. E., Criss, M. M., Pettit, G. S., Dodge, K. A., & Bates, J. E. (2003). Friendship quality, peer group affiliation, and peer antisocial behavior as moderators of the link between negative parenting and adolescent externalizing behavior. *Journal of Research on Adolescence, 13*(2), 161-184.

Little, R. J. & Rubin, D. B. (1989). *Statistical analysis with missing data.* New York, NY: John Wiley & Sons.

Loehlin, J. C., & Nichols, R. C. (1976). *Heredity, environment, and personality: A study of 850 sets of twins*. Austin, Texas: University of Texas Press.

McGue, M. & Iacono, W. (2008). The adolescent origins of substance use disorders. *International Journal of Methods in Psychiatric Research, 17*(S1), S30-S38.

Metzler, C. W., Noell, J., Biglan, A., & Ary, D. (1994). The social context for risky sexual behavior among adolescents. *Journal of Behavioral Medicine, 17*(4), 419-438.

Michael, K., & Ben-Zur, H. (2007). Risk-taking among adolescents: Associations with social and affective factors. *Journal of adolescence, 30*(1), 17-31.

Michell, L. (1997). Loud, sad or bad: Young people's perceptions of peer groups and smoking. *Health education research, 12*(1), 1-14.

Michell, L., & Amos, A. (1997). Girls, pecking order and smoking. *Social science & medicine, 44*(12), 1861-1869.

Miles, D. R., & Carey, G. (1997). Genetic and environmental architecture on human aggression. *Journal of personality and social psychology, 72*(1), 207-217.

Moffitt, T. E. (1993). Adolescence-limited and life-course-persistent antisocial behavior: A developmental taxonomy. *Psychological review, 100*(4), 674-701.

Moffitt, T. E. (2003). Life-course-persistent and adolescence-limited antisocial behavior: A 10-year research review and a research agenda. In B. B. Lahey, T. E. Moffitt & A. Caspi (Eds.), *Causes of conduct disorder and juvenile delinquency.* (pp. 49-75)Guilford Press.

Moody, J. (2001). Peer influence groups: Identifying dense clusters in large networks. *Social Networks, 23,* 261-283.

Moody, J. (2001). Peer influence groups: Identifying dense clusters in large networks. *Social Networks, 23,* 261-283.

Morash, M., & Moon, B. (2007). Gender differences in the effects of strain on the delinquency of south Korean youth. *Youth & Society, 38*(3), 300-321.

Morgan, M., & Grube, J. W. (1991). Closeness and peer group influence. *British Journal of Social Psychology, 30*(2), 159-169.

Mosbach, P., & Leventhal, H. (1988). Peer group identification and smoking: Implications for intervention. *Journal of abnormal psychology, 97*(2), 238-245.

Muthen L. K. & Muthen, B. O. (2004). *Mplus User's Guide.* Los Angeles, CA.

Nangle, D. W., Erdley, C. A., Newman, J. E., Mason, C. A., & Carpenter, E. M. (2003). Popularity, friendship quantity, and friendship quality: Interactive influences on children's loneliness and depression. *Journal of Clinical Child and Adolescent Psychology, 32*(4), 546-555.

Neale, M. C. & Cardon, L. R. (1992). *Methodology for genetic studies of twins and families.* New York, NY: Kluwer Academic/Plenum Publishers.

Padilla-Walker, L. M. (2006). 'Peers I can monitor, it's media that really worries me!' parental cognitions as predictors of proactive parental strategy choice. *Journal of Adolescent Research, 21*(1), 56-82.

Pearson, M., Sweeting, H., West, P., Young, R., Gordon, J., & Turner, K. (2006). Adolescent substance use in different social and peer contexts: A social network analysis. *Drugs: Education, Prevention & Policy, 13*(6), 519-536.

Plomin, R., DeFries, J. C., & Loehlin, J. C. (1977). Genotype-environment interaction and correlation in the analysis of human behavior. *Psychological Bulletin, 84*(2), 309-322.

Poelen, E. A. P., Engels, R. C. M. E., Vorst, H. V. D., Scholte, R. H. J., & Vermulst, A. A. (2007). Best friends and alcohol consumption in adolescence: A within-family analysis. *Drug and alcohol dependence, 88*(2), 163-173.

Price, J. M. (1996). In Bukowski W. M., Newcomb A. F. and Hartup W. W. (Eds.), *Friendships of maltreated children and adolescents: Contexts for expressing and modifying relationship history*. New York, NY, US: Cambridge University Press.

Reitz, E., Dekovic, M., Meijer, A. M., & Engels, R. C. M. E. (2006). Longitudinal relations among parenting, best friends, and early adolescent problem behavior: Testing bidirectional effects. *Journal of Early Adolescence, 26*(3), 272-295.

Rhee, S. H., & Waldman, I. D. (2002). Genetic and environmental influences on antisocial behavior: A meta-analysis of twin and adoption studies. *Psychological bulletin, 128*(3), 490-529.

Rose, R. J. & Dick, D. (2004). Gene-environment interplay in adolescent drinking behavior. *Alcohol research and health, 28*(4), 222-229.

Rosenberg, L. A., McHenry, T. B., & Rosenberg, A. M. (1962). Sociometric ratings as predictors of academic performance. *Journal of Applied Psychology, 46*(4), 265-268.

Rowe, D. C., & Osgood, D. W. (1984). Heredity and sociology theories of delinquency: A reconsideration. *American Sociological Review, 49*(4), 526-540.

Schafer, J. L. & Graham, J. W. (2002). Missing data: Our view of the state of the art. *Psychological Methods, 7*(2), 147-177.

