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Directional Relationships Between Alcohol Use and Antisocial Behavior Across Adolescence

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Abstract

Background—The co-occurrence of alcohol use and antisocial behavior is well established, but different hypotheses exist regarding the direction of effects between the 2 behaviors. We used longitudinal data to examine the directional relationship between the 2 behaviors across adolescence.

Methods—A cross-lagged model was applied to longitudinal data from the Avon Longitudinal Study of Parents and Children. The sample used in the present study consisted of 4,354 females and 3,984 males. Alcohol use and antisocial behavior were measured with multiple items collected at 12, 13, 15, and 17 years of age.

Results—Both alcohol use and antisocial behavior were highly stable, as evidenced by highly significant autoregressive paths. Regarding the cross-lagged paths, neither behavior was predictive of the other during early adolescence (between ages 12 and 13). During mid-to late adolescence (from ages 13 to 17), antisocial behavior was predictive of subsequent alcohol use. Alcohol use was predictive of antisocial behavior in late adolescence (between ages 15 and 17), although this relationship was mainly driven by males and was not significant in the female subgroup.

Conclusions—The result generally supported the direction from antisocial behavior to alcohol use, especially during mid-to late adolescence. However, there was also a suggestion that the direction of relationship between the 2 behaviors changes across adolescence. The results highlight the importance of considering developmental stages to understand the directional relationships between the 2 behaviors.

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SUPPORTING INFORMATION
Additional Supporting Information may be found in the online version of this article:
Table S1. Item parameters of alcohol use items from Model 2.
Table S2. Item parameters of antisocial behavior items from Model 2.

Keywords

ALSPAC; Alcohol Use; Antisocial Behavior; Directional Relationship; Longitudinal Design

The co-occurrence of antisocial behavior with alcohol use is one of the most robust findings in the alcohol field (Armstrong and Costello, 2002; Molina et al., 2002; Moss and Lynch, 2001; Sanford, 2001). For example, in a review of studies on adolescent substance use/abuse and psychiatric comorbidity (Armstrong and Costello, 2002), conduct disorder was the most commonly diagnosed psychiatric condition among adolescents who used or abused alcohol and other drugs. In another study, conduct disorder was the only diagnosis that showed a significant association with alcohol problems in both men and women (Moss and Lynch, 2001).

Developmentally, antisocial behavior precedes alcohol use (Kuperman et al., 2001), and, more importantly, antisocial behavior in early adolescence and childhood is an important predictor of alcohol-related problems in late adolescence and in early adulthood (Englund et al., 2008; Merline et al., 2008; Windle, 1990). This may suggest a causal relationship from antisocial behavior to alcohol use. However, there is also support for different types of directional hypotheses between the 2 behaviors. Researches that focused on the relatively short-term pharmacological (disinhibitory) effects of alcohol in the context of experimental studies generally supported the effect of alcohol to cause or aggravate antisocial behavior (Bushman and Cooper, 1990; Cherek et al., 1985; Miczek et al., 2004). In addition, several longitudinal studies have also found longer term effects of alcohol use on antisocial behavior (Brook et al., 1998; Ellickson et al., 2003; Maldonado-Molina et al., 2011; Resnick et al., 2004) due to chronic damage to the central nervous system (Howard, 2006) and/or impaired social functioning (Ellickson et al., 2003) associated with extended alcohol use. It is also possible that the relationship is reciprocal (White et al., 1999).

Another possibility is that the 2 behaviors co-occur due to a common set of etiological factors. This has been supported by phenotypic and genetic studies. Studies on the phenotypic covariance structure of comorbid psychiatric disorders have consistently reported higher order internalizing and externalizing factors among individual disorders (Krueger et al., 1998, 2002). In these studies, the externalizing factor included alcohol and other substance use disorders and antisocial behavior (including conduct disorder and antisocial personality disorder). The externalizing factor was distinct from the internalizing factor, which can be divided into 2 subfactors: distress and fear. The distress factor included major depression, dysthymia, and generalized anxiety disorder, and the fear factor included phobic and panic disorders (Krueger, 1999; Watson, 2005). Analyses of genetically informative data have suggested that a shared genetic liability contributes to the common externalizing factor (Dick et al., 2005; Kendler et al., 2003; Krueger et al., 2002; Slutske et al., 1998). Association studies have found candidate genes (e.g., *GABRA2* and *CHRM2*) that are associated with both conduct/behavior problems and alcohol use/misuse (Dick et al., 2006, 2008, 2009).

Longitudinal data provide an opportunity to test directional relationships from earlier events to later events in cases where experimental manipulation is not possible. We are aware of 2

previous cross-lagged analyses of the relationship between alcohol use and antisocial behavior during adolescence. In a study of 1,380 adolescents measured at ages of 12, 15, and 18 (White et al., 1993), aggression at age 12 predicted alcohol use and alcohol-related aggressive behaviors at 15, but alcohol use at either 12 or 15 years of age did not predict aggressive behaviors at 15 or 18 years of age, respectively. In another study that followed 2,586 adolescents at ages 11, 13, and 15 years (Young et al., 2008), the cross-lagged paths from antisocial behaviors to alcohol use were significant at all time points, but no path from alcohol use to antisocial behaviors was significant. Accordingly, both studies supported the effect of antisocial behavior on subsequent alcohol use, but did not provide support for the effects of alcohol use on subsequent antisocial behavior.

