J Youth Adolescence (2018) 47:349–368
DOI 10.1007/s10964-017-0703-7

EMPIRICAL RESEARCH

The Developmental Unfolding of Sibling Influences on Alcohol Use over Time

Diana R. Samek[1] · **Rebecca J. Goodman**[1] · **Lucy Riley**[1] · **Matt McGue**[2] · **William G. Iacono**[2]

Received: 6 March 2017 / Accepted: 5 June 2017 / Published online: 13 June 2017

Abstract Research has long demonstrated that siblings are similar in their alcohol use, however much of this work relies on cross-sectional samples or samples of adolescents alone and/or exclusive focus on older siblings' impact on younger siblings. Using a three time-point design from early adolescence to early adulthood (*M* ages = 14.9, 18.3, and 22.4 years, respectively; 55% female; 54% European ancestry, 38% Asian ancestry), we evaluated the prospective older and younger sibling influences on alcohol use across time (*N* = 613 sibling pairs; 35% sisters, 26% brothers, 39% mixed-gender; average age difference = 2.34 years; 34% full-biological siblings, 46% genetically-unrelated adopted siblings, 20% pairs where one child was the biological offspring of parents and the other was adopted). The results from both the traditional and random-intercept cross-lagged panel analyses showed that older siblings' alcohol use predicted younger siblings' alcohol use across each developmental transition and across a variety of sibling contexts (e.g., gender composition, age difference, genetic relatedness). On the other hand, younger siblings' alcohol use only predicted older siblings' alcohol use when siblings were close in age (1.5 years or less) and under conditions of high sibling companionship. These results add to a body of literature illustrating how both older and younger siblings are important socializing agents of adolescent and early adult alcohol use. Assessing or co-treating siblings for alcohol problems may be an important add-on to existing adolescent and early adult alcohol prevention and intervention programs.

Keywords Alcohol use · Adolescence · Deviancy training · Siblings · Transitions · Young adulthood

Introduction

Research has consistently demonstrated that siblings are similar in their adolescent substance use (D'Amico and Fromme 1997; Fagan and Najman 2005; Rowe and Gulley 1992) and that this similarity is largely influenced by shared environmental rather than genetic influences (for a review, see Hopfer et al. 2003). Recent research attempting to identify the environmental mechanisms linking older sibling and younger sibling substance use has shown that older siblings' facilitation of use (i.e., helping them get alcohol; McGue and Iacono 2009; Samek et al. 2015a), as well as sibling co-use (i.e., using alcohol together; Whiteman et al. 2016), appear to be important mechanisms that explain this link. Modeling of sibling behavior and sharing the same friends have also been shown to explain linkages of older and younger sibling substance use (Rowe and Gulley 1992; Whiteman et al. 2013). This body of research is consistent with a deviance training theory of adolescent substance use (Rende et al. 2005; Slomkowski et al. 2001) and suggests older siblings may be important socializing agents of their younger siblings' adolescent substance use. Indeed, siblings may be more important socializing agents than parents when it comes to adolescent alcohol use, as earlier research has shown little impact of parents' alcohol use on their adolescents' alcohol use—and that the impact of parents'

✉ Diana R. Samek
di.samek@gmail.com

[1] Department of Human Development and Family Studies, Auburn University, 203 Spidle Hall, Auburn, AL 36849, USA

[2] Department of Psychology, University of Minnesota, N-218 Elt H, 75 East River Road, Minneapolis-St. Paul, MN 55455, USA

alcohol use on their adolescents' alcohol use occurs predominately through shared genetic rather than environmental pathways (McGue et al. 1996).

Although research has progressed to identify the environmental mechanisms that link older and younger siblings' alcohol and substance use, a critical gap in the literature is that much of the prior research has been focused on cross-sectional samples of adolescents alone (e.g., Rowe and Gulley 1992; Samek et al. 2015a; Whiteman et al. 2013, 2016). Thus, it is not clear how well these sibling influences may hold up through early adulthood when substance use rates tend to peak (i.e., at ages 18–25; Substance Use and Mental Health Services Administration [SAMHSA] 2014). Conger and Little (2010) also point out that sibling dynamics may change in interesting and important ways in early adulthood and there is a considerable gap in the research on siblings for this time period. For example, having a close and supportive relationship with a sibling may be an important protective factor in the transition to college, as depression and suicidal ideation also increase markedly at this time (Garlow et al. 2008). On the other hand, having a close relationship with a sibling who engages in heavy drinking might also prove to be a risk factor in the transition to college, as heavy drinking and substance use increase rapidly in the first year of college (White et al. 2005) and sibling facilitation, modeling, or co-use may escalate this behavior.

It also remains critical to evaluate the direction of effects from older to younger and younger to older sibling influences, as the majority of research has evaluated only older siblings' impact on younger siblings' substance use (e.g., Rowe and Gulley 1992; Samek and Rueter 2011; Samek et al. 2015a; Whiteman et al. 2013, 2016). It remains unclear to what extent younger siblings also socialize their older siblings' alcohol use and whether this depends on the developmental context evaluated. To build on prior research, the specific aims of this study are to evaluate the prospective associations between older and younger sibling alcohol use across three time points from early adolescence (ages 13–16) to late adolescence (ages 17–19) and early adulthood (ages 21–23). We also evaluate moderation by key sibling contexts, including sibling gender composition, age difference, family type (adoptive vs. nonadoptive), shared vs. mixed ethnicity (through the use of our adoption design), and self- and sibling-reported sibling relationship companionship.

Theoretical Frameworks

Deviancy training theory proposes that deviant or antisocial siblings may form coalitions with one another within the family, which in turn will promote further deviancy within and outside family interactions (Bullock and Dishion 2002). This is also known as the siblings as "partners in crime" theory (Slomkowski et al. 2001) and suggests that siblings may commit delinquent acts (such as underage drinking) particularly if they have positive and more "peer-like" sibling relationships rather than coercive or conflictual sibling relationships. In line with this theory, we might expect older siblings to have a particularly important impact on their younger siblings when the older sibling is immersed in a network of relatively older peers who may be more likely to drink, as the rates of drinking increases with age (SAMHSA 2014). Thus, simply having an older sibling who has drunk alcohol may lay the groundwork for deviancy training of the younger sibling at an earlier age compared to if they did not have an older sibling. On the other hand, as younger siblings age and become more immersed in their own peer networks of age-normative drinking, they may have an important effect on older siblings' drinking, particularly if older siblings would otherwise "mature out" of heavy drinking by later young adulthood (e.g., see Bachman et al. 2002).

Other theoretical frameworks that are important to studying sibling relationships include attachment or social bonding explanations (Bowlby 1969; Hirschi 1969). Research has consistently shown that having a close, supportive, or loving relationship with a sibling is associated with a reduced likelihood of a variety of problematic outcomes, including adolescent substance use (Samek and Rueter 2011) and externalizing problems (Branje et al. 2004; Criss and Shaw 2005), as well as internalizing problems (Whiteman et al. 2015) and peer incompetence (Kim et al. 2007). In a meta-analysis of 34 studies, Buist et al. (2013) showed that more sibling conflict and less sibling warmth were significantly associated with fewer internalizing and externalizing problems. Further, Buist et al. showed that effect sizes (r) for sibling conflict were generally stronger than warmth in relation to both internalizing problems (.27 vs. −.12) and externalizing problems (.28 vs. −.14).

A third framework for studying sibling influences on adolescent alcohol use considers shared genetic risk, as alcohol and substance use disorders are largely influenced by genetic factors. For example, a recent meta-analysis of 17 twin and adoption studies showed that additive genetic influences accounted for approximately half the total variation of alcohol use disorder in adulthood (Verhulst et al. 2014). What is most striking in this literature is that even though adult substance use disorders are strongly influenced by genetics, initiation of alcohol and substance use in adolescence is much more strongly influenced by shared environmental rather than genetic influences (for a review, see Hopfer et al. 2003). For example, McGue and colleagues (1996) evaluated the extent to which the association between parent and adolescent alcohol use was explained

by predominately genetic or environmental influences by comparing parent-adolescent correlations in adoptive vs. non-adoptive families. The results were striking in that any association between parent drinking and adolescent drinking was significant (and moderate in magnitude) but only for parents and their biological offspring and was essentially zero for parents and their adopted children. On the other hand, the association between sibling and adolescent alcohol use were significant for both full-biological siblings (who share half their segregating DNA) and adopted siblings (who shared none of their segregating DNA). These results suggest any resemblance between parent and adolescent drinking is likely entirely explained by shared genetics, whereas any resemblance between siblings' adolescent drinking is principally (but not solely) explained by shared environmental effects.

Variation in Sibling Context

When studying sibling relationships, it is important to take several aspects of sibling context into account, including how close they are in age or if they are the same or mixed gender (see Conger and Little 2010). Several studies have shown that siblings tend to be more similar in their substance use when they are closer in age (Samek et al. 2015a; Trim et al. 2006), perhaps because they are more likely to identify with one another, model each other's substance use behavior, and/or share similar peer and friend groups. There is mixed evidence on whether siblings are more similar in their substance use if they are the same gender, with some research showing more similarity (Boyle et al. 2001; Trim et al. 2006; Rowe and Gulley 1992) and more recent research showing no differences across sibling gender composition (Samek and Rueter 2011; Whiteman et al. 2016).

Although prior research has evaluated for moderation by a number of sibling contexts, and has shown that positive relationships within sibling pairs are associated with a reduction in the likelihood of substance use and other problematic outcomes (as reviewed above), less research has evaluated how perceptions of sibling relationship closeness or sibling relationship quality may moderate associations between older and younger sibling alcohol use. Recent studies have shown close sibling relationships can act as either a protective effect or a risk effect, and that largely depends on sibling gender (Samek and Rueter 2011; Samek et al. 2015b; Slomkowski et al. 2001; Rowe and Gulley 1992). Several studies have now shown that having a close relationship among *sisters* reduces the likelihood of later adolescent substance use—however having a close relationship among *brothers* increases the risk of later adolescent substance use (Samek et al. 2015b; Slomkowski et al. 2001). These findings have often been interpreted through competing developmental processes – deviancy training or social contagion processes are used to describe why it appears to be risky to have a close relationship to an older brother and attachment or social bonding perspectives are used to describe why it is protective to have a close relationship with sisters (Samek et al. 2015b; Slomkowski et al. 2001).

Although this research illustrates some important differences in gender socialization by older siblings, less research has examined the interaction between sibling relationship quality *and* older sibling substance use as they relate to younger sibling substance use over time. In fact, we know of no research study that has examined the developmental unfolding of the interactions between older sibling alcohol use and sibling relationship closeness as they relate to younger sibling alcohol use in a multiple time-point, longitudinal analysis. Prior research by Rowe and Gulley (1992) showed siblings were more similar in their delinquency if they had warmer relationships or shared more friends; however, this study relied on a cross-sectional sample. Although Slomkowski et al.'s (2001) sample was longitudinal, only the impact of older sibling delinquency on younger sibling delinquency was evaluated prospectively; thus, it is unclear how younger siblings may also impact their older sibling, or how these results may vary beyond the early adolescent time period evaluated (ages 11 to 14). Samek et al.'s (2015b) study evaluated change from middle to late adolescence (from ages 15 to 18), but did not evaluate potential differences in birth order (i.e., older to younger vs. younger to older sibling influences). The present study adds to this body of knowledge by teasing out these effects through prospective analyses spanning early adolescence to early adulthood (when alcohol use peaks; SAMHSA 2014), and by separately evaluating older to younger and younger to older sibling influences on alcohol use.

Current Study

This study builds on prior research using mostly cross-sectional designs to evaluate the prospective associations between older and younger siblings' alcohol use from early adolescence into early adulthood. Several research questions and hypotheses were tested to replicate and extend the body of research on sibling influences of adolescent alcohol use. We first examined whether the prospective associations between older siblings' alcohol use on younger siblings' subsequent alcohol use were generally stronger than the prospective associations between younger siblings' alcohol use on older siblings' subsequent alcohol use. As we have a three-time point design, we also evaluated whether this varied as a function of the developmental time period

examined (e.g., early to late adolescence vs. late adolescence to early adulthood). In line with a deviancy training hypothesis (Patterson 1984; Rowe and Gulley 1992; Slomkowski et al. 2001), and because older adolescents tend to use more alcohol than younger adolescents (SAMHSA 2014), we expected older siblings' alcohol use would significantly predict younger siblings' subsequent alcohol use. We expected that older to younger sibling influences would be particularly strong in early adolescence relative to later adolescence or early adulthood, as several studies have demonstrated children and young adolescents tend to be more malleable or sensitive to environmental context compared to later on in adulthood (Kendler et al. 2011; Samek et al. 2017). On the other hand, by early adulthood, younger siblings may be drinking just as much or *more* than their older siblings, thus it is possible we may find significant prospective associations between younger siblings' alcohol use and older siblings' alcohol use at this time.