Schneider, B. H., Atkinson, L., & Tardif, C. (2001). Child-parent attachment and children's peer relations: A quantitative review. *Developmental Psychology, 37(1),* 86-100.

Silberg, J., Rutter, M., D'Onofrio, B., & Eaves, L. (2003). Genetic and environmental risk factors in adolescent substance use. *Journal of Child Psychology and Psychiatry, 44*(5), 664-676.

Simons-Morton, B., & Chen, R. S. (2006). Over time relationships between early adolescent and peer substance use. *Addictive Behaviors, 31*(7), 1211-1223.

Smith, B. J., Phongsavan, P., Bauman, A. E., Havea, D., & Chey, T. (2007). Comparison of tobacco, alcohol and illegal drug usage among school students in three pacific island societies. *Drug and alcohol dependence, 88*(1), 9-18.

Spitz, E., Moutier, R., Reed, T., Busnel, M. C., Marchaland, C. (1996). Comparative diagnoses of twin zygosity by SSLP variant analysis, questionnaire, and dermatoglyphic analysis. *Behavior genetics, 26*(1), 26-55.

Sussman, S., Dent, C. W., Stacy, A. W., Burciaga, C., Raynor, A., Turner, G. E., Charlin, V., Craig, S., Hansen, W. B., Burton, D., & Flay, B. K., (1990). Peer-group association and adolescent tobacco use. *Journal of abnormal psychology, 99*(4), 349-352.

Thornberry, T. P., Krohn, M. D., Lizotte, A. J., & Chard-Wierschem, D. (1993). The role of juvenile gangs in facilitating delinquent behavior. *Journal of Research in Crime and Delinquency, 30*(1), 55-87.

Tzekina, I., Danthi, K., & Rockmore, D. N. (2007). Evolution of community structure in the world trade web. *The European Physical Journal B - Condensed Matter and Complex Systems, 9*(2), 88-98.

Udry, J. R. (2003). *References, instruments and questionnaires consulted in the development of the add health in-home adolescent interview. in add health user guides.*, 2003 from www.cpc.unc.edu/projects/addhealth/data/using/guides

Urberg, K. A., Cheng, C., & Shyu, S. (1991). Grade changes in peer influence on adolescent cigarette smoking: A comparison of two measures. *Addictive Behaviors, 16*(1), 21-28.

Urberg, K. A., Degirmencioglu, S. M., & Pilgrim, C. (1997). Close friend and group influence on adolescent cigarette smoking and alcohol use. *Developmental psychology, 33*(5), 834-844.

Urberg, K. A., Luo, Q., Pilgrim, C., & Degirmencioglu, S. M. (2003). A two-stage model of peer influence in adolescent substance use: Individual and relationship-specific differences in susceptibility to influence. *Addictive Behaviors, 28*(7), 1243-1256.

Urberg, K. A., Shyu, S., & Liang, J. (1990). Peer influence in adolescent cigarette smoking. *Addictive Behaviors, 15*(3), 247-255.

Walden, B., McGue, M., lacono, W. G., Burt, S. A., & Elkins, I. (2004). Identifying shared environmental contributions to early substance use: The respective roles of peers and parents. *Journal of abnormal psychology, 113*(3), 440-450.

Wechsler, H., Nelson, T. F., Lee, J. E., Seibring, M., Lewis, C., & Keeling, R. P. (2003). Perception and reality: A national evaluation of social norms marketing

interventions to reduce college students' heavy alcohol use. *Journal of Studies on Alcohol, 64,* 484-494.

Young, S., Heptinstall, E., Sonuga-Barke, E. J. S., Chadwick, O., & Taylor, E. (2005). The adolescent outcome of hyperactive girls: Self-report of psychosocial status. *Journal of Child Psychology and Psychiatry, 46*(3), 255-262.