The relationship between alcohol use and antisocial behavior may not necessarily be the same in males and females. Sex differences in cross-lagged relationships were previously observed (Silberg et al., 2003; Young et al., 2008). In Silberg and colleagues (2003), the cross-lagged correlation between early alcohol use and later conduct disorder was noticeably higher in males than in females (0.25 in males and 0.17 in females). Young and colleagues (2008) observed a cross-lagged coefficient from antisocial behavior to alcohol use between ages 13 and 15 that was larger in males compared to females (0.23 for males and 0.11 for females). Although differences in the cross-lagged relationships were observed in these studies, sex differences were not formally tested (Silberg et al., 2003; Young et al., 2008), or the model could not be fit in the female subsample due to the low prevalence of antisocial behavior (White et al., 1993). Studies of sex differences in the comorbidity of alcohol use and antisocial behavior have yielded mixed results. Alcoholism subtypes that are characterized by high antisociality are generally overrepresented in alcoholic males as compared to alcoholic females (Epstein et al., 2002; Moss et al., 2007; Pombo and Lesch, 2009). However, the relationship between alcohol use disorder and antisocial behaviors was not particularly stronger in men in recent studies that adjusted for socioeconomic status and other comorbid psychiatric conditions (Dawson et al., 2010; Goldstein et al., 2012). Furthermore, sex differences in the prevalence of alcohol use disorders and comorbidity with antisocial behavior have not necessarily been replicated in adolescent samples (Johnston et al., 2012; Moffitt et al., 2001; Young et al., 2002). To fill this gap in the literature, we tested for sex differences in the relationships between the 2 behaviors using multiple group structural equation modeling in a sample that was sufficiently powered to detect sex differences.

In this study, we applied a cross-lagged model to measures of alcohol use and antisocial behavior from the Avon Longitudinal Study of Parents and Children (ALSPAC) to examine the directional relationships between the 2 behaviors. ALSPAC is a large population-based sample that has followed a cohort of more than 10,000 children since their mothers were pregnant. Here, we used measures of alcohol use and antisocial behavior collected at 12, 13, 15, and 17 years of age to examine the interrelationship between antisocial behavior and alcohol use across this age range. This represents, to our knowledge, the largest cross-lagged analysis to examine the directional relationships between antisocial behavior and alcohol use to date. The sample size and prevalence rates of the 2 behaviors were large enough to allow us to formally test potential sex differences in the relationships between the 2 behaviors.

MATERIALS AND METHODS

Sample

The Avon Longitudinal Study of Parents and Children (ALSPAC) is an ongoing population-based prospective study designed to understand the genetic and environmental factors that influence health and development. All pregnant women identified as residing in Bristol and the surrounding areas of South West England with an expected date of delivery between April 1, 1991 and December 31, 1992 were invited to participate. Among 20,248 eligible pregnancies during 1990 to 1992, the mothers of 14,541 pregnancies (71.8%) were enrolled, with 13,988 live infants at 1 year from birth. Postnatal recruitment was conducted to further increase the enrollment rate and to improve the representativeness of the ALSPAC sample. Postnatal recruitment efforts at ages 7 to 18 years added 713 children (4.85% of overall ALSPAC sample) from 706 pregnancies yielding total of 14,701 live-born children from 15,247 enrolled pregnancies (75.3%) (Boyd et al., 2013). Please note that the study website contains details of all the data that are available through a fully searchable data dictionary at "http://www.bris.ac.uk/alspac/researchers/data-access/data-dictionary."

We used a subset of the ALSPAC sample for which measures of alcohol use and antisocial behavior were available at 12, 13, 15, and 17 years of age. Participants' average ages at assessment were 12.8, 13.8, 15.5, and 17.8 years for alcohol use, and 12.8, 13.9, 15.5, and 17.8 for antisocial behavior. Of 8,338 adolescents who had either alcohol use or antisocial behavior data at 1 or more measurement occasions and had nonmissing responses on sex were included in our analysis (Table 1). Our sample included 381 postnatally recruited participants (4.57%), which is similar proportion of postnatal recruitment in the overall ALSPAC sample (4.85%). Among included participants, 4,354 (52.2%) were females and 3,984 (47.8%) were males. Descriptive statistics of key demographic variables for the overall ALSPAC sample and individuals included in this study are summarized in Table 2. Compared to the overall ALSPAC sample, individuals included in this study were more likely to (i) be female, (ii) be White, and (iii) have parents with professional occupations and college degree or higher education levels. Ethical approval for the study was obtained from the ALSPAC Ethics and Law Committee and the Local Research Ethics Committees.

Measures

Alcohol use and related problems were measured by computerized questionnaires during in-person clinic sessions. Items that measured alcohol use and related problems were adapted from the Semi-Structured Assessment of the Genetics of Alcoholism interview, developed by the Collaborative Study on the Genetics of Alcoholism (Bucholz et al., 1994; Hesselbrock et al., 1999). These items corresponded to the Diagnostic and Statistical Manual of Mental Disorders 4th Edition (DSM-IV); American Psychiatric Association, 1994 criteria of alcohol abuse and dependence. Antisocial behavior items were adapted from the Edinburgh Study of Youth Transitions and Crime (ESYTC) (Smith and McVie, 2003) and represented various domains of delinquent behaviors, such as theft, violence, and truancy. At ages 12, 15, and 17, the same computerized questionnaire protocol that was used for alcohol use was used to measure antisocial behavior during in-person clinic sessions. At age 13, measures of antisocial behavior were not available from the same computerized

questionnaire, and we instead used antisocial behavior data collected by mailed questionnaire, which was administered when participants' average age was 13.9 years. Some items were excluded from the analyses because of low endorsement rates, which caused convergence problems with parameter estimation. The measurement items used in this study are listed in Tables 3 and 4 for alcohol use and antisocial behavior, respectively.