Second, we examined whether the prospective associations between older and younger siblings' alcohol use were moderated by key aspects of sibling context. Based on earlier research demonstrating the importance of accounting for variation in several sibling contexts (e.g., Samek et al. 2015b; Slomkowski et al. 2001), we evaluated whether older to younger or younger to older sibling influences were moderated by sibling gender composition, age difference, family type (e.g., adoptive vs. nonadoptive), shared ethnicity, and sibling relationship companionship (measured in terms of how much they hang out and have fun together). Understanding whether each of these sibling contexts moderate the associations between older and younger siblings' alcohol use over time is important for purposes of generalization as well as theory building. As discussed by Samek and Rueter (2011) and Whiteman et al. (2011), a social learning perspective (Bandura 1969) proposes that siblings may be more likely to model one another's behavior if they identify with one another, which may be more likely if they are the same vs. mixed gender, if they are close in age vs. further apart, if both are adopted or are the biological offspring of their parents vs. one adopted and one is the biological offspring of their parents, if they share the same ethnicity vs. not, as well as if they spend more time together (residing in the same home vs. different homes) or generally have "close" relationships (e.g., usually spending time and having fun together vs. rarely). Finally, we evaluated whether sibling gender composition and sibling companionship interact to predict subsequent older and younger siblings' alcohol use. Based on earlier research demonstrating important differences of sibling companionship and closeness by gender (Samek et al. 2015b; Slomkowski et al. 2001), we expected that older and younger brothers' alcohol use would more strongly predict one another's alcohol use when the brother pair reports high levels of companionship but a similar moderation effect would not be observed among sisters.

Methods

Participants

The Sibling Interaction and Behavior Study (SIBS) was used to address these aims. SIBS has been described extensively in prior publications (McGue et al. 2007; Samek et al. 2014), thus is only briefly described here. Three types of families participated: families with two adopted children ($n = 285$), families with two biological offspring ($n = 208$; siblings were full biological siblings), and families with one adopted and one biological child ($n = 124$). All siblings in these families were within 5 years of age (average age difference = 2.4 years, SD = .85). Adoptive families were recruited through three large adoption agencies and all adopted children were placed in the adoptive home prior to age 2 ($M_{age} = 4.7$ months, SD = 3.4 months, 96% were placed prior to 1 year of age). Families with biologically related children were ascertained through publicly available birth certificates and were recruited to match the adoptive sample in terms of age and sex.

After the intake assessment, four families were deemed ineligible (due to child developmental delay, death, or because the adopted children were genetically related), leaving a total of 613 eligible families for the present analyses. Here, we use data from all available assessments, including the intake assessment (M age of adolescents = 14.9 years, SD = 1.92), as well as the two follow-up assessments (FU1 M age = 18.3, SD = 2.1, 94% retention; FU2 M age = 22.4, SD = 1.9; 92% retention). Demographics are described in more detail in Table 1. Twenty-one percent of the adopted sample were adolescents of European ancestry, 67% were of Asian ancestry (from primarily international adoptees), and 12% had other ethnic minority ancestry. The respective ethnic proportions for the non-adopted sample were 96, <1%, and <4%. These rates were consistent with state demographics for adoptive and non-adoptive families at the time of assessment (for a detailed overview, see McGue et al. 2007).

Procedures

Siblings and their parents were invited to the lab for a half-day visit at the baseline assessment (Time 1). Written informed consent was obtained from all individual participants included in the study (parent consent and child assent for children <18 years of age). Participating family members completed separate diagnostic interviews (with

Table 1 Descriptive statistics of study variables ($N = 613$ sibling pairs)

	M	SD	Range	% Valid data
Older sibling				
T1 Age	16.09	1.48	12.91–20.97	100%
T2 Age	19.44	1.70	15.96–25.44	94%
T3 Age	23.53	1.42	20.48–28.33	93%
T1 Alcohol frequency	.68	.99	0–4	89%
T2 Alcohol frequency	1.79	1.27	0–5	94%
T3 Alcohol frequency	2.51	1.11	0–5	93%
T1 Alcohol quantity	1.71	2.71	0–9	89%
T2 Alcohol quantity	4.41	3.10	0–9	89%
T3 Alcohol quantity	4.36	2.25	0–9	93%
Younger sibling				
T1 Age	13.76	1.57	10.73–19.41	100%
T2 Age	17.07	1.77	13.67–24.17	95%
T3 Age	21.16	1.43	19.00–26.60	91%
T1 Alcohol frequency	.23	.64	0–5	90%
T2 Alcohol frequency	1.05	1.16	0–5	92%
T3 Alcohol frequency	2.13	1.19	0–5	91%
T1 Alcohol quantity	.64	1.88	0–9	90%
T2 Alcohol quantity	3.14	3.32	0–9	86%
T3 Alcohol quantity	4.35	2.71	0–9	91%
Sibling contexts				
Age difference	2.34	.89	1–5	100%
T1 Sibling companionship	8.81	2.31	3–15	100%
T2 Sibling companionship	8.11	2.50	3–15	96%
Groupings for Moderation Analyses	***n***	**% of total sample**	**–**	**% Valid data**
Sibling gender composition				100%
Sisters	215	35%		
Brothers	157	26%		
Mixed gender	241	39%		
Sibling age difference				100%
<1.5 years	98	16%		
1.5–2 years	149	24%		
2+ years	366	60%		
Family type				100%
Both siblings adopted	284	46%		
Full biological siblings	206	34%		
1 Sibling adopted, 1 sibling biological offspring of parents	123	20%		
Shared ethnicity				100%
Same ethnicity	488	80%		
Mixed ethnicity	125	20%		
Sibling co-residence				
Co-residence at T2	387	63%		87.4%
Co-residence at T3	76	12%		92.8%
Sibling companionship at T1				99.5%
Low (25th percentile or less)	160	26%		

Table 1 continued

Groupings for Moderation Analyses	*n*	% of total sample	% Valid data
Average (26th–74th percentile)	283	46%	
High (75th percentile or more)	167	27%	
Sibling companionship at T2			95.9%
Low (25th percentile or less)	174	28%	
Average (26th–74th percentile)	247	40%	
High (75th percentile or more)	167	27%	
Sibling gender × T1 sibling companionship			99.5
Brothers, low companionship	30	5%	
Brothers, middle companionship	79	13%	
Brothers, high companionship	45	7%	
Sisters, low companionship	44	7%	
Sisters, middle companionship	90	15%	
Sisters, high companionship	81	13%	
Mixed gender, low companionship	86	14%	
Mixed gender, middle companionship	114	19%	
Mixed gender, high companionship	41	7%	
Sibling gender × T2 sibling companionship			95.9%
Brothers, low companionship	36	6%	
Brothers, middle companionship	71	11%	
Brothers, high companionship	40	7%	
Sisters, low companionship	45	7%	
Sisters, middle companionship	79	13%	
Sisters, high companionship	84	13%	
Mixed gender, low companionship	93	15%	
Mixed gender, middle companionship	97	16%	
Mixed gender, high companionship	43	7%	

Note: Age at T1-T3 refers to age in years. Sibling companionship was averaged across older and younger sibling reports (T1: $r = .53$, $p < .001$; T2: $r = .63$, $p < .001$). % Valid data refers to the percentage of non-missing data for each variable at each time point. Percentages of sub-groups (e.g., sibling companionship at Time 1) refer to the percentage of those in that group relative to the entire sample ($N = 613$ sibling pairs). Alcohol frequency responses ranged from 0 = *Never* to 5 = *Every day or nearly every day*. Alcohol quantity responses ranged from 0 = *never* to 9 = *10+ drinks* each time alcohol was consumed.

T1 Time 1, *T2* Time 2, *T3* Time 3

separate interviewers), as well as computerized assessments and other self-reported questionnaires. The same procedure was completed at the first follow-up assessment (Time 2); however, only one parent (usually the mother) came to the lab with both children. In a minority of cases where it was impossible to schedule an in-lab visit, phone interviews were used (14% of total sample). At the second follow-up assessment (Time 3), phone interviews were conducted with all of the participating siblings.

Measures

Alcohol use

Measures included older and younger sibling reported alcohol frequency (ranging from 0 = *Never* to 5 = *Every day or nearly every day*) and quantity (ranging from 0 = *Never* to 9 = *10+ drinks* each time alcohol was consumed) at each time point. Alcohol frequency and quantity variables were averaged to compute the final alcohol use variable at each time point (correlations between the two drinking measures ranged from .52 to .87 across older and younger siblings and time; $ps < .001$).

Sibling contexts

Demographic variables (age, gender, race/ethnicity) of siblings were used to calculate variables denoting several sibling contexts, including sibling age difference, gender composition, family type, shared ethnicity, and sibling co-residence (details shown in Table 1).

Demographics of siblings were reported by parents at the baseline assessment. Sibling gender composition was coded into three groups, sisters ($n = 215$ sibling dyads, 35% of sample), brothers ($n = 157$ sibling dyads, 26% of sample), or mixed gendered ($n = 241$ sibling dyads, 39% of sample). The mean sibling age difference was 2.34 years (SD = .89), and ranged from .04 to 4.93 years. Following earlier work using the SIBS sample (Samek and Rueter 2011; Samek et al. 2015a, b), siblings were grouped by whether they were 1.5 years of age apart or less ($n = 98$ sibling dyads, 16% of sample), 1.5–2 years of age apart ($n = 149$ sibling dyads, 24% of sample), and greater than 2 years of age apart ($n = 366$, 60% of sample) for the multiple group moderation analyses (described in the Analysis Plan). Family type indicates whether siblings were (1) both adopted and not genetically related to one another ($n = 284$, 46% of sample), (2) both biological offspring of parents and therefore, full-biological siblings ($n = 206$, 34% of sample), and (3) where one sibling was adopted and the other was the biological offspring of parents ($n = 123$, 20% of sample). Sibling shared ethnicity was coded such that they either had the same ethnicity ($n = 488$, 80% of sample) or mixed ethnicity ($n = 125$, 20% of sample).

Finally, we analyzed sibling co-residence as a moderator as it may be that siblings are more likely to impact one another if they reside in the same home. At Time 1, all siblings lived in the same residence at least half of the year; this was assessed as part of the eligibility interview (no additional information was collected on number of weeks they lived together per year). At Time 2, one parent (usually the mother) completed a demographic interview prior to the visit and answered an item "number of weeks older and younger sibling lived together in the last year;" they lived together an average of 38.4 weeks in the last year (SD = 18.5). If siblings lived together at least half of the year, they were coded as co-residing ($n = 387$ pairs, 63% of total sample). At Time 3, this was assessed via a semi-structured Social Adjustment Interview: "Do you currently live with [the sibling who has participated in this study with you]?" ($n = 76$ pairs; 12.4% of total sample).

Sibling companionship The Sibling Relationship Questionnaire (Furman and Buhrmester 1985) was used to assess sibling companionship (3 items, e.g., "How much free time do you and this sibling spend together?"); each item was answered on a scale of 1 (*hardly at all*) to 5 (*EXTREMELY much*). Sibling companionship was measured at Times 1 and 2 but not Time 3; αs ranged from .86 to .87 across time. For the moderation analyses, older and younger sibling reports were averaged at each assessment (*r*s ranged from .53 to .63 across time, *p*s < .001) and subsequently coded into three groups, where 1 represented lower than average sibling companionship (score was at the 25th percentile or less), 2 represented average companionship (score was between 26th and 74th percentile), and 3 representing higher than average companionship (score was at the 75th percentile or higher).