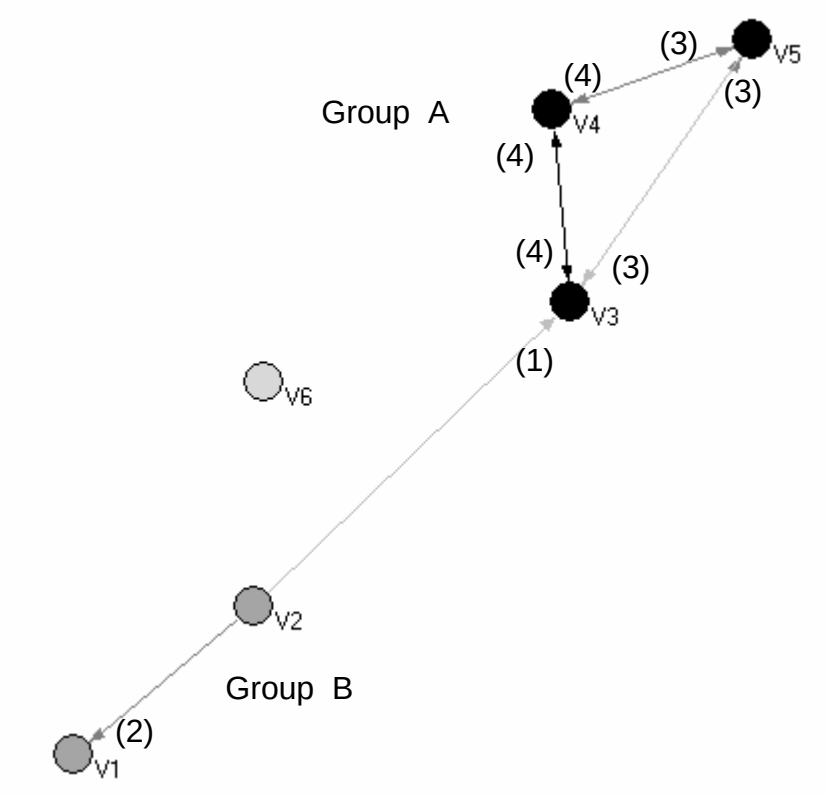
Appendix A

Introduction to Social Networks

Vertices and Arcs. A network is a set of objects, or *vertices,* that are connected by *arcs*, which represent relationships between vertex pairs. In Figure A1, a small network with six vertices is present. A bidirectional arrow indicates a two-way relationship (i.e., in the case of friends, reciprocal friend nominations) while a unidirectional arrow indicates a one-way relationship. These *arcs* are weighted in the all subsequent analyses using the strength of relationship such that the greater the relationship the smaller the distance between two vertices. While limitations of visual presentation requiring two- or three-dimensional representation may not accurately reflect true distances between vertices, these vectors are maintained throughout quantitative analyses that permit n-dimensional representation to identify strengths of relationships (see de Nooy, Mrvar, & Batagelj, 2005 for complete introduction).

Partitioning. Networks can be divided into subnetworks of related vertices based on a number of partitioning devices. There is currently no agreed upon partitioning device for large, dense networks such as those in Add Health. Some algorithms, including components and k-cores have been found to be unhelpful in revealing usable subnetworks within large networks such as the schools in Add Health. As a result, identification of groups within large networks has relied on clustering of common characteristics (Moody, 2001). However, this is inappropriate for the current analysis as grouping based on shared characteristics may create spurious associations between group substance use and adolescent alcohol use.

Figure A1. Example of small social network with six vertices, eight arcs, and two connected islands (minimum = 2, maximum = 4).



The numbers in parentheses are the weights of the arcs. For bidirectional arrows, the number near the head of the arrow represents the value for that arc. That is, v5 nominated v4 with a relationship quality of 4, and v4 nominated v5 with a relationship quality of 3.

Therefore, we use the *islands* algorithm in *Pajek* and create subnetworks within a user-defined minimum and maximum with a level of relatedness, *t*, that is greater than the connections to other linked vertices. For the current study, the value of *t* falls in the range of one to five corresponding to the friendship quality weights. For example, if there were three adolescents whose nominations reflect a weight of five, and do not share

any other nominations with a weight of five, than this would represent a complete island. If however, there were only two adolescents with a weight of five, and two more adolescents shared a weight of four, these adolescents would form an island with $t = 4$. In Figure A1, the small network demonstrates this using a minimum of two and a maximum of four. Group A has three members with $t = 3$ and Group B has two members with $t = 2$. For the main analyses, we defined groups as larger than three and smaller than twenty-five. Although *v2* is connected with *v3,* the relationship quality is one and falls below the *t*-values for both groups. If a minimum group size of four was indicated, neither group A nor Group B would have created a full group independently and these would make up one group with five members and $t = 1$. The vertex, *v6*, shares no connections with other vertices and is therefore not included in a group.

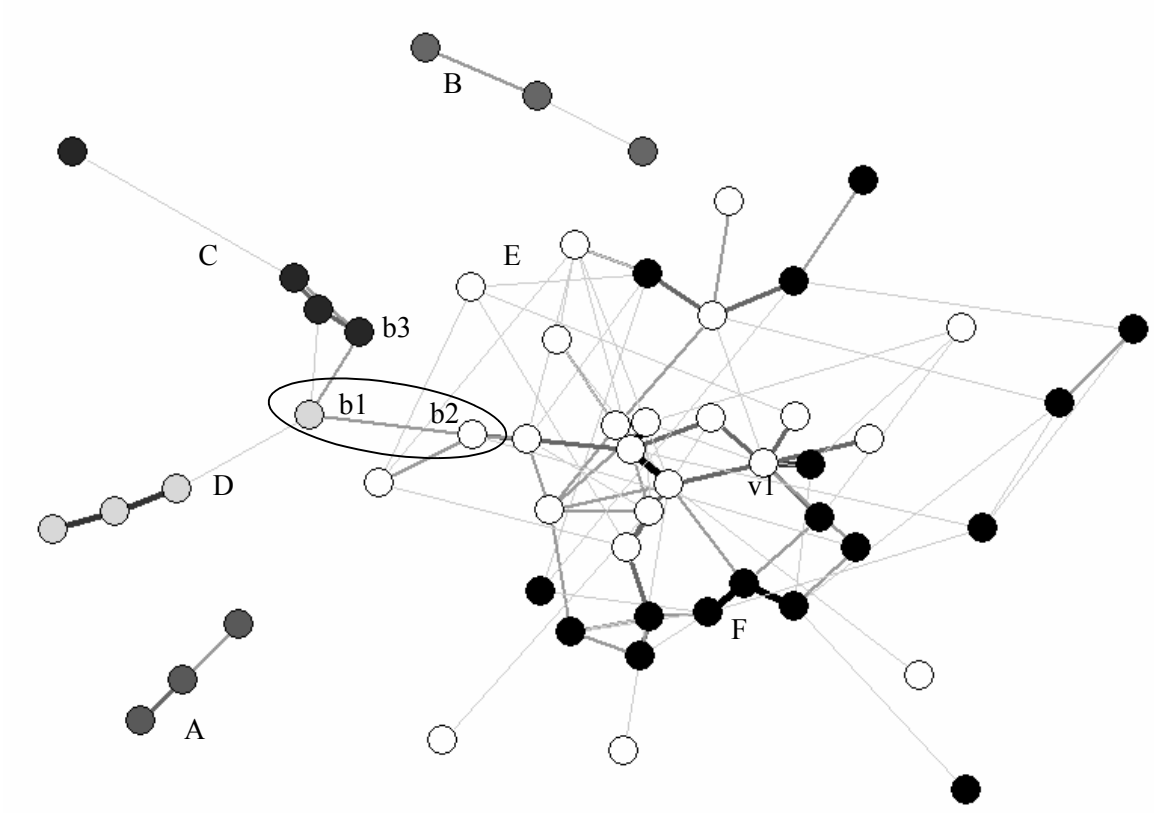
For the current study, a minimum of three and a maximum of 25 were used to identify peer groups. There is no guiding theory as to the selection of a minimum and maximum value. Therefore, a minimum of three was chosen as groups smaller than this reflect dyadic relationships, and 25 was chosen as a maximum because qualitative inspection indicated that smaller maximums resulted in a large number of adolescents falling outside of peer groups and larger maximums resulted in few, loosely connected groups. See Appendix D for evaluation of groups identified in this study and Appendix B for qualitative descriptions of some of these peer groups.