Statistical Analysis

Before applying a cross-lagged model to the data, we examined the unidimensionality of the alcohol use and antisocial behavior items at each occasion using exploratory factor analysis (EFA). We also examined the mean and covariance structure of the alcohol use and antisocial behavior factors by fitting a confirmatory factor analysis (CFA) with unstructured factor means and covariance matrix. This model allows the estimation of the mean and covariance of factors of alcohol use and antisocial behavior with the minimal number of parameter constraints that is required to identify the model (Mehta et al., 2004; Millsap and Yun-Tein, 2004). We then fit cross-lagged models to examine the directional relationship between the 2 behaviors.

The cross-lagged model that is used in our study is illustrated in a path diagram in Fig. 1 for 2 time points. Factors for alcohol use (ALC) and antisocial behavior (ASB) were measured by multiple items at each occasion. The cross-lagged model estimates cross-lagged paths, from 1 factor measured earlier to another factor measured later, as well as autoregressive paths, from a factor measured earlier to the same factor measured later. Cross-lagged paths then represent the effects of a preceding factor to another subsequent factor after accounting for the autoregressive effect on itself. In cross-lagged analyses, it is desirable to have equivalently measured factors across time for more meaningful interpretation of path coefficients. This requirement has been commonly met using the same items over time to measure latent variables and setting their measurement parameters equal across time (White et al., 1993; Young et al., 2008). However, this strategy is not applicable to the ALSPAC data because the measures of alcohol use and antisocial behavior varied over time. Accordingly, we used the item response theory approach to calibrate alcohol use and antisocial behavior factors to the equivalent scales across measurement occasions (McArdle et al., 2009). Setting measurement parameters of common items equal across time calibrates the measures of latent variables by different sets of indicators across time to a commensurate scale.

We examined the equivalency of the relationship between alcohol use and antisocial behavior between sexes using multiple-group analyses. Examining the equivalency of the directional relationship between the 2 behaviors across sex involves comparing 2 sets of parameters: path coefficients (cross-lagged and autoregressive paths) and the measurement parameters (factor loadings and thresholds for categorical indicators) of ALC and ASB factors. Path coefficients, especially of the cross-lagged paths across time points, estimate the strength of the longitudinal relationship between the 2 behaviors. Even when the path coefficients are equivalent across sexes, the relationship between the 2 behaviors may not be comparable if the measurements of alcohol use and antisocial behavior are not equivalent across sexes. Thus, when we examined the equivalency of the path coefficients, we also

examined the equivalency of the measurement parameters of ALC and ASB factors. We fit multiple-group cross-lagged models with male and female participants as subgroups. Models with and without equality constraints on path coefficients and measurement parameters were compared and their differences of chi-squared statistics were tested. Significant differences in chi-squared statistics between models with and without across-group equality constraints indicate that the parameters that are constrained equal across groups may not be appropriate. Parameters were estimated by weighted least square estimator using Mplus version 7 (Muthén and Muthén, 2012).

Attrition of participants is inevitable in longitudinal data collection. If participants who missed follow-up assessments are systematically different in the measured factors from the participants with full data, the assumptions that Mplus' weighted least square estimator relies on are violated (Asparouhov and Muthén, 2010). To check the appropriateness of this assumption, we tested whether the factor models of alcohol use and antisocial behavior at each point are equivalent across individuals who did and did not miss subsequent measurements by conducting multiple-group CFA with individuals with or without the subsequent measurements as subgroups at each occasion.

RESULTS

EFA of the alcohol use and antisocial behavior items at each measurement occasion indicated that a single factor could reasonably be assumed for each set of alcohol use and antisocial behavior items at each time point. For alcohol use items, the ranges of fit indices of single factor models were [0.992, 0.996] for comparative fit index (CFI), [0.988, 0.995] for Tucker-Lewis index (TLI), and [0.036, 0.071] for root mean square error of approximation (RMSEA). For antisocial behavior items, the ranges of fit indices were [0.942, 0.992] for CFI, [0.935, 0.991] for TLI, and [0.016, 0.054] for RMSEA. In addition, from multiple-group CFAs at each measurement occasion, no significant differences were observed in the parameters of factor models between the subgroups of individuals with and without subsequent assessments (*p*-values of chi-squared difference tests were between 0.1281 and 0.6104), indicating that this assumption for the weighted least square estimator was not violated. Table 5 summarizes means and covariance matrices of the ASB and ALC factors from different ages estimated from a CFA with unstructured means and covariance matrix. Means of ASB factors increased from age 12 to age 15 and declined between ages 15 and 17. Males had higher levels of antisocial behavior than females at all ages. Means of ALC factors increased between ages 12 and 17 in both females and males without noticeable sex differences. The variances of both ASB and ALC factors decreased throughout the included age range.