Sibling gender composition × sibling companionship Moderation of sibling gender composition by sibling companionship was tested by recoding for all possible pairs. There were 9 total groupings: (1) sisters, low companionship ($n = 44$ at Time 1; $n = 45$ at Time 2), (2) sisters, average companionship ($n = 90$ at Time 1; $n = 79$ at Time 2), (3) sisters, high companionship ($n = 81$ at Time 1; $n = 84$ at Time 2), (4) brothers, low companionship ($n = 30$ at Time 1; $n = 36$ at Time 2), (5) brothers, average companionship ($n = 79$ at Time 1; $n = 71$ at Time 2), (6) brothers, high companionship ($n = 45$ at Time 1; $n = 40$ at Time 2), (7) mixed gender pairs, low companionship ($n = 86$ at Time 1; $n = 93$ at Time 2), (8) mixed gender pairs, average companionship ($n = 114$ at Time 1; $n = 97$ at Time 2) and (9) mixed gender pairs, high companionship ($n = 41$ at Time 1; $n = 43$ at Time 2). If neither sibling reported on sibling companionship, the gender composition ×sibling companionship variable was coded as missing ($n = 3$ pairs at Time 1, $n = 45$ pairs at Time 2).

Covariates

We also analyzed whether results were impacted by the inclusion of several covariates, including baseline mother- and father-child relationship quality, mother and father frequency of alcohol use, antisocial peer affiliation, and sibling conflict.

Mother- and father-child relationship quality Adolescent-reported relationship quality with parents was measured using the Parental Environment Questionnaire (Elkins et al. 1997). Adolescents rated statements concerning their relationship with parents on a scale of 1 (*Definitely true*) to 4 (*Definitely false*). Four scales were used (parent-child conflict, involvement, positive regard of parent by adolescent, and positive regard of adolescent by parent), with items coded such that a higher score indicates better relationship quality (αs ranged from .78 to .89 for each scale). These four scales were averaged to compute the final mother- and father-child relationship quality variables; correlations among the four scales ranged from .64 to .77 for mother-child relationship quality and .62 to .74 for father-child relationship quality.

Mother and father frequency of alcohol use The Substance Abuse Module was used to assess frequency of parent-reported alcohol use with the single item: "In the past

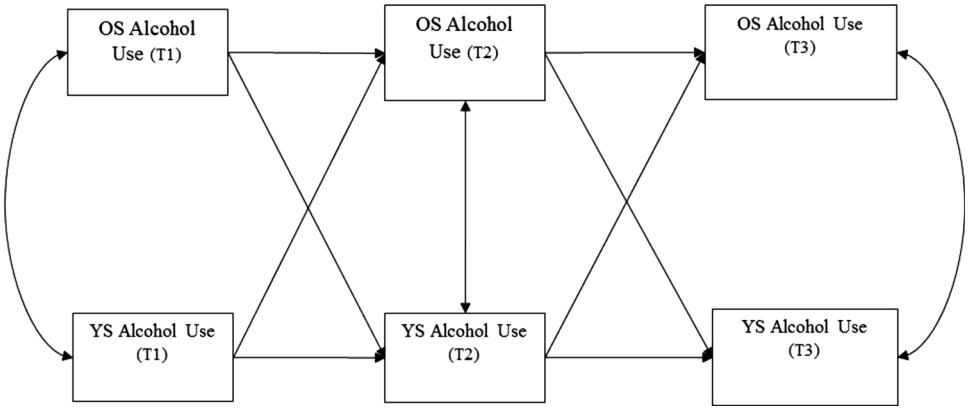

Fig. 1 Conceptual model of the developmental unfolding of sibling influences on alcohol use over Time. This figure shows the cross-lagged model analyzing sibling influences on alcohol use over time. *OS* older sibling, *YS* younger sibling, *T1* Time 1, *T2* Time 2, *T3* Time 3

12 months, how often on average have you had any alcohol to drink," answered on a scale of 0 (*Never*) to 10 (*3 or more times a day*).

Antisocial peer affiliation Adolescents' report of affiliation with antisocial peers was assessed using a 9-item scale from the Friends survey (e.g., "My friends get into trouble with the police"), $\alpha = .83$. Adolescents rated friendships on a scale of 1 (*All of my friends are like that*) to 4 (*None of my friends are like that*). Items were coded and summed so that a higher score indicated a greater degree of antisocial peer affiliation.

Sibling conflict The Sibling Relationship Questionnaire (Furman and Buhrmester 1985) was used to assess sibling conflict (3 items, e.g., "How much do you and this sibling get mad at and get in arguments with each other?"); each item was answered on a scale of 1 (*hardly at all*) to 5 (*EXTREMELY much*); $\alpha = .90$.

Analysis plan

Preliminary analyses were conducted to examine descriptive statistics and correlations among study variables using IBM SPSS Statistics, version 22.

In order to address study aims of examining the reciprocity of relationships in older and younger sibling alcohol use across time, a cross-lagged panel analysis was used (for an overview, refer to Berrington et al. 2006). All cross-lagged and moderation analyses were conducted in Mplus version 7 (Muthén and Muthén 1998–2017) using Full Information Maximum Likelihood (FIML) to account for missing data. The maximum likelihood with robust standard errors (MLR) estimator was used to account for the non-normality of alcohol use variables. As shown in Fig. 1, the prospective relationships between older and younger siblings' alcohol use at three time points was examined after accounting for both residual correlations and autoregressive effects across time. Moderation of cross-paths was evaluated by key sibling contexts, which were grouped by age difference, gender composition, family type, shared ethnicity, and an aggregate measure of self- and sibling-reported sibling companionship at Times 1 and 2 (see Table 1 for details). Significant differences in cross-paths across groups were tested by constraining all cross-paths to be equivalent and using the Satorra-Bentler chi-square difference test to evaluate for a significant decrement in model fit in comparing the variant and invariant models.

Follow-up sensitivity and alternate model testing were conducted. First, we tested whether results were consistent using Hamaker et al. (2015) recently developed random-intercept cross-lagged panel models, which accounts for both within- and between- individual variation in the associations between older and younger sibling alcohol use over time (whereas the traditional cross-lagged model accounts for only within-individual variation over time—this is explained further, below). We conducted a sensitivity analysis to confirm results for sibling age difference were consistent across the original trichotomous coding in comparison to dichotomous coding that may be more generalizable to populations beyond our sample (2 years of age apart or less vs. 3 or more years apart in age). We also compared our original model results to models that included several covariates, including (a) the main effects of sibling companionship at Time 1 and 2, (b) the main effects of mother- and father-child relationship quality, mother and father frequency of alcohol use, antisocial peer affiliation, and sibling conflict (all assessed at baseline).

Results

Preliminary Analyses

Table 1 shows descriptive statistics. On average, alcohol use frequency and quantity increased across time for both older and younger siblings. Sibling companionship showed little

Table 2 Zero-order correlation among study variables

	1	2	3	4	5	6	7
1. YS Alcohol use T1	1.0						
2. YS Alcohol use T2	.41***	1.0					
3. YS Alcohol use T3	.13***	.43***	1.0				
4. OS Alcohol use T1	.34***	.37***	.19***	1.0			
5. OS Alcohol use T2	.15***	.37***	.25***	.42***	1.0		
6. OS Alcohol use T3	−.00	.16***	.29***	.13**	.46***	1.0	
7. Sibling companionship T1	−.02	−.08	−.01	−.11**	−.10*	−.06	1.0
8. Sibling companionship T2	.04	−.05	−.03	−.04	−.10*	−.13**	.60***

Notes. Older and younger sibling alcohol use were computed by taking the average of past 12 month alcohol quantity and frequency (correlations between the two drinking measures ranged from .52 to .87 across older and younger siblings and time; *ps* < .001). Sibling companionship was computed by taking the average of older and younger sibling reported companionship (correlations ranged from .53 to .63 across time, *ps* < .001).

YS younger sibling, *OS* older sibling, *T1* Time 1, *T2* Time 2, *T3* Time 3

*$p < .05$; **$p < .01$; ***$p < .001$.

change in overall averages from Time 1 ($M = 8.81$, SD = 2.31) to Time 2 ($M = 8.11$, SD = 2.50); sibling companionship was not assessed at Time 3. There was little missing data on study variables across the three time points (see last column in Table 1). Zero-order correlations for the alcohol use and companionship variables are provided in Table 2. Older sibling alcohol use had a moderately positive correlation with younger sibling alcohol use at each time point (ranging from .29 to .37, all *ps* < .001). There was moderate stability of alcohol use from Time 1 to Time 2 (*rs* ranging from .13 to .46 for older siblings and from .13 to .43 for younger sibling, all *ps* < .001). Sibling companionship was largely stable from Time 1 to Time 2 ($r = .60$, $p < .001$). Sibling companionship was either modestly or not significantly correlated with older or younger sibling alcohol use across time (see Table 2 for details).

Prospective Cross-Lagged Analyses

Cross-lagged panel results for all sibling pairs are shown in Fig. 2. Following the zero-order correlations, both older sibling and younger sibling alcohol use were moderately stable across time (βs ranged from .32 to .46, all *ps* < .001). Residual correlations between older and younger sibling alcohol use were also significant at each time point ($r = .34$, $p < .001$ at time 1, $r = .27$, $p < .001$ at time 2, and $r = .20$, $p < .001$ at time 3). After accounting for the stability of older and younger sibling alcohol use across time, and residual correlations at each time point, there were significant effects of older siblings' alcohol use on younger siblings' subsequent alcohol use, but not younger siblings' alcohol use on older siblings' subsequent alcohol use; this was the case for each developmental transition (see Fig. 2 for details). As expected, this association was stronger for the transition in earlier adolescence ($\beta = .25$, $p < .001$) than in the transition for young adulthood ($\beta = .11$, $p = .009$).

Moderation Analyses

We next evaluated whether model results varied across several sibling contextual variables. There was no significant moderation, as determined by the non-significant decrement in model fit in comparing the variant and invariant models, by sibling gender composition (Time 1 to Time 2: SB χ^2 (4) = 1.20, $p = .88$; Time 2 to Time 3: SB χ^2 (4) = 3.83, $p = .43$), family type (Time 1 to Time 2: SB χ^2 (4) = 3.33, $p = .50$; Time 2 to Time 3: SB χ^2 (4) = 3.05, $p = .55$), sibling shared ethnicity (Time 1 to Time 2: SB χ^2 (2) = 1.36, $p = .51$; Time 2 to Time 3 SB χ^2 (2) = .70, $p = .71$), sibling companionship at Time 2 (Time 1 to Time 2: SB χ^2 (4) = 7.72, $p = .10$; Time 2 to Time 3 SB χ^2 (4) = 1.29, $p = .86$), or by sibling co-residence at Time 3 (Time 2 to Time 3: SB χ^2 (2) = .87, $p = .65$). However, there were three significant moderation effects: (1) sibling age difference significantly moderated the cross-paths from Time 2 to Time 3 (SB χ^2 (4) = 12.75, $p = .01$), (2) sibling companionship at Time 1 significantly moderated the cross-paths from Time 1 to Time 2 (SB χ^2 (4) = 10.40, $p = .03$), and 3) sibling co-residence at Time 2 significantly moderated the cross-paths from Time 2 to Time 3 (SB χ^2 (2) = 9.27, $p = .01$), These moderation results are illustrated in Figs. 3–5 and are described below.