Appendix B

Qualitative Examination of Peer Groups

The richness of information available through examining peer networks becomes evident when we examine a sample of students in greater detail. In Figure B1, a selection of 54 students belonging to six peer groups (A-F) is shown from a school with 205 students and fifteen peer groups. Structural examination reveals that individuals in these groups are clustered, but some are also intertwined (e.g., groups E and F). Size varies between these groups with small groups, like A and B, including only three adolescents each, and larger groups, like E and F including 23 and 17 adolescents, respectively.

Figure B1. A subset of 54 students from six peer groups.

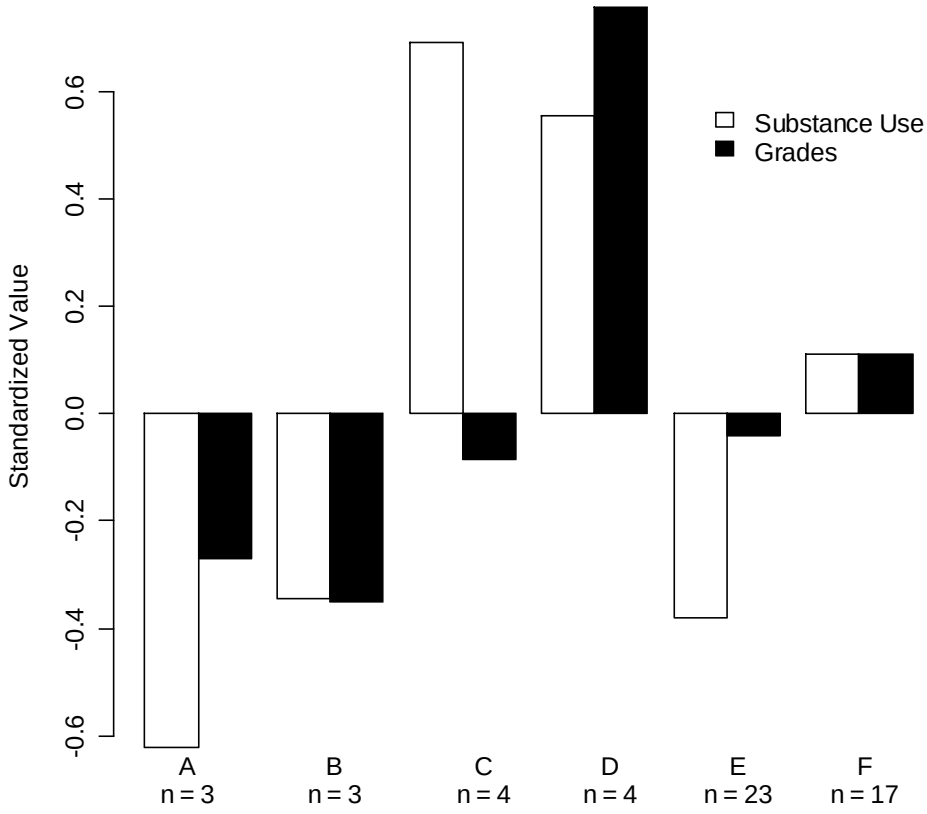


We can also see that certain vertices appear to have special roles. For example, v1 is both a *coordinator,* connecting otherwise unconnected vertices within his own group E, and a *gatekeeper,* connecting vertices in his group that are otherwise unconnected to vertices in group F (Batagelj & Mrvar, 1996). V1 is engaged in a large number of groups and clubs. He is sixteen, in the eighth grade, and drinks occasionally, but does not get drunk or smoke. He is an average student and is involved in the band, choir, soccer and tennis teams, the school newspaper, and the yearbook. His involvement in these activities may facilitate the development of his role as someone who connects individuals in his own peer group and maintains connections with students in other peer groups. Certain relationships may also create bridges between groups that otherwise would remain unconnected. Groups E and F are both composed of eighth grade students, while D is composed of tenth grade students. However, b2, a fifteen year-old, female shares a bidirectional relationship with b1, a seventeen year-old, tenth grade male. We may speculate that b1 and b2 may be in a romantic relationship and serve as gatekeepers connecting otherwise unconnected peer groups. B1 and b3 are also both gatekeepers, connecting groups C and D. B2 is a tenth grade, sixteen-year old, female so there may be an interesting 'dynamic' between b1, b2, and b3 connecting these otherwise disparate peer groups. Of course, this is all speculation, but perhaps romantic relationships create connections between otherwise unrelated adolescents. Such qualitative inspection may fuel future research into peer systems.