The difference of chi-squared statistics between the measurement invariant model, in which measurement parameters (factor loadings and thresholds) are constrained equal between males and females, and the measurement noninvariant model was significant ($\Delta\chi^2$ = 305.425, $\Delta df = 124$, $p < 0.001$). This can indicate that measurement parameters between the subgroups are not equivalent, and alcohol use and antisocial behavior were differentially measured in male and female participants. However, the chi-squared difference test is prone to type I error especially when sample size is this large. In addition, fit indices indicated that

the measurement invariant model fit well to the data (CFI = 0.960, TLI = 0.961, RMSEA [90% CI] = 0.018 [0.017, 0.018]). In fact, the measurement invariant model fit slightly better than the measurement noninvariant model in terms of fit indices (CFI = 0.957, TLI = 0.957, RMSEA [90% CI] = 0.019 [0.018, 0.019]). Thus, in the following analyses, measurement parameters were constrained to be equal across the sexes to ensure equivalent measurement of alcohol use and antisocial behavior factors in male and female subgroups.

Tables 6 and 7 summarize the standardized path coefficients and correlations from cross-lagged models fit to the ALSPAC data. In Model 1 (Table 6), path coefficients were constrained equal across male and female subgroups. Autoregressive paths indicated that both ASB and ALC factors were highly stable over time. All autoregressive paths were highly significant, and preceding ALC or ASB factors were the strongest predictors of its subsequent factors. Cross-lagged paths showed different patterns of the relationship at different ages. Neither the ASB-to-ALC nor the ALC-to-ASB path was supported between ages 12 and 13. From ages 13 to 17, ASB-to-ALC paths were supported (0.274, CI = [0.221, 0.327], $p < 0.001$ between ages 13 and 15, and 0.124, CI = [0.067, 0.181], $p < 0.001$ between ages 15 and 17). Between ages 15 and 17, the ALC-to-ASB path was also supported (0.116, CI = [0.043, 0.189], $p = 0.002$). Residuals were strongly correlated at all occasions and showed an increasing trend through ages 13 to 17 (0.239 at age 13, 0.455 at age 15, and 0.648 at age 18). Strong residual correlation indicated that alcohol use and antisocial behavior were still associated with each other after accounting for preceding alcohol use and antisocial behavior.

In Model 2 (Table 7), path coefficients were allowed to vary across male and female subgroups, while other parameters, including measurement parameters and cross-sectional residual correlations, were constrained to be equal across the sexes. The patterns of path coefficients from male and female subgroups were mostly similar to those from Model 1. However, a notable difference between male and female subgroups was observed for the ALC-to-ASB path between ages 15 and 17 (underlined). This path was significant in Model 1 and in the male subgroup of Model 2, but was not significant in the female subgroup. However, this difference did not result in a significant chi-squared difference between Model 1 and Model 2 ($\Delta\chi^2 = 11.146$, $\Delta df = 12$, $p = 0.5165$).

DISCUSSION

We examined the directional relationships between alcohol use and antisocial behavior by applying a cross-lagged model to longitudinal data from ALSPAC. This study is, to our knowledge, currently the largest cross-lagged analysis of the directional relationships between alcohol use and antisocial behavior. The large sample size, along with measures covering various domains of the 2 behaviors, also provided a rare opportunity to test potential sex differences in the relationships between the behaviors. The results indicated that the relationship between alcohol use and antisocial behavior might change across adolescence. During early adolescence (between ages 12 and 13), neither alcohol use nor antisocial behavior predicted subsequent measures of one another. Early antisocial behavior was predictive of subsequent alcohol use during mid-to late adolescence (from ages 13 to 17). However, alcohol use was only predictive of antisocial behavior during late adolescence

(between ages 15 and 17), and this relationship appeared to be mainly driven by males. The results of the model comparisons indicated that the relationships between alcohol use and antisocial behavior were largely equivalent across the sexes, although a possible sex difference was suggested in late adolescence.

Our observation that antisocial behavior predicted alcohol use (but not vice versa) during mid-to late adolescence is in line with previous results of cross-lagged studies (Silberg et al., 2003; White et al., 1993; Young et al. 2008) and is consistent with the observations that antisocial behavior precedes and predicts alcohol use (Englund et al., 2008; Kuperman et al., 2001; Merline et al., 2008; Windle, 1990). The result may support the “susceptibility” hypothesis, which posits that predispositions toward antisocial activities lead a person to choose situations that encourage heavy drinking (Bushman and Cooper, 1990; Graham et al., 1998; White et al., 1993). Although we did not find robust evidence for an association of alcohol use with subsequent antisocial behavior, we note that previous findings on the disinhibitory effects of alcohol on antisocial behavior and aggression largely come from experimental settings that focused on the immediate effect of alcohol on one’s behavior (Bushman and Cooper, 1990; Cherek et al., 1985; Miczek et al., 2004). Cross-lagged analyses, including our study, have focused on relatively longer term effects, mostly over a year (White et al., 1993; Young et al., 2008). Studies that reported longer term effects of alcohol use on antisocial behavior (Brook et al., 1998; Ellickson et al., 2003; Maldonado-Molina et al., 2011; Resnick et al., 2004) have examined antisocial behavior measured in early adulthood as a consequence of earlier alcohol use.