As shown in Fig. 3, across all three age groups, older siblings' alcohol use at Time 1 significantly predicted

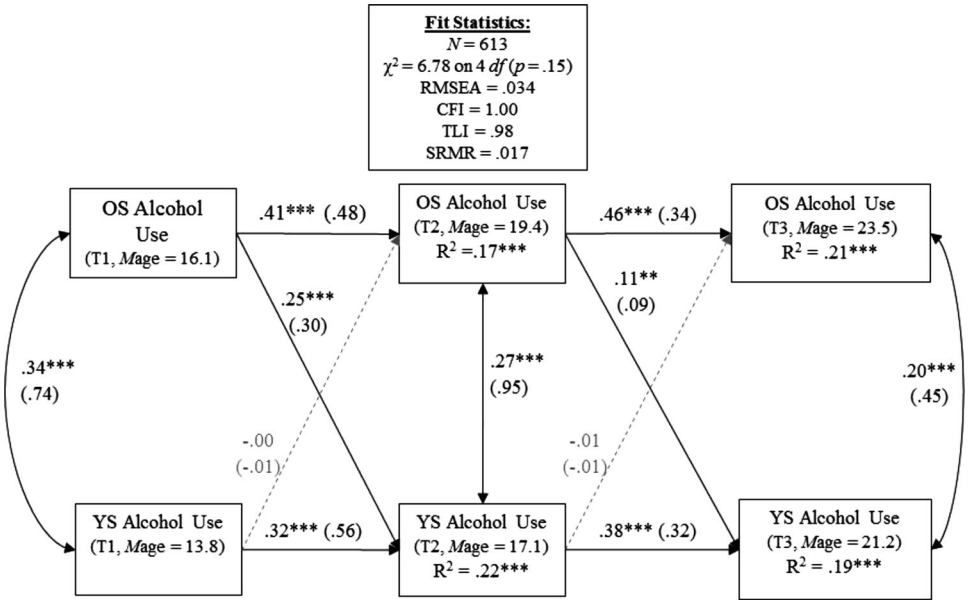

Fig. 2 The developmental unfolding of sibling influences on alcohol use over time. This figure shows the standardized (unstandardized) coefficients and fit statistics from the cross-lagged model analyzing sibling influences on alcohol use over time. *OS* older sibling, *YS* younger sibling, *T1* Time 1, *T2* Time 2, *T3* Time 3, *M*age mean age in years of older and younger siblings at each assessment. For clarity of presentation, *gray/dashed paths* are not significantly different than zero. Statistical significance is denoted by $*p < .05$, $**p < .01$, $***p < .001$

subsequent younger siblings' alcohol use at Time 2. The only significant differences concern the Time 2 to Time 3 developmental transition. Younger sibling's alcohol use at Time 2 significantly predicted subsequent older siblings' alcohol use at Time 3, but for those closest in age (within 1.5 years). This is the first instance in which younger siblings' alcohol use predicted older siblings' alcohol use and is consistent with the notion that younger siblings also appear to be important socializing agents of their older siblings' alcohol use, at least concerning the transition from late adolescence to early adulthood.

The only other difference in Time 2 to Time 3 cross-paths was that older siblings' alcohol use at Time 2 predicted younger siblings' alcohol use at Time 3, but only for those that are 1.5 to 2 years of age (the middle age difference group). Making sense of this result requires looking at the overall picture of findings for those greater than 2 years of age apart and those less than 1.5 years (Fig. 3). For those greater than 2 years apart, neither older nor younger siblings' alcohol use in late adolescence was a salient predictor of subsequent siblings' alcohol use in early adulthood (i.e., Time 2 to Time 3). For those within 1.5 years of age, younger siblings' alcohol use was shown to be a more salient predictor than older siblings' alcohol use in predicting subsequent early adult alcohol use (as discussed above, concerning Time 2 to Time 3). For those in the middle (1.5 to 2 years of age apart), older siblings' alcohol use in late adolescence remained a significant predictor of younger siblings' alcohol use in early adulthood (i.e., from Time 2 to Time 3). These results suggest older siblings are important socializing agents of their younger siblings' alcohol use, perhaps more so in early adolescence, particularly if they are further apart in age, and that younger siblings are also important socializing agents of their older siblings' alcohol use, but only if they are close in age (within 1.5 years of age), and only pertaining to the late adolescent to early adult developmental transition.

As shown in Fig. 4, the results showed that younger siblings' alcohol use at Time 1 significantly predicted older siblings' alcohol use at Time 2, but only for those with the highest levels sibling companionship at Time 1 (75th percentile or higher; $b = .24$, $\beta = .15$, $p = .04$; SB χ^2 $(4) = 10.40$, $p = .03$). No other significant differences were found (see Fig. 4 for details). This is the second instance in which younger siblings' alcohol use significantly predicted subsequent older siblings' alcohol use and in combination with age difference moderation results suggests that younger siblings are important socializing agents of their older siblings' alcohol use, but only if they have high levels of a close and companionate relationship in early adolescence or if they are close in age in later adolescence. As younger siblings drink less than older siblings at Time 1 (see Tables 1–2 for descriptive statistics), we conducted follow-up analyses to evaluate the rates of older and younger sibling alcohol use at Time 1 for those with the highest levels of sibling companionship and compared these to the average rates for the entire sample. Although the average frequency × quantity alcohol score for younger siblings at high levels of companionship ($M = -.22$, SD = .75) were not that different for the average score for entire sample of younger siblings ($M = -.25$, SD = .74), we found that older siblings at high levels of companionship drank somewhat less ($M = .14$, SD = 1.03) compared to the entire sample of older siblings ($M = .25$, SD = 1.10).

Finally, and as shown in Fig. 5, older siblings' alcohol use at Time 2 significantly predicted younger siblings'

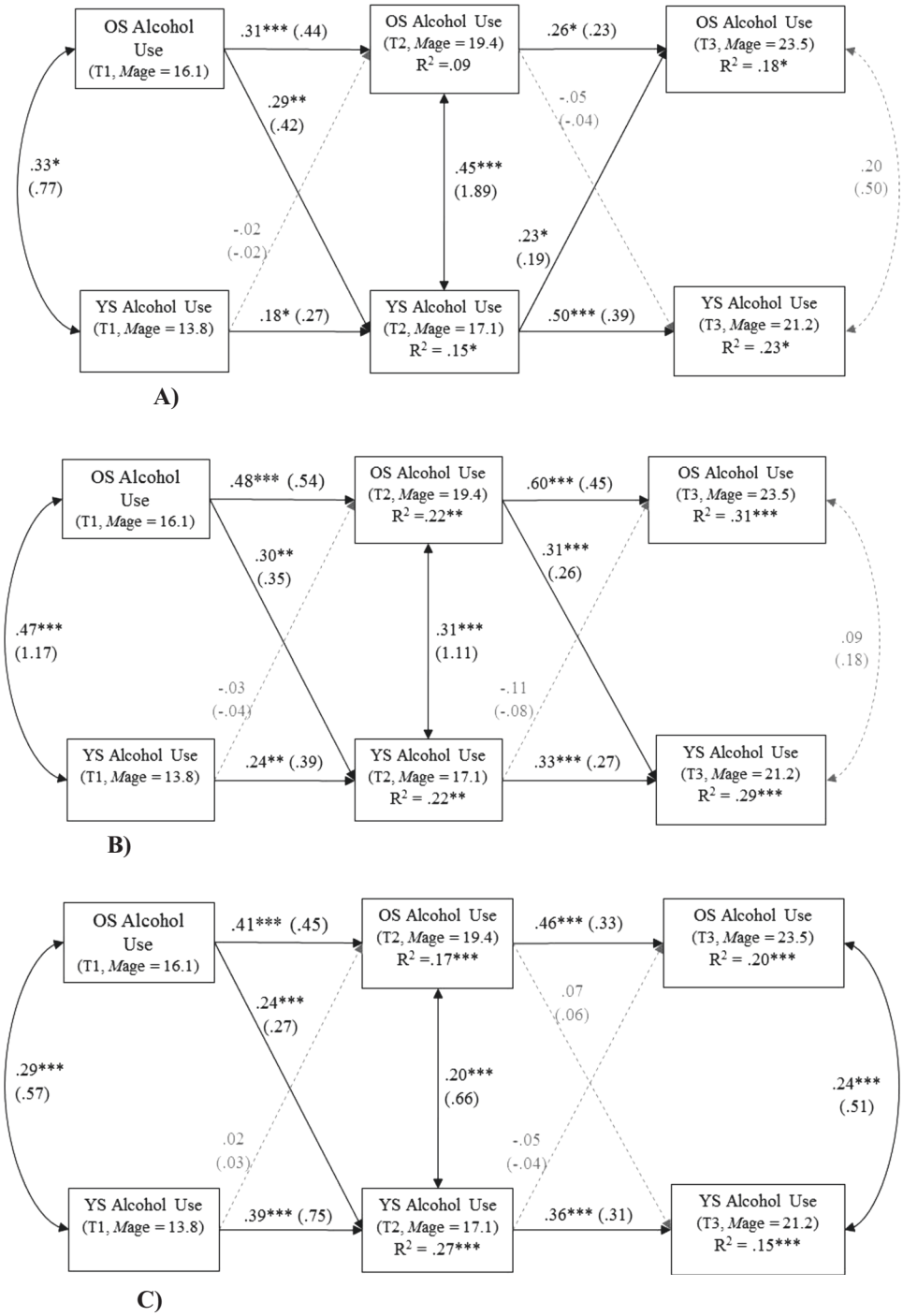

Fig. 3 Moderation by sibling age difference. **a** Results for sibling with age difference 1.5 years or less ($n = 98$), **b** results for sibling with age difference 1.5 to 2 years ($n = 149$), **c** results for sibling with age difference 2+ years ($n = 366$). This figure shows the standardized (unstandardized) coefficients from the cross-lagged model analyzing sibling influences on alcohol use over time. *OS* older sibling, *YS* younger sibling, *T1* Time 1, *T2* Time 2, *T3* Time 3, *M*age mean age in years of older and younger siblings at each assessment. This model that allowed all paths to vary fit the data well, as indicated by the fit statistics: χ^2 (12) = 14.57, $p = .27$; RMSEA = .03 (.00, .08), CFI = 1.00, TLI = .98, SRMR = .023. Sibling age difference significantly moderated the Time 2 to Time 3 cross-paths (SB χ^2 (4) = 12.75, $p = .01$). For those closest in age (with 1.5 years or less), younger siblings' alcohol use in adolescence had a more salient effect on subsequent older siblings' alcohol use in early adulthood than vice versa. Conversely, for those greater than 2 years apart, neither older nor younger siblings' alcohol use in late adolescence is a salient predictor of alcohol use in early adulthood. For those in the middle (1.5 to 2 years of age apart), older siblings' alcohol use in late adolescence remained a significant predictor of younger siblings' alcohol use in early adulthood. For clarity of presentation, black paths indicate significant associations, whereas gray/dashed paths are not significantly different than zero. Statistical significance is denoted by *$p < .05$, **$p < .01$, ***$p < .001$

alcohol use at Time 3, but only for those siblings who lived together (for at least half the year) at Time 2. Conversely, for siblings who did not live together (for at least half the year), younger siblings' alcohol use at Time 2 was actually significantly and inversely related to older siblings' alcohol use at Time 3. This suggests sibling co-residence is an important factor in considering whether older or younger siblings have an impact on one another's drinking in the late adolescence to early adult transition.

Sibling Gender Composition × Sibling Companionship Interactions

There was no significant moderation of cross-paths between sibling gender composition× sibling companionship from Time 1 to Time 2 (using Time 1 sibling companionship; SB χ^2 (16) = 16.85, $p = .40$) or from Time 2 to Time 3 (using Time 2 sibling companionship; SB χ^2 (16) = 9.93, $p = .87$). As our hypotheses concerned a comparison of males