We can also examine characteristics of these peer groups more generally to get an idea of the 'type' of groups they represent. Figure B2 shows the average grades and

substance use for each of the groups and Figure B3 shows the average clubs per student in each group.

Figure B2. Average substance use and academic achievement by peer group.

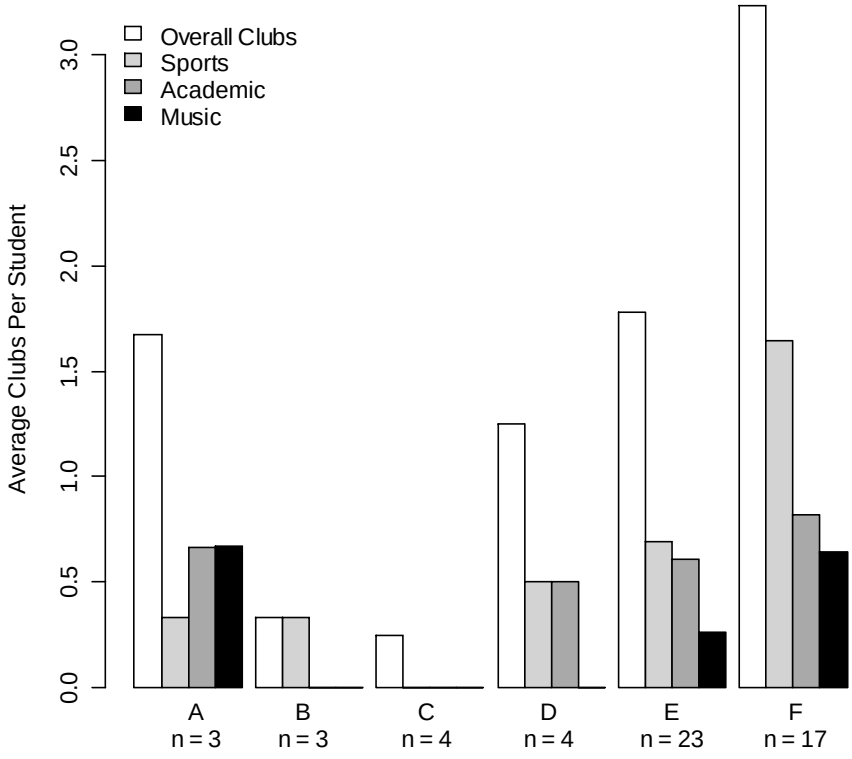


Groups C and D, connected via b1 and b3, both have high levels of substance use, but group C has average grades and is uninvolved in activities and group D has above average grades and has moderate involvement in school activities. Groups E and F, both made up of primarily eighth graders, have average grades. Students in both of these groups are joined primarily by tight connections indicating they are generally social groups of students. The strength of the relationship connecting the original members in the island (before including the influence partition) is the maximum of five indicating a tightly connected group of students and may reflect the popular groups within the eighth

grade class. Group F has average substance use and is highly involved in sports and clubs; group E has below average substance use and is similarly involved in academic and music organization, but less involved in sports. The majority of students in group F are Caucasian (53%, *n* = 9) and female (65%, *n* = 11), while only 26% of students (*n* = 6) in group E are Caucasian and the gender distribution is more even with eleven males and twelve females. The lower relative substance use may reflect the age of these students, as they are the youngest students in this school. The highly social and involved students in groups E and F are contrasted with group A. Students in group A only share loose connections with one another, but all three members are in the Spanish club at their school. Perhaps, this is a group of adolescents that is not particularly social, but has become friends through this club.

While limited conclusions can be made from such qualitative examination, exploring these networks provides a wealth of information by paying tribute to the complex interactions within the peer system. Such examination may lead to productive hypothesis generation regarding how adolescents select and interact with their peers.

Figure B3. Average number of clubs per student by peer group.

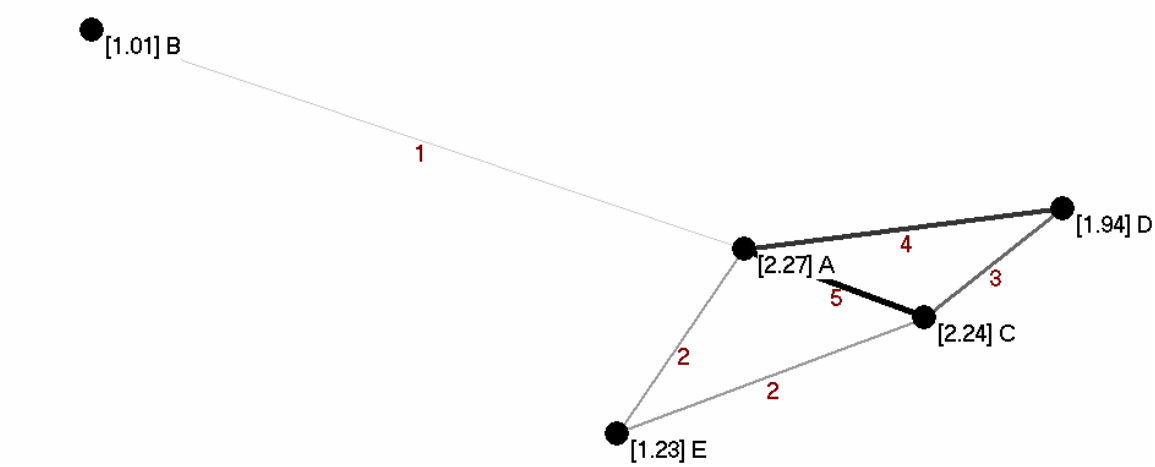


Appendix C

Closeness Centrality

Figure C1 displays a sample network with five vertices. In this hypothetical peer group, the line values reflect the friendship quality with greater friendship quality reflecting greater values. Closeness centrality (values in brackets) is the ratio of the number of vertices in the connected network to the distance of the vertices. In this case, the distance is weighted by the inverse of these values such that closer relationships are related more. For example, closeness centrality for A would be: 5 / (1/2 + 1/5 + 1/4 + 1/1) = 2.27.