We did not find a significant effect of alcohol use on antisocial behavior in early- to mid-adolescence. This may suggest that adolescent alcohol use from ages 12 to 15 is not yet associated with the spectrum of negative outcomes (including antisocial behavior) that are evidenced later in adolescence. Between ages 15 and 17, we found significant effects from alcohol use to antisocial behavior as well as from antisocial behavior to alcohol use. Several factors may contribute to the emergence of the effects from alcohol use to antisocial behavior during later adolescence. First, alcohol use might reach the level that can result in long-term negative consequences during late adolescence. As seen in Table 5, the level of alcohol use steadily increased from ages 12 to 17. Alcohol use during early- to mid-adolescence (from ages 12 to 15) might not have reached the level that could cause negative effects. However, during late adolescence (from ages 15 to 17), an elevated level of alcohol use might be sufficient to cause long-term negative consequences by damaging one’s central nervous system (Howard, 2006) or by impairing social functioning (Ellickson et al., 2003). Second, increased alcohol use might prevent the desistance of antisocial behavior during late adolescence. The period between ages 16 and 20 is a rich developmental period that is characterized by increased responsibility and tasks to accomplish that are important for a successful transition to adulthood (Brown et al., 2008). These changes are not compatible with antisocial lifestyles, and the normative trajectories of antisocial behavior during late adolescence generally follow a decreasing trend (Moffitt, 1993). However, elevated alcohol use during this period may keep an adolescent from desisting from antisocial behavior by interfering with his/her ability to manage developmental demands (Hussong et al., 2004).

The directional relationships suggested in this study do not completely rule out other types of relationships between the 2 behaviors. First, a cross-lagged model based on retrospective measures may not be able to capture a short-term disinhibitory effect of alcohol on antisocial behavior. Evidence from experimental studies indicates that alcohol can increase aggression and violence (Bushman and Cooper, 1990; Cherek et al., 1985; Miczek et al., 2004). Highly significant residual correlations between alcohol use and antisocial behavior may also indicate such short-term or cross-sectional relationships between the 2 behaviors, but the directional relationship between residuals could not be included in the model without fixing other parameters to a constant.

Second, alcohol use and antisocial behavior may share common causes. As discussed previously, antisocial behavior and alcohol use are part of a broader externalizing behavior factor (Krueger et al., 1998, 2002). It is also known that common genetic influences contribute to a spectrum of correlated externalizing behaviors (Dick et al., 2005, 2008, 2009; Kendler et al., 2003; Krueger et al., 2002; Slutske et al., 1998), and that genetic associations with these behaviors may change across development. For example, variants in the *GABRA*2 gene are associated with conduct disorder during childhood, and then alcohol problems beginning in late adolescence through adulthood (Dick et al., 2006, 2013). This suggests that genetic predispositions may manifest differently at different ages, which may be due to environmental changes such as greater autonomy and greater opportunities to express those predispositions. This may explain the sequential expression of antisocial behavior and alcohol use and could provide an alternative explanation for the directional relationships between the 2 behaviors found here. As the field continues to identify genes associated with alcohol problems and antisocial behavior, future models that incorporate genotypic information that is available in the ALSPAC sample could be used to estimate the directional relationships between the 2 behaviors over and above their shared genetic liability.

Although most items used in this study were adopted from previously established systems, such as DSM-IV and ESYTC, items used in our study may not perfectly map onto any of these systems due to item exclusions and availabilities at different measurement occasions. In addition, the results of our study should be interpreted in terms of the relationships between the latent factors measured by alcohol use and antisocial behavior items, not the relationships between the diagnoses of alcohol dependence and conduct disorder. We used available items as indicators of continuous latent variables in our cross-lagged models. Thus, the diagnostic criteria for DSM-IV alcohol dependence do not apply to the sets of items used in our study. ESYTC, from which most antisocial behavior items were adopted, was not developed for diagnostic purposes.

Differences in the measurements of alcohol use and antisocial behavior items across time may have affected the relationship between the 2 behaviors observed in this study. We aligned the scales of factors measured by different items across time by constraining the measurement parameters to be equal for items that overlapped across time. This method permits the estimation of factors equivalent across time when measurement invariance holds. Measurement invariance across time can be tested by comparing models with or without equality constraints on measurement parameters if there are enough overlapping

items to identify the measurement model (Millsap and Yun-Tein, 2004). Unfortunately, our data did not allow the test of measurement invariance across time due to insufficient number of overlapping items, especially at early ages. Thus, we cannot completely rule out the possibility that the relationship between alcohol use and antisocial behavior was affected by noninvariant measurement of the factors across time.

The characteristics of the sample included in our analyses may limit the generalization of the directional relationship between alcohol use and antisocial behavior suggested in this study. Although the ALSPAC sample was designed to be representative of epidemiological characteristics of the area of South West England (Bristol area), residents in this area were more likely to be White and to have higher socioeconomic status compared to the overall British population. Furthermore, ALSPAC participants were more likely to have higher socioeconomic status compared to the population of the recruitment area (Fraser et al., 2012). In addition, the socioeconomic characteristics of the sample included in this study were still not completely equivalent with that of the overall ALSPAC sample (Table 2). Adolescents included in this study tended to be White, female, and to have parents who had higher educational achievement and higher status professional occupations compared to the overall ALSPAC sample. This may limit generalizability of results from our study to other populations given the evidence that socioeconomic status is related to both alcohol use and antisocial behaviors in the ALSPAC sample (Heron et al. 2013). We might expect that the more constrained variability introduced by the attrition of more disadvantaged subjects could have weakened the associations that potentially exist at the population level.