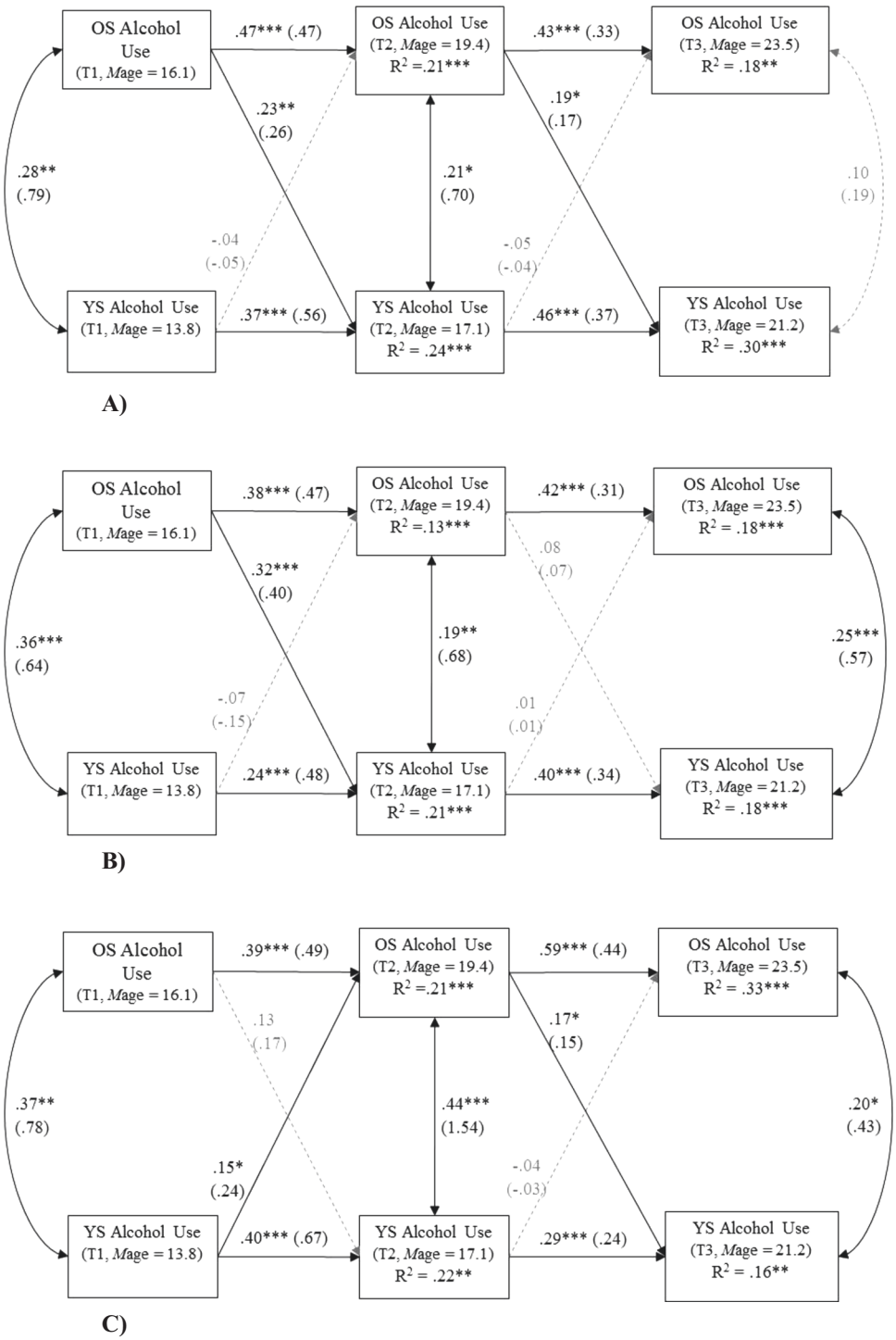

Fig. 4 Moderation by sibling companionship at T1. **a** Results for low sibling companionship levels at T1 ($n = 160$), **b** results for average sibling companionship levels at T1 ($n = 283$), **c** results for high sibling companionship levels at T1 ($n = 167$). This figure shows the standardized (unstandardized) coefficients from the cross-lagged model analyzing sibling influences on alcohol use over time by low, average, and high sibling companionship levels. *OS* older sibling, *YS* younger sibling, *T1* Time 1, *T2* Time 2, *T3* Time 3, *M*age mean age in years of older and younger siblings at each assessment. This model that allowed all paths to vary fit the data well, as indicated by the fit statistics: χ^2 (12) = 11.20, $p = .51$; RMSEA = .00 (.00, .07), CFI = 1.00, TLI = 1.00, SRMR = .022. Time 1 sibling companionship significantly moderated the associations between Time 1 and Time 2 cross-paths (SB χ^2 (4) = 10.40, $p = .03$). As shown in the Figure, younger siblings' alcohol use at Time 1 significantly predicted older siblings' alcohol use at Time 2, but only for those with high levels of sibling companionship. For clarity of presentation, black paths indicate significant associations, whereas *gray/dashed paths* are not significantly different than zero. Statistical significance is denoted by $*p < .05$, $**p < .01$, $***p < .001$

and females at high levels of companionship, a subsequent analysis was conducted to compare these two groups. Results showed no significant differences in associations from Time 1 to Time 2 (SB χ^2 (1) = .55, $p = .55$) or from Time 2 to Time 3 (SB χ^2 (2) = .68, $p = .72$). Thus, results did not support our expectations regarding moderation by sibling gender composition and sibling companionship, possibly due to having less power with the gender composition × companionship sub-group sizes (see Table 1).

Sensitivity and Alternative Model Testing

We conducted a number of post-hoc analyses to determine if modeling choice or coding may have impacted results. Figure 6 shows results of our longitudinal analysis using a

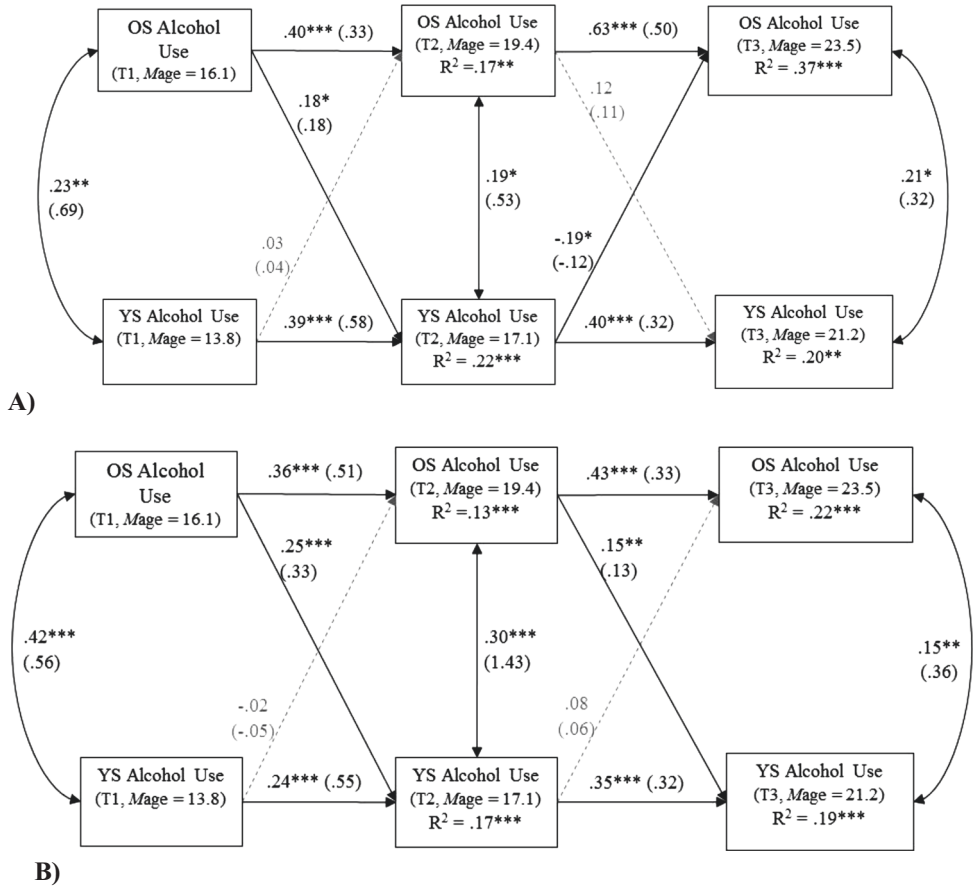

Fig. 5 Moderation by sibling co-residence at Time 2. **a** Results for siblings who do not live together for at least half the year at T2 ($n = 149$), **b** results for siblings who do not live together for at least half the year at T2 ($n = 387$). This figure shows the standardized (unstandardized) coefficients from the cross-lagged model analyzing sibling influences on alcohol use over time by sibling co-residence at Time 2. *OS* older sibling, *YS* younger sibling, *T1* Time 1, *T2* Time 2, *T3* Time 3, *M*age mean age in years of older and younger siblings at each assessment. This model that allowed all paths to vary fit the data well, as indicated by the fit statistics: χ^2 (8) = 11.13, $p = .20$; RMSEA = .04 (.00, .09), CFI = .99, TLI = .98, SRMR = .021. Time 2 sibling co-residence significantly moderated the associations between Time 2 and Time 3 cross-paths (SB χ^2 (2) = 9.27, $p = .01$). As shown by the figure, older siblings' alcohol use at Time 2 significantly predicted younger siblings' alcohol use at Time 3, but only for those siblings who lived together. Conversely, for siblings who did not live together, younger siblings' alcohol use at Time 2 was significantly and inversely related to older siblings' alcohol use at Time 3. For clarity of presentation, black paths indicate significant associations, whereas *gray/dashed paths* are not significantly different than zero. Statistical significance is denoted by $^*p < .05$, $^{**}p < .01$, $^{***}p < .001$

random-intercept cross-lagged panel (Hamaker et al. 2015), which accounts for both within- and between-individual variation in older and your sibling alcohol use over time. As shown in Fig. 6, this model accounts for overall variation in alcohol use across time by having alcohol use at Times 1, 2, and 3 load onto a latent factor of alcohol use for both older and younger siblings, and correlates these two latent factors (in addition to modeling the stability paths, cross-paths, and residual correlations between older and younger sibling alcohol use at each time point). As the correlations between Time 1 and Time 3 alcohol use were quite small for both older and younger siblings to begin with ($rs = .13$, $ps < .001$; see Table 2), this model had difficulty converging. To deal with this, we set the Time 3 loading to zero for both the latent older and younger sibling alcohol use variables and the model successfully converged (we confirmed essentially identical results when setting the Time 1 loading to zero). As shown in Fig. 6, the overall pattern of effects from the random-intercept cross-lagged model were consistent with our traditional cross-lagged model results in that older siblings' alcohol use had a significant effect on subsequent younger siblings' alcohol use across both developmental transitions (with evidence these effects were stronger from early to late adolescence vs. late adolescence to early adulthood). Consistent with our earlier results, younger siblings' alcohol use did not have a significant impact on their older siblings' subsequent alcohol use across either developmental transition.

We also confirmed results were consistent when we included the main effects of sibling companionship into our model. As shown in Fig. 7, results confirmed the same pattern of results in that older siblings' alcohol use predicted