Figure C1. Sample of closeness centrality calculations based on friendship quality weights.



Actual values of closeness centrality are typically considerably lower than this example as larger numbers of individuals in the system reduce the relative importance of each individual. Un-weighted centrality estimates can range from zero to one, however, using the friendship quality weights (with a maximum value of ten when two adolescents indicate maximal relationships with one another), centrality can range from zero to ten. While the range in centrality varied from zero to 8.514, only 0.07% of adolescents had centrality greater than 2. The actual distribution of closeness centrality is shown in Figure C2.

Figure C2. Distribution of closeness centrality as weighted by friendship quality.

Note: values greater than two not shown, but are rare (< 0.1%).

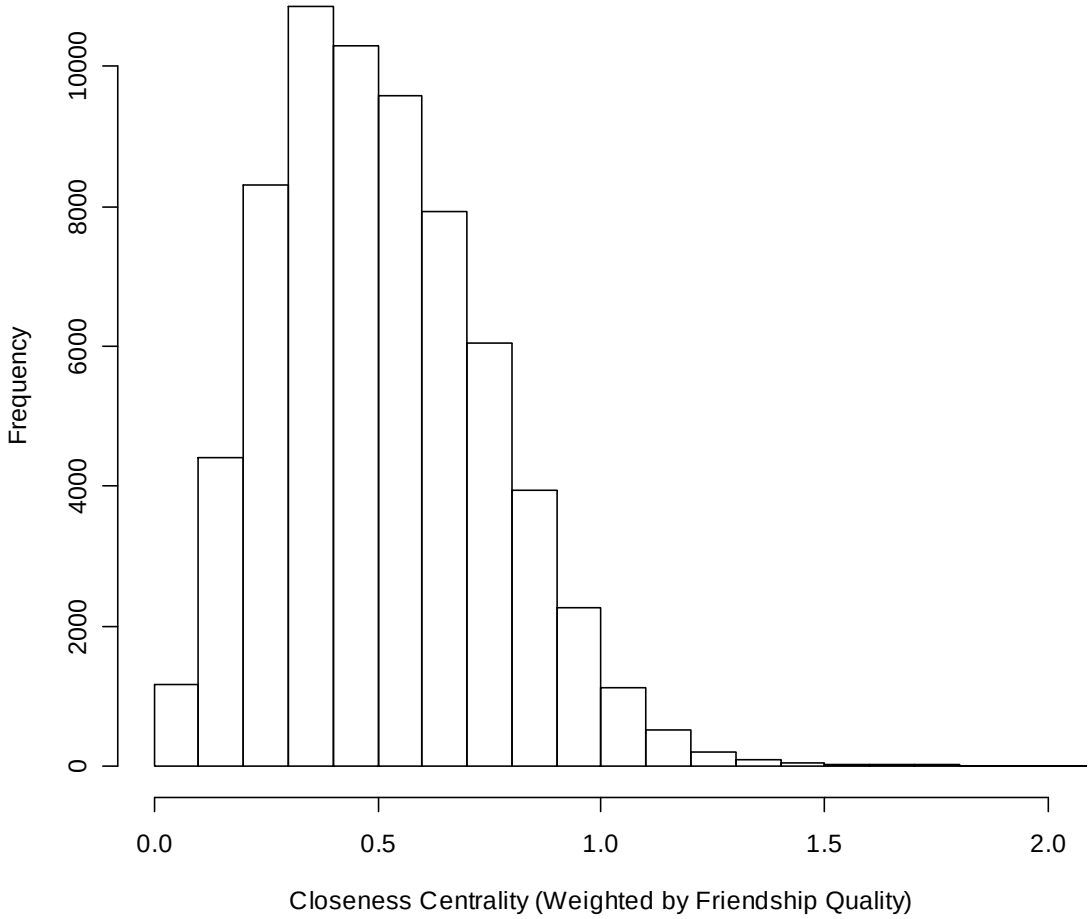
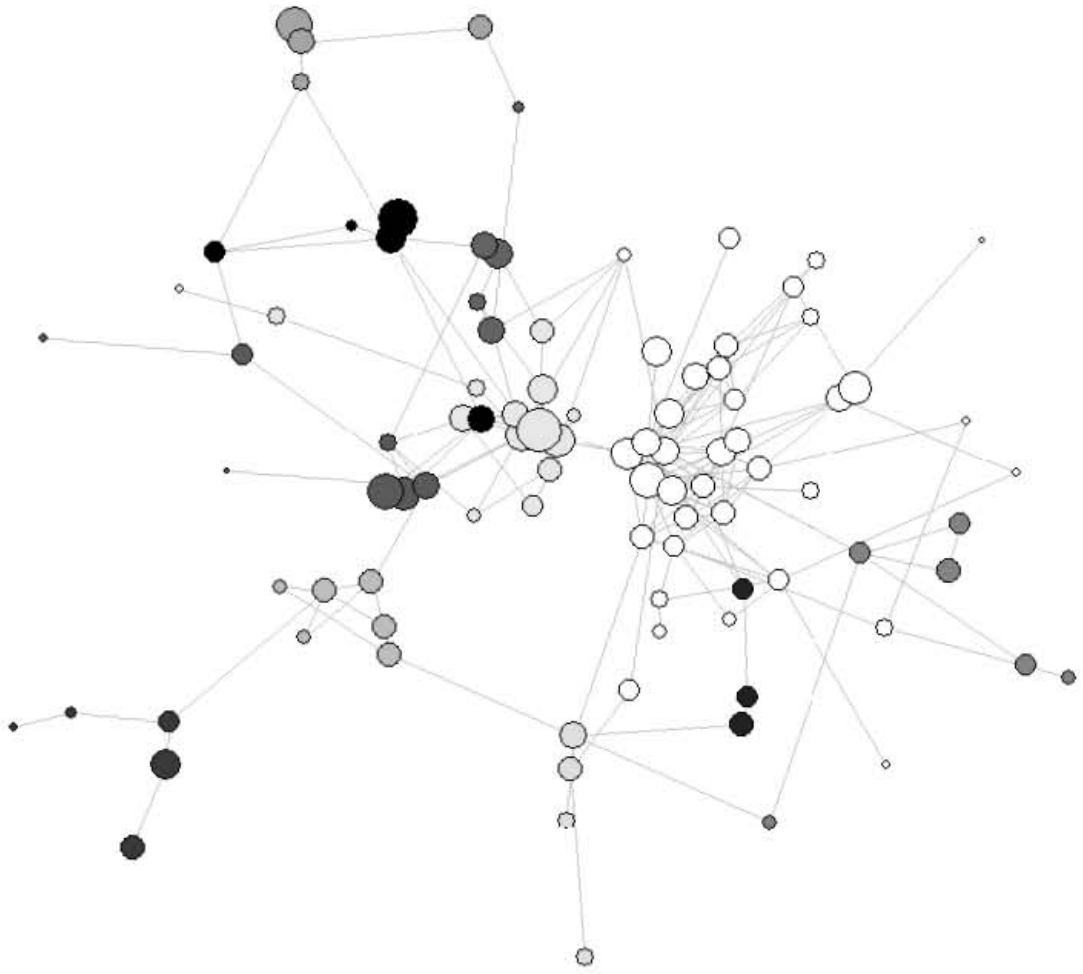