In conclusion, the results from the current study emphasize the importance of considering developmental stages to examine the directional relationship between alcohol use and antisocial behavior, as we observed different patterns of relationships between the 2 behaviors at different ages. Although the overall pattern of associations between alcohol use and antisocial behavior was mostly equivalent between males and females, the significant effect from alcohol use to antisocial behavior during late adolescence was primarily driven by males. This might indicate that the patterns of the directional relationship between antisocial behavior and alcohol use shift between adolescence and adulthood and begin to evidence sex differences. ALSPAC's ongoing data collection will allow us to investigate how the relationships between the 2 behaviors changes during the transition to adulthood and whether sex difference observed in our study persists beyond adolescence.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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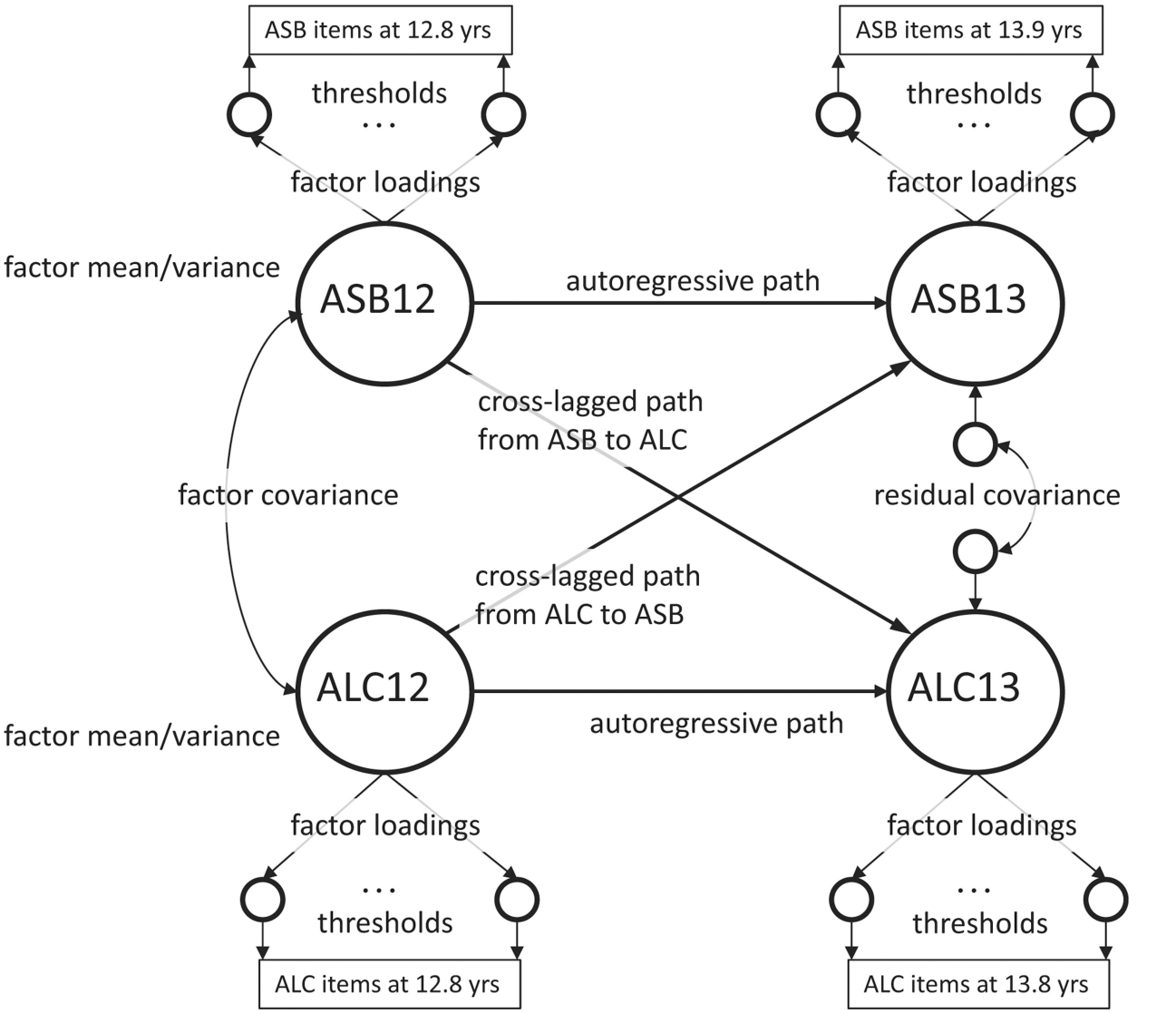

Fig. 1.
The cross-lagged model of alcohol use and antisocial behavior with ages 12 and 13.

Table 1

Number of Individuals and Measurement Items at Each Age

	Antisocial behavior		Alcohol use	
Age	***n***	**No. of items**	***n***	**No. of items**
12.8	6,738	9	3,628	3
13.8/13.9[a]	6,172	10	3,558	3
15.5	3,325	16	3,399	15
17.8	3,952	6	4,202	14

[a] Age 13 alcohol use and antisocial behavior were measured at 13.8 and 13.9 years, respectively.

Table 2

Demographics of Samples Included in this Study and Overall ALSPAC Sample

Demographics	In this study (%)	ALSPAC (%)
Sex		
Male	3,984 (47.8)	7,573 (51.5)
Female	4,354 (52.2)	7,121 (48.5)
Ethnicity		
Non-White	905 (10.8)	3,034 (20.1)
White	7,443 (89.2)	12,068 (79.9)
Social class-mother		
Professional	461 (7.0)	596 (5.9)
Managerial & technical	2,250 (34.3)	3,180 (31.4)
Skilled: nonmanual	2,773 (42.2)	4,326 (42.8)
Skilled: manual	440 (6.7)	791 (7.8)
Partly skilled	536 (8.2)	997 (9.9)
Unskilled	102 (1.6)	221 (2.2)
Armed forces	2 (<0.1)	4 (<0.1)
Social class-father		
Professional	900 (12.9)	1,205 (10.9)
Managerial & technical	2,504 (35.9)	3,749 (34.0)
Skilled: nonmanual	830 (11.9)	1,199 (10.9)
Skilled: manual	1,988 (28.5)	3,464 (31.4)
Partly skilled	583 (8.4)	1,078 (09.8)
Unskilled	163 (2.3)	316 (02.9)
Armed forces	11 (0.2)	28 (0.3)
Highest education-mother		
Nondegree	7,154 (85.5)	13,586 (89.4)
Degree	1,218 (14.5)	1,607 (10.6)
Highest education-father		
Nondegree	6,540 (80.1)	12,531 (85.2)
Degree	1,620 (19.9)	2,181 (14.8)