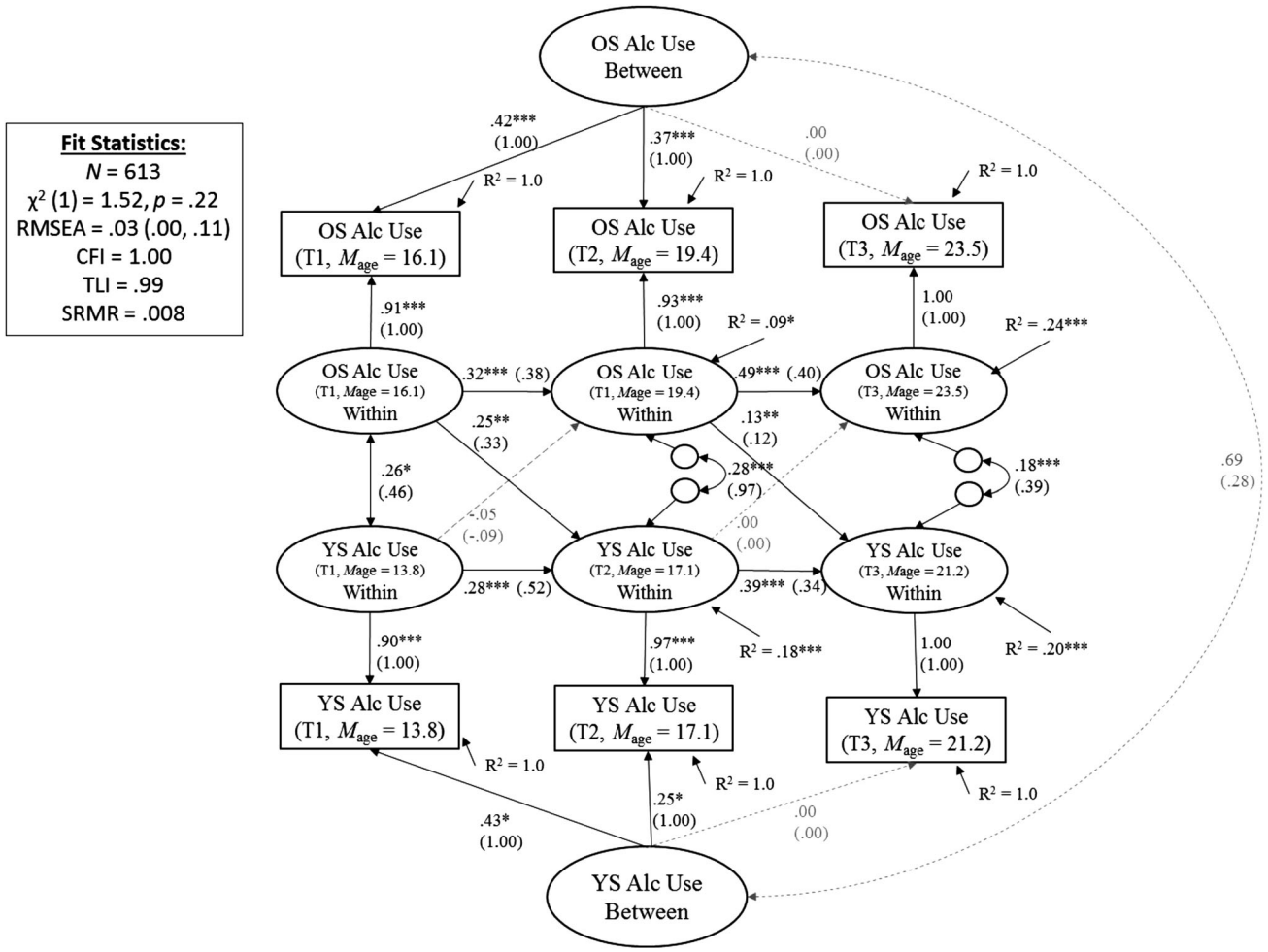

Fig. 6 Results using Hamaker et al.'s (2015) random-intercept cross-lagged panel approach. Showing standardized (unstandardized) coefficients and model fit statistics from the cross-lagged model analyzing sibling influences on alcohol use over time. *OS* older sibling, *YS* younger sibling, *T1* Time 1, *T2* Time 2, *T3* Time 3, *M*age mean age in years of older and younger siblings at each assessment. This model accounts for both within and between person effects through the incorporation of modeling latent and time-invariant influences on alcohol use over time, as well as the correlation between older and younger siblings' latent alcohol use (in addition to the within-sibling stability and rank-order change as measured by the traditional cross-lagged panel results presented in Fig. 2). Results using this more advanced analysis show overall the same pattern of results in that older siblings' alcohol use significantly predicted younger siblings' subsequent alcohol use across both developmental transitions, while younger siblings' alcohol use did not predict older siblings' subsequent alcohol use across either developmental transition. *Note*: Time 1 and Time 3 alcohol use were not highly correlated for either younger or older sibling and this model would not converge unless we specified the loading to equal zero for either Time 3 or Time 1 (we confirmed the same pattern of results with either the Time 1 or Time 3 loading set to zero). For clarity of presentation, *black paths* indicate significant associations, whereas *gray/dashed paths* are not significantly different than zero. Statistical significance is denoted by $*p < .05$, $**p < .01$, $***p < .001$

younger siblings' alcohol use across each developmental transition, with effects stronger from early to late adolescence ($\beta = .25$, $p < .001$) compared to late adolescence and early adulthood ($\beta = .11$, $p = .01$). Younger siblings' alcohol use did not significantly predict older siblings' alcohol use for either developmental transition (see Fig. 7 for details). Interestingly, only older siblings' perceived sibling companionship with their younger sibling predicted subsequent rank-order decreases in alcohol use, and only from Time 2 to Time 3 ($\beta = -.10$, $p = .02$); no other within-time correlations or prospective associations were significant (see Fig. 7 for details). To double check whether our moderation results involving sibling companionship at Time 1 (described earlier and shown in Fig. 4) changed as a result of adding in these main effects, we re-ran our moderation analyses with them included. Results were replicated in that that younger siblings' alcohol use at Time 1 was a significant predictor of older siblings' alcohol use at Time 2, but only for those with high levels of sibling companionship (high: $b = .24$, $\beta = .14$, $p = .01$; middle: $b = -.14$, $\beta = -.07$, $p = .10$; low; $b = -.03$, $\beta = -.02$, $p = .62$) and that constraining the Time 1 to Time 2 cross-paths resulted in a

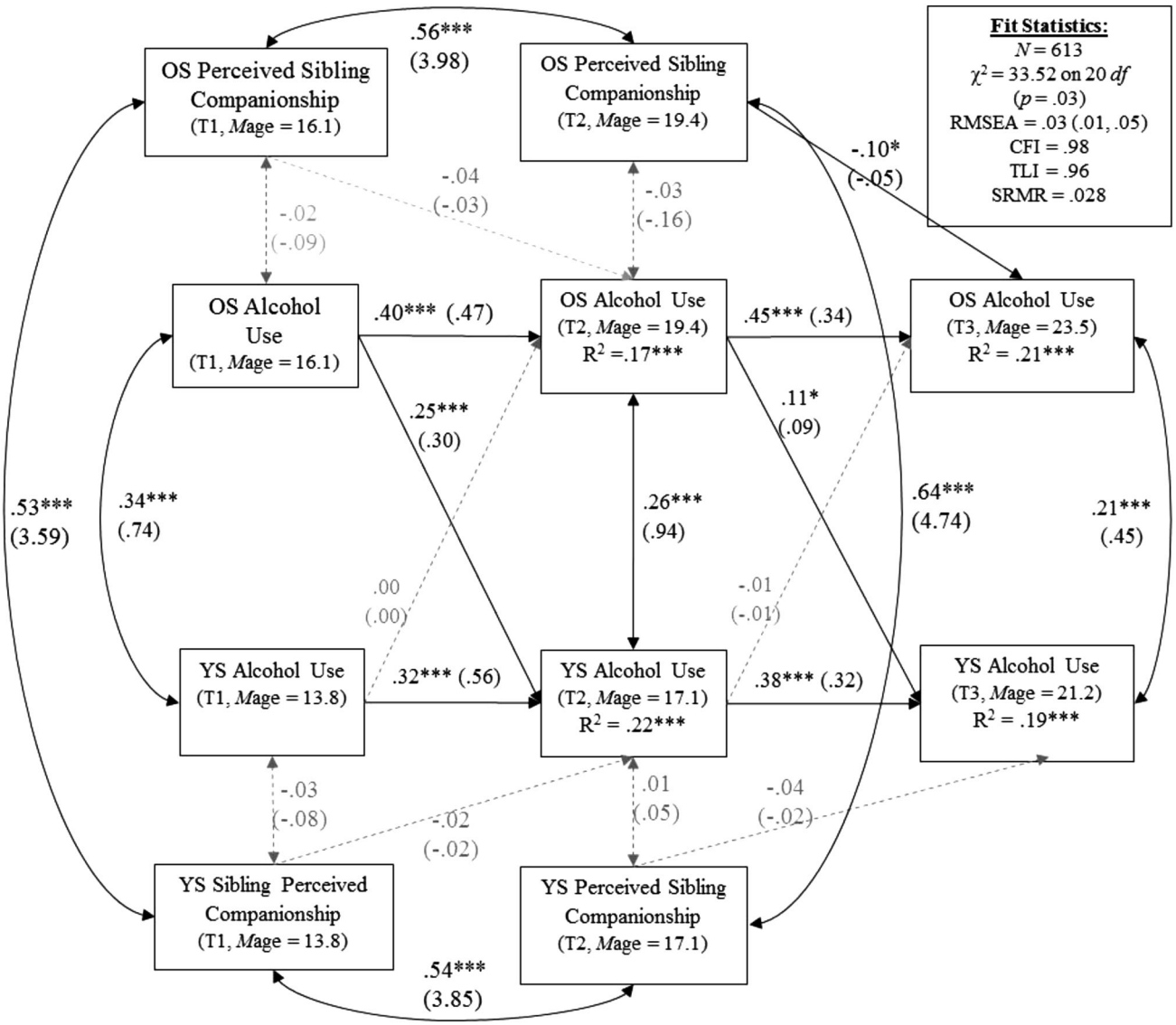

Fig. 7 Results after accounting for sibling companionship main effects. Showing standardized (unstandardized) coefficients and model fit statistics from the cross-lagged model analyzing sibling influences on alcohol use over time. *OS* older sibling, *YS* younger sibling, *T1* Time 1, *T2* Time 2, *T3* Time 3, *M*age mean age in years of older and younger siblings at each assessment. After accounting for the within-time correlation between sibling companionship and alcohol use, and the prospective association between earlier sibling companionship and later alcohol use for each sibling, results showed the same pattern of effects as the model that excluded these main effects. Older siblings' alcohol use predicted younger siblings' alcohol use across each developmental transition, with effects stronger from early to late adolescence compared to late adolescence and early adulthood. Younger siblings' alcohol use did not significantly predict older siblings' alcohol use for either developmental transition. For clarity of presentation, *gray/dashed paths* are not significantly different than zero. Statistical significance is denoted by $*p < .05$, $**p < .01$, $***p < .001$

significant decrement of model fit (SB χ^2 (4) = 10.06, $p = .04$).

We also conducted a sensitivity analysis by confirming whether results were consistent when recoding sibling age difference variable as dichotomous variable and a sub-set of the original sample (2 or years apart in age or less: $n = 247$, 40% of the sample vs. 3 or more years apart in age: $n = 130$, 21% of the sample) as this may be more generalizable beyond our sample. Using this dichotomous variable showed no significant moderation by sibling age difference (Time 1 to Time 2 cross-paths: SB χ^2 (2) = 3.05, $p = .22$; Time 2 to Time 3 cross-paths: SB χ^2 (2) = 1.54, $p = .46$), suggesting younger siblings' may only have a significant impact if they are particularly close in age (less than 1.5 years of age apart, as described in our earlier analysis).

Finally, to determine whether results would hold up after accounting for other important predictors of adolescent alcohol use, we examined model results when including

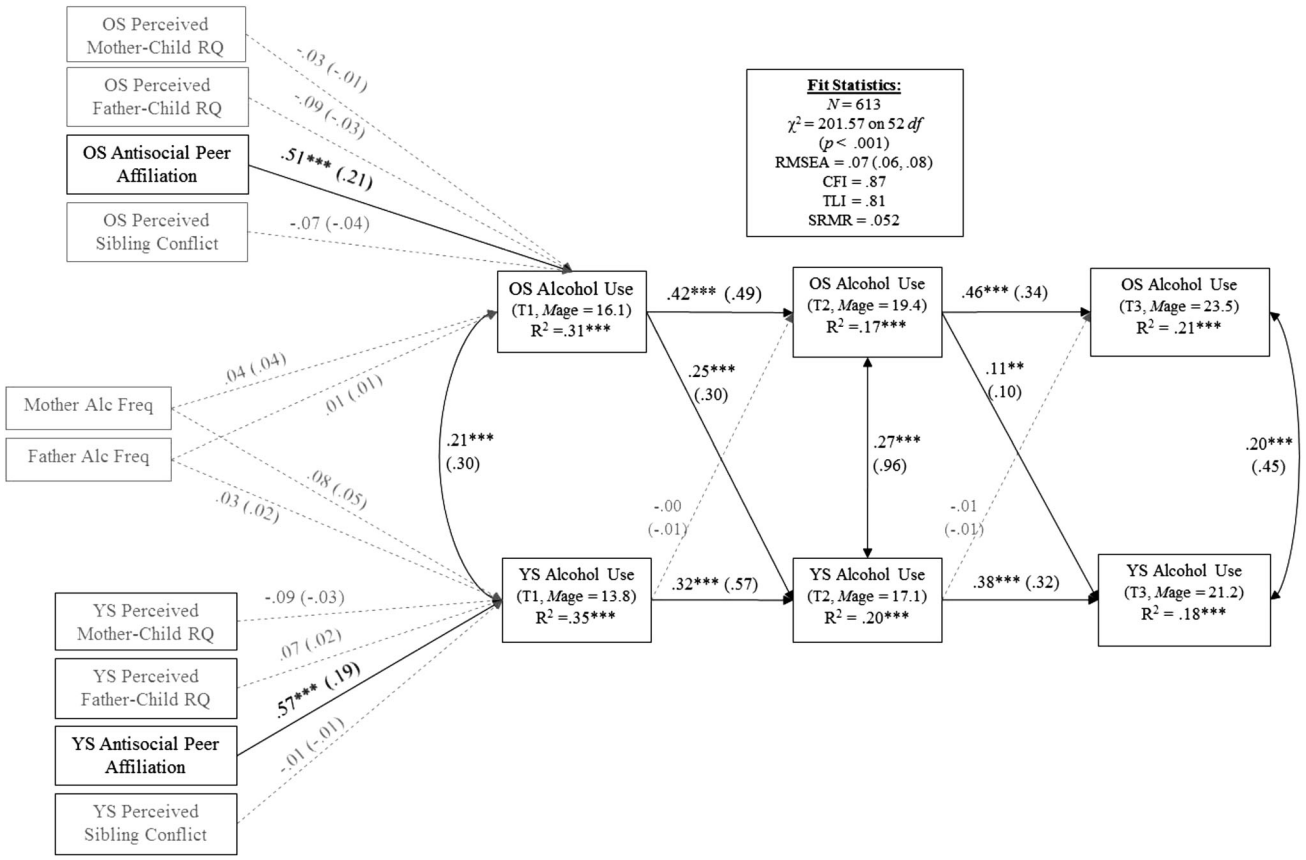

Fig. 8 Results after accounting for parent-child relationship quality, parent alcohol use, antisocial peer affiliation, and sibling conflict at baseline. Showing standardized (unstandardized) coefficients and model fit statistics from the cross-lagged model analyzing sibling influences on alcohol use over time. *OS* older sibling, *YS* younger sibling, *T1* Time 1, *T2* Time 2, *T3* Time 3, *M*age mean age in years of older and younger siblings at each assessment. All covariates were correlated in this model, but are not shown for clarity of presentation. For clarity of presentation, *gray/dashed paths* are not significantly different than zero. Statistical significance is denoted by $*p < .05$, $**p < .01$, $***p < .001$

covariates of mother and father-child relationship quality, mother and father frequency of alcohol use in the last 12 months, as well as antisocial peer affiliation and sibling conflict (all assessed at baseline). As shown in Fig. 8, inclusion of these covariates did not impact the overall pattern of results. This suggests older siblings' alcohol use has statistically and practically significant impacts on subsequent younger siblings' alcohol use, particularly in the developmental period of early adolescence to late adolescence.