Figure C3 shows 96 students in a school with 11 islands. In this figure, the size of each vertex (representing a student) is scaled to the closeness centrality. That is, larger vertices reflect greater closeness centrality. As demonstrated, students closer to their peers are generally larger demonstrating while students further from their peers are smaller.

Figure C3. Example of social network with vertices weighted by closeness centrality.

Note: The size of a vertex is weighted by the value of closeness centrality.



Appendix D

Evaluation of Peer Groups.

Evaluation of Cohesiveness of Peer Groups. One way to test the extent to which these islands are identifying cohesive groups is to calculate the relative likelihood that an adolescent will nominate someone within their group instead of someone in another group. Calculating this for one school of 71 students demonstrates this. In this school, 65 adolescents belong to an island and six adolescents did not have valid nominations. There are seven islands with between six and eighteen members. There are 4,160 possible nominations in the school (if every adolescent nominated every adolescent in the school) and 640 of these could occur within islands (if every adolescent in a group nominated every other adolescent in the group). In the school, 141 total nominations were made with 105 occurring within the islands and 36 occurring between adolescents in different islands. This results in an odds ratio of 18.994 and log-odds of 2.944 indicating that an adolescent in this school is nearly three times more likely to nominate a friend in his or her group than outside of the group. Another school, with 877 students has 853 students who belong to 47 groups (group sizes ranging from three to 53) had 726,756 possible nominations with 21,724 potentially occurring within islands. There were actually 4,191 nominations with 1,644 of these occurring within islands. The log-odds for this school is 3.117 indicating that an adolescent in this school is over three times as likely to nominate a friend in his or group than outside of the group. Relative likelihood of selecting peers within and outside of peer groups is not provided for every school as these calculations are computationally intensive and evaluating the cohesiveness for a large number of schools, especially when schools have large numbers

of islands, is prohibitive. However, calculations for these two schools do suggest that the islands algorithm is identifying cohesive groups within schools.

Evaluation of Meaningfulness of Peer Groups. Another way researchers have identified groups in networks is to identify groups based on clustering of characteristics (Moody, 2001). However, this technique was not appropriate for the current study as characteristics that may be used to identify groups may also be associated with alcohol use and may create spurious associations between the group substance use and target alcohol use. However, reversing the logic as a means of evaluation provides evidence that the groups identified through structural means (e.g., through their connections with one another) also provide meaningful groupings that do share characteristics. If the islands are identifying meaningful groups of adolescents, the relationship of adolescents to group level characteristics would be stronger than the relationship of adolescents to school level characteristics. For example, the school level substance use accounts for 7.327% of the variance in adolescent substance use (F = 6,750.31, df = 85,372, p < 0 .0001). However, group level substance use accounts for 21.703%, or almost three times, the variance in adolescent substance use (F = 9756.58, df = 85,372, p < 0 .0001). A similar finding emerges with academic grades with group mean level grades accounting for 14.661% of the variance in individual grades (F = 11148.0, df = 85,372, p < 0 .0001) and school mean levels accounting for 9.454% (F = 7850.65 , df = 85,372, p < 0 .0001) and school level only accounting for 1.081% additional variance after including the group level mean in the model. Based both on the cohesiveness of the group and shared characteristics among the members, these groups seem to be relevant and meaningful subsets of the greater network.