Table 3

Alcohol Use Items

Items	Key words[a]
12 years	
Had 3 or more drinks	3+ drinks
Had whole drink	Whole drink
Maximum number of drinks in a typical week	Typical
13 years	
Had whole drink	Whole drink
Maximum number of drinks in a typical week	Typical
Ever had 3 or more drinks	3+ drinks – ever
15 years	
Spent great deal of a day drinking	Day drinking
Had a blackout	Blackout
Felt the need to cut back or stop	Cut back
Parents/friends complained	Complaints
Had 4 or more drinks	4+ drinks
Continued drinking despite problems	Continued drinking
Used alcohol in dangerous situations	Dangerous situations
Had 5 or more drinks	5+ drinks
Gotten into fights when drinking	Fights
Not done what would usually do	Daily tasks
Had whole drink	Whole drink
Typical drinking	Typical
Had been physically hurt	Physical injury
Had problems with police	Problem with police
Went over limits set	Over limits
17 years	
Spent great deal of day drinking	Day drinking
Had problems with police	Problem with police
Unable to remember what happened the night before	Blackout
Felt the need to cut back or stop	Cut back
Friend/parent/doctor complained	Complaints
Continued despite problems	4+ drinks
Had 6 or more drinks	6+ drinks
Gotten into fights when drinking	Fights
Failed to do what was expected	Daily tasks
Unable to keep up with school work etc.	School
Typical drinking	Typical
Frequency of drinking	Frequency
Has been injured	Physical injury
Unable to stop drinking	Limits

[a] tem parameters (loadings and thresholds) were constrained equal across time for the items with the same key word.

Table 4

Antisocial Behavior Items

Items	Key words[a]
12 years	
Ran away from home and stayed out overnight	Stay out
Stole something, victim not present	Theft
Physically cruel to somebody	Cruelty – personal
Child destroyed/broke something	Damage
13 years	
Deliberately damaged or destroyed property	Damage
Has been rowdy or rude in a public place	Rude
Taken money or something else from school	Theft – school
Taken money or something else from shops	Theft – shops
Skipped school	Truancy
Not paid the correct fare or not paid on a bus or train	Fare
Hit, kicked, or punched someone on purpose	Violence – physical
Written things or sprayed paint on a property	Graffiti
Carried a knife or weapon with them for protection	Weapon
15 years	
Set fire or tried to set fire to something on purpose	Arson
Ignored someone they know on purpose	Bully
Deliberately damaged or destroyed property	Damage
Sold an illegal drug to someone	Drug dealing
Has been rowdy or rude in a public place	Rude
Hit, spat, or thrown stones at someone they know	Beating
Sold something that did not belong to them or stolen	Trade stolen
Stolen something from a shop or store	Theft – shops
Threatened to hurt someone they know	Threat
Traveled on a bus/train without paying	No fare
Ridden in a stolen car/van/motorbike	Vehicle
Hit/kicked/punched a brother, sister, or someone else on purpose	Beating – siblings
Said nasty things to someone they know	Insult
Written things or sprayed paint on property	Graffiti
Carried a knife or other weapon with them	Weapon
17 years	
Damaged or destroyed property	Damage
Sold an illegal drug to someone during last year	Drug dealing
Got in trouble with the police	Police
Was loud, rowdy or unruly in a public place	Rude
Stole something from a shop or store	Theft – shops
Hit, kicked, punched or attacked someone with weapon	Violence – physical

[a] Item parameters (loadings and thresholds) were constrained equal across time for the Items with the same key word.

Table 5

Factor Means and Correlation Matrix by Sex

Correlations	ASB12[a]	ASB13	ASB15	ASB17	ALC12	ALC13	ALC15	ALC17
Male								
ASB12	–	–	–	–	–	–	–	–
ASB13	0.695	–	–	–	–	–	–	–
ASB15	0.670	0.758	–	–	–	–	–	–
ASB17	0.546	0.596	0.732	–	–	–	–	–
ALC12	0.615	0.466	0.412	0.330	–	–	–	–
ALC13	0.468	0.476	0.425	0.374	0.662	–	–	–
ALC15	0.451	0.499	0.633	0.572	0.464	0.613	–	–
ALC17	0.305	0.375	0.448	0.715	0.277	0.371	0.596	–
Mean[b]	0.000	0.272	0.769	0.181	0.000	0.473	1.577	2.264
Variance[c]	1.000	0.896	0.842	0.707	1.000	0.915	0.615	0.544
Female								
ASB12	–	–	–	–	–	–	–	–
ASB13	0.703	–	–	–	–	–	–	–
ASB15	0.574	0.720	–	–	–	–	–	–
ASB17	0.529	0.606	0.721	–	–	–	–	–
ALC12	0.711	0.432	0.356	0.318	–	–	–	–
ALC13	0.537	0.511	0.362	0.321	0.718	–	–	–
ALC15	0.480	0.499	0.620	0.486	0.535	0.618	–	–
ALC17	0.286	0.339	0.438	0.704	0.319	0.361	0.579	–
Mean	−0.443	0.185	0.527	−0.220	0.047	0.511	1.690	2.254
Variance	1.041	0.835	0.750	0.676	0.978	0.921	0.649	0.595

[a] ASB and ALC are factors for antisocial behavior and alcohol use, respectively.