Discussion

Prior research has shown siblings are quite similar in their alcohol and substance use (D'Amico and Fromme 1997; Fagan and Najman 2005; Rowe and Gulley 1992) and that this similarity is at least in part explained through older siblings' facilitation of use, sibling co-use, and modeling of older sibling substance use behavior (McGue and Iacono 2009; Samek et al. 2015a; Whiteman et al. 2013, 2016). However, much of this research has been on cross-sectional samples of adolescents alone or has focused exclusively on older sibling's impact on younger siblings' alcohol and substance use. The purpose of this study was to expand on this work by evaluating the prospective associations between older and younger siblings' alcohol use in the important developmental transitions of not only early to late adolescence, but also through early adulthood, when alcohol use is most common (SAMHSA 2014). Results are consistent with the notion that older siblings are important socializing agents of their younger siblings' alcohol use (Whiteman et al. 2016; Samek et al. 2015a). Our study showed that this appears to be true across a number of sibling contexts, including sibling gender composition, shared ethnicity, whether siblings are adopted or biological offspring of their parents, and at different levels of sibling relationship companionship. Results are also consistent with the notion that younger siblings appear to be less influential socializing agents of their older siblings' alcohol use, unless

siblings are close in age (1.5 years or less) or report high levels of companionship. This was an important contribution to the literature as we know of no research to date that has simultaneously evaluated both older and younger siblings' influences on one another's alcohol use via a longitudinal design and analysis.

Altogether, results align well within a social contagion or deviancy training framework in understanding the impact of older or younger siblings' alcohol use (Rende et al. 2005; Slomkowski et al. 2001) and this appears to be consistent for brothers, sisters, and mixed gender sibling pairs. Thus, results did not meet our expectations that brothers may be more likely to engage in deviancy training than sisters, at least not at these developmental transitions. Taken with prior research, it may be that brothers are particularly influential in early compared to later adolescence (in line with Slomkowski et al. 2001 which evaluated early adolescent delinquency of younger siblings based on older siblings delinquency and sibling relationship quality) or that perhaps larger sample sizes are needed to detect differences in brothers vs. sisters impact (in line with Samek et al. 2015b who did not evaluate differences in birth order thus had more power to compare effects by sibling gender). Further research is needed to better understand the extent to which sibling gender composition and relationship closeness interact to predict other substance use or related externalizing behavior.

Siblings as "Partners in Crime"

A deviancy training theory proposes that deviant children may form coalitions with one another within the family, which in turn will promote further deviancy via the sibling relationship (Bullock and Dishion 2002). This is also known as the siblings as "partners in crime" theory (Slomkowski et al. 2001). Our study suggests older siblings appear to have a particularly strong impact in forming such coalitions with their younger siblings, as older siblings' alcohol use was significantly associated with younger siblings' alcohol use across time. Nonetheless, the effect size for this association is stronger from early to late adolescence than from late adolescence to early adulthood.

There are at least two possible explanations for this pattern of findings. First, siblings may spend less time together as they transition into early adulthood—thus older siblings' may not be around as much for younger siblings to model their drinking behavior. This is consistent with our results showing older siblings' alcohol use in late adolescence was a significant predictor of younger siblings' alcohol use in early adulthood, but only for those siblings who lived together for at least half the year in late adolescence. Second, there is some evidence that children and young adolescents tend to be more malleable or sensitive to environmental context compared to later on in adulthood (Kendler et al. 2011). For example, Samek et al. (2017) showed that antisocial peer affiliation significantly moderated the additive genetic influence on adolescent externalizing disorders (including substance use disorders), such that the additive genetic influence on externalizing disorders was greater under conditions of a greater degree of antisocial peer affiliation and smaller under a lesser degree of antisocial peer affiliation. This finding is consistent with a diathesis-stress explanation for the development of adolescent externalizing problems, but was most remarkable was that this finding did not hold up in later young adulthood. That is, there was no evidence of gene-environment interaction involving antisocial peer affiliation and adult externalizing disorders at ages 20, 24, and 29. Similar results have been found for gene-environment interaction involving parent-child relationship problems and externalizing disorders at ages 17 but not at ages 20 or 24 (Samek et al. 2015), supporting the notion that gene-environment interaction involved in substance use and externalizing disorders may be developmentally-limited to adolescence. This is consistent with our results, which showed that older siblings may be particularly influential for younger siblings in early adolescence relative to later adolescence and early adulthood.

One of the most interesting findings from this study was a demonstration that younger siblings' alcohol use significantly predicted older siblings' subsequent alcohol use—earlier in development in some cases (under high levels of sibling companionship) and later in development in other cases (if they were close in age). These findings suggest that younger siblings may be important socializing agents of their older siblings' alcohol use, at least in some instances. Thus, social learning, deviancy training, and modeling explanations (e.g., Whiteman et al. 2013) may need to be expanded to include circumstances in which older siblings might model younger siblings' behavior as well as general circumstances when younger siblings are most likely to model older siblings' behavior. As younger siblings' alcohol use was associated with their older siblings' subsequent alcohol use—but only for those close in age or those with greater than average levels of sibling companionship or relationship closeness—it appears that at least some identification factors may be more relevant to whether and how much younger siblings can impact their older siblings' alcohol use. On the other hand, our results suggest this is not necessarily the case for the extent to which older siblings' alcohol use can impact younger siblings' alcohol use.

Practical Implications

The formation of collusive or deviant sibling relationships remains an important area to address in existing adolescent

alcohol and substance use prevention and intervention programs. A multitude of programs have long addressed various components important to adolescents' lives, such as aspects of parenting behavior and monitoring, as well as issues at school or in the community (for a review, see Griffin and Botvin 2010). However, there is little attention to siblings in programs aimed to reduce adolescent alcohol or substance use. At the very least, results from this study and others (McGue and Iacono 2009; Samek et al. 2015a; Slomkowski et al. 2001; Whiteman et al. 2016) suggest it may be important to assess the alcohol use of target adolescents/early adults, as well as their older and younger siblings' alcohol use. It may also be important to assess their overall relationship quality with those siblings and the extent to which siblings may be facilitating or using alcohol together. As our findings suggest older siblings may have a stronger impact on younger sibling alcohol use in early rather than later adolescence, it may be particularly beneficial to target those with an older or younger sibling in early adolescence. Finally, it may also prove to be useful to consider targeting or co-treating siblings for substance use problems for the particularly deviant or collusive sibling relationships (Bullock and Dishion 2002). However, it may be important to treat each member of the sibling pair individually, as prior research has shown that treating deviant peer groups may inadvertently reinforce deviant behavior, and therefore fail at reducing problematic behavior (Dishion et al. 1999).

Limitations and Strengths

This study is not without limitations. We did not have data on sibling companionship in early adulthood and were unable to evaluate how early adult sibling companionship may have impacted or moderated the associations between older and younger sibling alcohol use from late adolescence to early adulthood. Also, there may be other aspects of sibling relationship quality important to offsetting or amplifying sibling influences on alcohol and substance use that we did not study here, such as the overall level of conflict, competition, or aggression in the sibling relationship. Although the sample was diverse due to the inclusion of international adoptees, the sample was mostly white or of Asian ancestry, and it is unclear how results would replicate across other ethnic and racial groups. Siblings in this study were only up to 5 years of age apart, therefore it is unclear how much older or much younger siblings may be relevant to the development of adolescent and adult alcohol use.

There are many notable strengths of this study, including the longitudinal nature and size of the sample. Our ability to tease apart the prospective associations between older and younger siblings' alcohol use on one another suggests that younger siblings appear to also be socializing their older siblings, but only under some conditions (being close in age and having higher than average levels of sibling companionship). The large sample size allowed us to evaluate for potential moderation by several important aspects of sibling context (e.g., age differences, gender composition, etc.) and to better understand to what extent these findings are more universally applied to sibling relationships vs. being dependent on factors such as gender composition or family type.

Conclusion

Siblings have long been shown to be moderately to substantially similar in their adolescent alcohol and substance use (e.g., Fagan and Najman 2005; Rowe and Gulley 1992). Yet little research had addressed antecedent vs. consequence in these relationships and tended to focus on how older siblings impacted younger siblings in cross-sectional analyses or analyses limited to adolescence alone (e.g., Samek et al. 2015a; Whiteman et al. 2013, 2016). This study addresses a number of these gaps, including the detangling of older to younger vs. younger to older effects in the critical transition from early adolescence to early adulthood. Our results align well within a deviancy training framework (Slomkowski et al. 2001) and suggest it may be important for current adolescent alcohol and substance use prevention programs to at the very least consider assessing sibling alcohol use, relationship quality, as well as facilitation of or co-use (Samek et al. 2015a; Whiteman et al. 2016). Our results show older siblings are important socializing agents of their younger siblings' alcohol use. This held true across a number of sibling contexts (including gender composition, age difference, shared vs. unshared genetic relationships, relationship closeness). Notably, we found younger siblings' alcohol use was predictive of their older siblings' alcohol use when they were close in age and reported relatively high levels of sibling companionship. This finding has particularly important implications for our theorizing on sibling relationships and deviancy training generally, as it calls attention to the fact that younger siblings may be just as important socializing agents of their older siblings' alcohol use.

Acknowledgements We would like to thank the participating families from the Sibling Interaction and Behavior Study and the recruitment, interviewing, and data management staff at the Minnesota Center for Twin and Family Research.

Author Contributions D.R.S. conceived the idea for this manuscript and completed the initial draft of the intro, method, and discussion sections as well as the bulk of the revisions. R.J.G. and L.R. assisted with data analysis and prepared initial drafts of the results section (L.R. descriptive statistics, R.J.G. inferential statistics). D.R.S., R.J.G., and L.R. reviewed and edited multiple drafts of the manuscript.

D.R.S. handled all revisions prior to other co-author approval. M.M. and W.G.I. are the Principal and Co-Investigator of the SIBS (data source) thus participated in the design of the study and provided edits, feedback, and suggestions on the manuscript.

Funding This research was supported by Grants AA11886 from the National Institute on Alcohol Abuse and Alcoholism and MH66140 from the National Institute of Mental Health. The first author was also supported by the USDA National Institute of Food and Agriculture, Hatch project 1006129. The content is solely the responsibility of the authors and does not necessarily represent the official views of the funding agencies.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no competing interests.

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. This study received IRB approval from the University of Minnesota, Minneapolis.

Informed Consent Informed consent was obtained for all individuals participants included in the study. Parent consent was obtained for those younger than 18 years of age. Child assent was obtained in addition to parent consent for those younger than 18 years of age.

References

Albert, D., Chein, J., & Steinberg, L. (2013). The teenage brain: Peer influences on adolescent decision making. *Current Directions in Psychological Science*, *22*, 114–120.

Bachman, J. G., O'Malley, P. M., Schulenberg, J. E., Johnston, L. D., Bryant, A. L., & Merline, A. C. (2002). *The decline of substance use in young adulthood: Changes in social activities, roles, and beliefs*. Mahwah, NJ: Erlbaum.

Bandura, A. (1969). Social-learning theory of identificatory processes. In D. A. Goslin (Ed.), *Handbook of socialization theory and research* (pp. 213–261). Chicago, IL: Rand McNally.