Influence Partition. As identification using islands may lead to a number of adolescents not included in a peer group, the peer group was expanded to include the *influence partition* (Batagelj & Mrvar, 1996). For each vertex that is not included in an island, the vertex is placed in the island with which it shares the greatest ties. The adolescents in the expansion group do not necessarily have a lower relationship quality than those in the initial peer group. Some peer groups have low relationship quality and are formed around arcs of value one or two. Alternatively, an adolescent may share a tie of value four with another adolescent, but may not be included in the initial group because there are at least three adolescents sharing relationships valued five. Comparisons of adolescents included in the initial partition to those included through the expansion revealed that there was no substantive difference in the degree to which their substance use was related to the group ($r_{initial} = 0.454$, $n = 57{,}003$; $r_{expansion} = 0.476$, $n = 17{,}698$). While reason for inclusion in the peer group was significantly related to individual substance use ($p < .0001$, $df = 75{,}591$), it does not account for a meaningful proportion of the variance ($R^2 = 0.05\%$). Belonging to the initial partition reflected a small, positive association with centrality ($r = 0.080$, $df = 66{,}946$, $p < .0001$), however, did not predict additional variance in individual substance use over centrality alone ($p = 0.065$, $df = 66{,}727$). Despite these minor differences, we do not consider reason for inclusion in the peer group to be an important difference in the current analyses.

Appendix E

Path Specific Model Fit Comparisons

		Alcohol Use				
		χ^2	*df*	$\Delta\chi^{2a}$	Δdf	*p*
Full Model		1321.166	457			
No *E* Regression		1495.201	466	174.035	9.00	<0.001
Phenotypic Model: All Paths		1537.146	469	215.980	12.00	<0.001
Phenotypic Models: Individual Paths [b]						
Peer Group	I	1390.410	458	69.244	1.00	<0.001
	S1	1338.602	458	17.436	1.00	<0.001
	S2	1366.902	458	45.736	1.00	<0.001
Closeness	I	1336.806	459	15.640	2.00	<0.001
	S1	1338.193	459	17.027	2.00	<0.001
	S2	*1322.801*	*459*	*1.635*	*2.00*	*0.442*
Group x Closeness	I	1382.534	458	61.368	1.00	<0.001
	S1	1334.864	458	13.698	1.00	<0.001
	S2	1362.426	458	41.260	1.00	<0.001
		Alcohol Problems				
		χ^2	*df*	$\Delta\chi^{2a}$	Δdf	*p*
Full Model		1333.574	457			
No *E* Regression		1547.232	466	213.658	9	<0.001
Phenotypic Model: All Paths		1602.482	469	268.908	12	<0.001
Phenotypic Models: Individual Paths [b]						
Peer Group	I	1419.350	458	85.776	1	<0.001
	S1	1351.785	458	18.211	1	<0.001
	S2	1369.399	458	35.825	1	<0.001
Closeness	I	1353.707	459	20.133	2	<0.001
	S1	1350.033	459	16.459	2	<0.001
	S2	*1335.592*	*459*	*2.018*	*2*	*0.365*
Group x Closeness	I	1405.591	458	72.017	1	<0.001
	S1	1347.722	458	14.148	1	<0.001
	S2	1364.162	458	30.588	1	<0.001

[a] Compared to Full Model

[b] Peer group and the interaction term do not reflect shared environmental variance (C), so the phenotypic models are defined by setting the regression coefficents on A and E equal (a = e).

Appendix F

Multivariate ACE Fit Estimates for Alcohol Problems

Variance Components [a]			***A***		***C***		***E***	
			Est.	*% Total*	*Est.*	*% Total*	*Est.*	*% Total*
	Group		0.859	80.96%	--		0.202	19.04%
	Centrality		0.194	18.44%	0.609	57.89%	0.249	23.67%
	Group x Centrality		14.798	81.76%	--		3.301	18.24%
Residual Variance Components [a]								
	I		0.136	25.86%	0.087	16.54%	0.303	57.60%
	S1		0.068	70.10%	--		0.012	12.37%
	S2		0.092	64.79%	--		0.050	35.21%
Regression Coefficients		***Phenotypic*** [b]	***A***		***C***		***E***	
Group	I	0.177 (0.01)	0.097	(0.02)	--		0.625	(0.04)
	S1	0.014 (0.01)	0.052	(0.01)	--		-0.177	(0.04)
	S2	0.061 (0.00)	*0.024*	(0.02)	--		0.389	(0.06)
Centrality	I	0.120 (0.01)	0.575	(0.23)	*0.035*	(0.03)	*0.035*	(0.08)
	S1	0.014 (0.01)	0.173	(0.07)	*0.013*	(0.02)	*-0.110*	(0.05)
	S2	*0.002* (0.01)	*-0.170*	(0.14)	*0.024*	(0.02)	*0.074*	(0.06)
Group x Centrality	I	0.042 (0.00)	0.025	(0.00)	--		0.144	(0.01)
	S1	0.004 (0.00)	0.012	(0.00)	--		-0.037	(0.01)
	S2	0.014 (0.00)	0.006	(0.00)	--		0.088	(0.02)

Effect sizes owing to peer variables		***Model Fit***	
Intercept	16.20%	CFI	0.974
Early Slope	2.14%	TLI	0.973
Late Slope	6.50%	RMSEA	0.051

Standard errors for estimates are in parantheses.

Parameters not significantly different from zero are in italics ($p > 0.05$)

[a] Negative variance and residual variance estimates were set to zero.

[b] Peer group and the interaction term do not have reflect shared environmental variance (C), so the phenotypic models are defined by setting the regression coefficents on A and E equal (a = e).