[b] Factor mean with age 12 in males set as the reference with the mean fixed at 0.

[c] Factor variances with age 12 in males set as the reference, with the variance fixed at 1.

Table 6

Parameter Estimates from Model 1[a]

	Estimate	95%CI	*p*
Autoregressive			
ASB12→ASB13[b]	0.787	0.681, 0.893	<0.001
ASB13→ASB15	0.751	0.688, 0.814	<0.001
ASB15→ASB17	0.680	0.609, 0.751	<0.001
ALC12→ALC13[b]	0.673	0.595, 0.751	<0.001
ALC13→ALC15	0.496	0.453, 0.539	<0.001
ALC15→ALC17	0.508	0.461, 0.555	<0.001
Cross-lagged			
ALC12→ASB13	−0.059	−0.177, 0.059	0.319
ALC13→ASB15	0.049	−0.018, 0.116	0.155
ALC15→ASB17	0.116	0.043, 0.189	0.002
ASB12→ALC13	0.063	−0.033, 0.159	0.204
ASB13→ALC15	0.274	0.221, 0.327	<0.001
ASB15→ALC17	0.124	0.067, 0.181	<0.001
Correlation[c]			
ASB12-ALC12	0.673	0.622, 0.724	<0.001
Residual correlation[c]			
ASB13-ALC13	0.239	0.116, 0.362	<0.001
ASB15-ALC15	0.455	0.384, 0.526	<0.001
ASB18-ALC17	0.648	0.579, 0.717	<0.001
Fit indices	χ^2 = 11.421, df = 5,425, p < 0.001		
	CFI = 0.966, TLI = 0.967		
	RMSEA [90%CI] = 0.016 [0.016, 0.017]		

CFI, comparative fit index; RMSEA, root mean square error of approximation; TLI, Tucker-Lewis index.

[a] In Model 1, all parameters were constrained to be equal between the male and female subgroups.

[b] ASB and ALC are factors for antisocial behavior and alcohol use, respectively.

[c] Correlations were estimated at the initial age (age 12), and residual correlations were estimated for the rest of the ages because ALC and ASB factors at ages 13 to 17 were endogenous factors (i.e., dependent latent variables).

Table 7

Parameter Estimates from Model 2[a]

	Male			Female		
Coefficients	**Estimate**	**95%CI**	***p***	**Estimate**	**95%CI**	***p***
Autoregressive						
ASB12→ASB13[b]	0.789	0.658, 0.920	<0.001	0.782	0.664, 0.900	<0.001
ASB13→ASB15	0.746	0.673, 0.819	<0.001	0.757	0.686, 0.828	<0.001
ASB15→ASB17	0.645	0.559, 0.731	<0.001	0.725	0.633, 0.817	<0.001
ALC12→ALC13[b]	0.670	0.564, 0.776	<0.001	0.673	0.573, 0.773	<0.001
ALC13→ALC15	0.497	0.436, 0.558	<0.001	0.498	0.443, 0.553	<0.001
ALC15→ALC17	0.507	0.436, 0.578	<0.001	0.507	0.448, 0.566	<0.001
Cross-lagged						
ALC12→ASB13	−0.062	−0.229, 0.105	0.468	−0.057	−0.202, 0.088	0.446
ALC13→ASB15	0.079	−0.017, 0.175	0.102	0.019	−0.071, 0.109	0.676
ALC15→ASB17	0.156	0.062, 0.250	0.001	0.057	−0.051, 0.165	0.300
ASB12→ALC13	0.047	−0.090, 0.184	0.503	0.078	−0.051, 0.207	0.237
ASB13→ALC15	0.276	0.202, 0.350	<0.001	0.269	0.202, 0.336	<0.001
ASB15→ALC17	0.120	0.036, 0.204	0.005	0.131	0.055, 0.207	0.001
Correlation[c]						
ASB12-ALC12	0.676	0.625, 0.727	<0.001			
Residual correlation[c]						
ASB13-ALC13	0.238	0.115, 0.361	<0.001			
ASB15-ALC15	0.459	0.390, 0.528	<0.001			
ASB18-ALC17	0.649	0.580, 0.718	<0.001			
Fit indices	χ^2 = 12,557.796, df = 5,413, p < 0.001					
	CFI = 0.960, TLI = 0.961					
	RMSEA [90%CI] = 0.017 [0.017, 0.018]					

CFI, comparative fit index; RMSEA, root mean square error of approximation; TLI, Tucker-Lewis index.

[a] In Model 2, autoregressive and cross-lagged paths were allowed to vary between the male and female subgroups, so separate autoregressive and cross-lagged paths by sex are presented.

[b] ASB and ALC are factors for antisocial behavior and alcohol use, respectively.

[c] Correlations were constrained equal across male and female subgroups in Model 2. Correlations were estimated at the initial age (age 12), and residual correlations were estimated at the rest of ages because ALC and ASB factors at ages 13 to 17 were endogeneous factors (i.e., dependent latent variables).