Berrington, A., & Smith, W. F. (2006). An overview of methods for the analysis of panel data. *ESRC National Centre for Research Methods*, 1–57. http://eprints.ncrm.ac.uk/415/1/MethodsReviewPaperNCRM-007.pdf.

Boyle, M. H., Sanford, M., Szatmari, P., Merikangas, K., & Offord, D. R. (2001). Familial influences on substance use by adolescents and young adults. *Canadian Journal of Public Health*, *92*(3), 206–209.

Bowlby, J. (1969). *Attachment and loss*. New York, NY: Basic Books. Volume I: Attachment.

Branje, S. J. T., van Lieshout, C. F. M., van Aken, M. A. G., & Haselager, G. J. T. (2004). Perceived support in sibling relationships and adolescent adjustment. *Journal of Child Psychology and Psychiatry*, *45*, 1385–1396. doi:10.1111/j.1469-7610.2004.00332.x.

Buist, K. L., Dekovic, M., & Prinzie, P. (2013). Sibling relationship quality and psychopathology of children and adolescents: A meta-analysis. *Clinical Psychology Review*, *33*, 97–106.

Bullock, B. M., & Dishion, T. J. (2002). Sibling collusion and problem behavior in early adolescence: Toward a process model for family mutuality. *Journal of Abnormal Child Psychology*, *30*, 143–153. doi:10.1023/A:1014753232153.

Conger, K. J., & Little, W. M. (2010). Sibling relationships during the transition to adulthood. *Child Development Perspectives*, *4*, 87–94. doi:10.1111/j.1750-8606.2010.00123.x.

Criss, M. M., & Shaw, D. S. (2005). Sibling relationships as contexts for delinquency training in low-income families. *Journal of Family Psychology*, *19*, 592–600. doi:10.1037/0893-3200.19.4.592.

D'Amico, E. J., & Fromme, K. (1997). Health risk behaviors of adolescent and young adult siblings. *Health Psychology*, *16*(5), 426–432.

Dishion, T. M., McCord, J., & Poulin, F. (1999). When interventions harm: Peer groups and problem behavior. *American Psychologist*, *54*, 755–764.

Elkins, I. J., McGue, M., & Iacono, W. G. (1997). Genetic and environmental influences on parent-son relationships: Evidence for increasing genetic influence during adolescence. *Developmental Psychology*, *33*, 351–363.

Fagan, A. A., & Najman, J. M. (2005). The relative contributions of parental and sibling substance use to adolescent tobacco, alcohol, and other drug use. *Journal of Drug Issues*, *35*, 869–883. doi:10.1177/002204260503500410.

Furman, W., & Buhrmester, D. (1985). Children's perceptions of the qualities of sibling relationships. *Child Development*, *56*, 448–461. doi:10.2307/1129733.

Gardner, M., & Steinberg, L. (2005). Peer influence on risk taking, risk preference, and risky decision making in adolescence and adulthood: An experimental study. *Developmental Psychology*, *41*, 625–635. doi:10.1037/0012-1649.41.4.625.

Garlow, S. J., Rosenberg, J., Moore, J. D., Haas, A. P., Koestner, B., Hendin, H., & Nemeroff, C. B. (2008). Depression, desperation, and suicidal ideation in college students: Results from the American Foundation for Suicide Prevention College Screening Project at Emory University. *Depression and Anxiety*, *25*, 482–488. doi:10.1002/da.20321.

Griffin, K. W., & Botvin, G. J. (2010). Evidence-based interventions for preventing substance use disorders in adolescents. *Child and Adolescent Psychiatric Clinics of North America*, *19*, 505–526. doi:10.1016/j.chc.2010.03.005.

Hamaker, E. L., Kuiper, R. M., & Grasman, R. P. P. P. (2015). A critique of the cross-lagged panel model. *Psychological Methods*, *20*, 102–116. doi:10.1037/a0038889.

Hirschi, T. (1969). *Causes of delinquency*. Berkeley: University of California Press.

Hopfer, C. J., Crowley, T. J., & Hewitt, J. K. (2003). Review of twin and adoption studies of adolescent substance use. *Journal of the American Academy of Child & Adolescent Psychiatry*, *42*, 710–719. doi:10.1097/01.CHI.0000046848.56865.54.

Johnson, D. R., & Young, R. (2011). Toward best practices in analyzing datasets with missing data: Comparisons and recommendations. *Journal of Marriage and Family*, *73*, 926–945. doi:10.1111/j.1741-3737.2011.00861.x.

Kendler, K. S., Gardner, C., & Dick, D. M. (2011). Predicting alcohol consumption in adolescence from alcohol-specific and general externalizing genetic risk factors, key environmental exposures, and their interaction. *Psychological Medicine*, *41*, 1507–1516.

Kim, J., McHale, S. M., Crouter, A. C., & Osgood, D. W. (2007). Longitudinal linkages between sibling relationships and adjustment from middle childhood through adolescence. *Developmental Psychology*, *43*, 960–973. doi:10.1037/0012-1649.43.4.960.

Low, S., Shortt, J. W., & Synder, J. (2012). Sibling influences on adolescent substance use: The role of modeling, collusion, and conflict. *Development and Psychopathology*, *24*, 287–300. doi:10.1017/S0954579411000836.

McGue, M., & Iacono, W. G. (2009). Siblings and the socialization of adolescent deviance: An adoption study approach. In K. McCartney & R. Weinberg (Eds.), *Experience and development: A festschrift to honor Sandra W. Scarr* (pp. 179–201). London, England: Taylor & Francis.

McGue, M., Keyes, M., Sharma, A., Elkins, I., Legrand, L., Johnson, W., & Iacono, W. G. (2007). The environments of adopted and non-adopted youth: Evidence on range restriction from the Sibling Interaction and Behavior Study (SIBS). *Behavior Genetics*, *37*, 449–462. doi:10.1007/s10519-007-9142-7.

McGue, M., Sharma, A., & Benson, P. (1996). Parent and sibling influences on adolescent alcohol use and misuse: Evidence from a U.S. adoption cohort. *Journal of Studies on Alcohol*, *57*, 8–18.

Muthén, L.K. and Muthén, B.O. (1998–2017). Mplus User's Guide. Eighth Edition. Los Angeles, CA: Muthén & Muthén.

Patterson, G. R., Dishion, T. J., & Bank, L. (1984). Family interaction: A process model of deviancy training. *Aggressive Behavior*, *10*, 253–267.

Rende, R., Slomkowski, C., Lloyd-Richardson, E., & Niaura, R. (2005). Sibling effects on substance use in adolescence: Social contagion and genetic relatedness. *Journal of Family Psychology*, *19*, 611–618. doi:10.1037/0893-3200.19.4.611.

Rowe, D. C., & Gulley, B. (1992). Sibling effects on substance abuse and delinquency. *Criminology*, *30*, 217–233.

Samek, D. R., Hicks, B. M., Keyes, M. A., Bailey, J., McGue, M., & Iacono, W. G. (2015). Gene – environment interplay between parent-child relationship problems and externalizing disorders in adolescence and young adulthood. *Psychological Medicine*, *45*, 333–344. doi:10.1017/S0033291714001445.

Samek, D. R., Hicks, B. M., Keyes, M. A., McGue, M., & Iacono, W. G. (2017). Antisocial peer affiliation and externalizing disorders: Evidence for gene × environment × development interaction. *Development and Psychopathology*, *29*, 155–172. doi:10.1017/S0954579416000109.

Samek, D. R., Keyes, M. A., Hicks, B. M., Bailey, J., McGue, M., & Iacono, W. G. (2014). General and specific predictors of nicotine alcohol dependence in early adulthood: Genetic and environmental influences. *Journal of Studies on Alcohol and Drugs*, *75*, 623–634.

Samek, D. R., McGue, M., Keyes, M., & Iacono, W. G. (2015a). Sibling facilitation mediates the associations between older and younger sibling alcohol use in late adolescence. *Journal of Research on Adolescence*, *25*, 638–651. doi:10.1111/jora.12154.

Samek, D. R., & Rueter, M. A. (2011). Considerations of elder sibling closeness in predicting younger sibling substance use: Social learning versus bonding explanations. *Journal of Family Psychology*, *25*, 931–941. doi:10.1037/a0025857.

Samek, D. R., Rueter, M. A., Keyes, M. A., McGue, M., & Iacono, W. G. (2015b). Parent involvement, sibling companionship, and adolescent substance use: A longitudinal genetically informed design. *Journal of Family Psychology*, *29*(4), 614–623. doi:10.1037/fam0000097.

Scarr, S., & McCartney, K. (1983). How people make their own environments: A theory of genotype→environment effects. *Child Development*, *23*, 424–435.

Substance Abuse and Mental Health Services Administration (SAMHSA) (2014). Results from the 2013 National Survey on Drug Use and Health: Summary of National Findings. NSDUH Series H-48, HHS Publication No. (SMA) 14-4863. Rockville, MD. http://www.samhsa.gov/data/sites/default/files/NSDUHresultsPDFWHTML2013/Web/NSDUHresults2013.pdf.

Slomkowski, C., Rende, R., Conger, K. J., Simons, R. L., & Conger, R. D. (2001). Sisters, brothers, and delinquency: Evaluating social influence during early and middle adolescence. *Child Development*, *72*, 271–283.

Trim, R. S., Leuthe, E., & Chassin, L. (2006). Sibling influence on alcohol use in a young adult, high-risk sample. *Journal of Studies on Alcohol*, *67*, 391–398.

Verhulst, B., Neale, M. C., & Kendler, K. S. (2014). The heritability of alcohol use disorders: A meta-analysis of twin and adoption studies. *Psychological Medicine*, *45*, 1061–1072. doi:10.1017/S0033291714002165.

White, H. R., Labouvie, E. W., & Papadaratsakis, V. (2005). Changes in substance use during the transition to adulthood: A comparison of college students and their noncollege age peers. *Journal of Drug Issues*, *35*(2), 281–306.

Whiteman, S. D., Jensen, A. C., & Maggs, J. L. (2013). Similarities in adolescent siblings' substance use: Testing competing pathways of influence. *Journal of Studies on Alcohol and Drugs*, *74*, 104–113.

Whiteman, S. D., Jensen, A. C., Mustillo, S. A., & Maggs, J. L. (2016). Understanding sibling influence on adolescents' alcohol use: Social and cognitive pathways. *Addictive Behaviors*, *53*, 1–6. doi:10.1016/j.addbeh.2015.09.007.

Whiteman, S. D., McHale, S. M., & Soli, A. (2011). Theoretical perspectives on sibling relationships. *Journal of Family Theory & Review*, *3*, 124–139. doi:10.1111/j.1756-2589.2011.00087.x.

Whiteman, S. D., Solmeyer, A. R., & McHale, S. M. (2015). Sibling relationships and adolescent adjustment: Longitudinal associations in two-parent African American families. *Journal of Youth and Adolescence*, *44*, 2042–2053. doi:10.1007/s10964-015-0286-0.

Diana R. Samek is an Assistant Professor in the Department of Human Development and Family Studies at Auburn University. She received her PhD in Family Social Science at the University of Minnesota and then went on to complete a 2-year post-doc at the University of Minnesota with Dr.'s McGue and Iacono. Dr. Samek's research interests pertain to substance use and externalizing disorder development in adolescence and young adulthood.

Rebecca J. Goodman is a Doctoral Candidate in the Department of Human Development and Family Studies at Auburn University. She received her MS in Marriage and Family Therapy from the Department of Human Development and Family Studies at Auburn University. Rebecca's research interests pertain to externalizing and internalizing problems with an emphasis on how close relationships are impacted by and impact such problems.

Lucy Riley is a Graduate Student in the Department of Human Development and Family Studies at Auburn University. She completed her BS in Human Development and Family Studies at Auburn University. Lucy's research interests pertain to close relationships, personality, and substance use.

Matt McGue is a Regents Professor in the Department of Psychology at the University of Minnesota. He received his PhD in Psychology from the University of Minnesota. Dr. McGue's research interests pertain to (1) the development of substance use disorders from adolescence to adulthood and (2) normative aging processes and mortality.

William G. Iacono is a Regents Professor and Distinguished McKnight University Professor in the Department of Psychology at the University of Minnesota. He received his PhD in Psychology from the University of Minnesota. Dr. Iacono's research interests pertain to the development and etiology of common mental disorders, including substance use, antisocial, and major depressive disorders.