Socioeconomic Status and Adolescent Alcohol Involvement: Evidence for a Gene–Environment Interaction

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ABSTRACT. Objective: Adolescence is an optimal developmental stage for examining the interplay of environmental factors and the genetic risk for alcohol involvement. The current study aimed to examine how socioeconomic status might interact with genetic risk for alcohol involvement among adolescents. **Method:** A total of 839 same-sex adolescent twin pairs (509 monozygotic and 330 dizygotic) from the 1962 National Merit Twin Study completed a questionnaire containing items assessing alcohol involvement. Twins were approximately 17 years old at the time of participation. Parents provided reports of family income and educational attainment. Models were fit examining parental education

and family income as moderators of genetic and environmental influences on alcohol use. **Results:** There was evidence for moderation of genetic and environmental influences on alcohol involvement by family income. For twins with the lowest levels of family income, genetic and shared environmental influences accounted for 50% and 26% of the variance in alcohol involvement, respectively, compared with 2% and 67% of the variance among those at the highest level of income. **Conclusions:** These findings suggest that etiological influences on alcohol involvement vary as a function of an adolescent's socioeconomic status. (*J. Stud. Alcohol Drugs*, 79, 725–732, 2018)

ALCOHOL IS THE MOST WIDELY USED substance among adolescents, with three quarters of high school juniors (75.3%) endorsing lifetime use, and almost half (42.7%) endorsing past-month use (Eaton et al., 2012). Adolescence is also the developmental stage when the contribution of the environment has the greatest impact (Dick, 2011; Polderman et al., 2015; Rose et al., 2001). A meta-analysis of twin studies of alcohol use estimated contributions of genetic, shared, and unique environmental influences to be 40%, 41%, and 19%, respectively, among adolescents compared with 42%, 12%, and 46% among adults (Polderman et al., 2015). The profound impact of the shared environment on alcohol use in adolescence suggests that this is an optimal developmental stage for examining environmental factors and their relationship with genetic risk.

Socioeconomic status (SES) has been studied as an environmental factor that may be related to alcohol use among adolescents. Although some theories suggest that poverty is associated with increased alcohol use (Bursik, 1988), this is not always supported by research. A systematic review of the literature concluded that most studies found no relationship between income and alcohol use in adolescence (Hanson & Chen, 2007), and more recent research suggests that higher (rather than lower) SES is related to increased alcohol use (Grittner et al., 2013; Melotti et al., 2012). When indicators of social status, like parental education, are used instead of

financial resources, an inverse association between SES and alcohol use is more likely to be found (Hanson & Chen, 2007). This suggests that family income and parental education might differentially affect adolescent alcohol use.

Genetic and environmental factors (such as family SES) are important independent contributors to alcohol use among adolescents, but it is likely that their combined interactive effect also contributes to alcohol use. A gene–environment interaction is a phenomenon whereby a protective or risk factor has a differential impact on a phenotype depending on the individual's genetic vulnerability (Young-Wolff et al., 2011). For example, some environmental factors, like socioeconomic disadvantage, may act to limit genetic variability in a trait by imposing a restricted environment that overwhelms genetic predispositions (Bronfenbrenner & Ceci, 1994; Kendler et al., 2012). The social control model (Shanahan & Hofer, 2005), similar to the bioecological model (Bronfenbrenner & Ceci, 1994), would align with this, suggesting that greater genetic influences would be seen in less restricted environments that allow genetic variability to be expressed. Low SES environments would act to decrease heritability and increase contributions of the shared environment to variance in alcohol use. The social control model focuses on restrictions on disposable income associated with low SES, as this would limit the ability to express genetic predispositions to use alcohol.

A competing theory, which focuses on stress associated with a low SES environment, would predict the opposite. The diathesis stress model (South et al., 2017) suggests that a stressful environment would trigger a predisposition for alcohol use. This theory would be supported through finding enhanced genetic influences in stressful or high-risk environments, such as low SES environments (South et al., 2017; Vendiniski et al., 2011). The diathesis stress model

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suggests that genetic effects do not present themselves until the environment is more permissive or conducive to alcohol use (Vendlinski et al., 2011). These competing models provide a framework for understanding how environments might interact with risk to provide protection or elicit greater susceptibility.

In a sample of 25- to 74-year-old twins, Hamdi et al. (2015) examined income and educational attainment as moderators of genetic and environmental influences on amount of alcohol used, frequency of use, and problematic use. Genetic influences on amount of alcohol used were greater for those with lower SES as measured by both education and income, whereas environmental influences were heightened for those with higher SES (Hamdi et al., 2015). SES did not moderate influences on other indicators of alcohol involvement. These findings are more in line with the diathesis stress model, although Hamdi et al. (2015) note that the positive correlation observed between SES and amount of alcohol used would not be expected under the model.

Current study

The current project aimed to build on prior studies by examining social and financial indicators of family SES as moderators of etiological influences on alcohol use among adolescents using data from the 1962 National Merit Scholarship Qualifying Test (NMSQT) twin sample. Although a previous study examined these components of SES as moderators of etiological influences on alcohol use, this was done among adults with a wide range of ages using an individual's own SES, rather than their family of origin's SES (Hamdi et al., 2015). Other studies only examined indicators of educational attainment or achievement (Benner et al., 2014; Timberlake et al., 2007), which does not fully capture SES. Furthermore, as research suggests that the environment has a greater impact on phenotypes among adolescents compared with adults (Dick, 2011; Polderman et al., 2015; Rose et al., 2001), adolescence may be a developmental period when such interactions are especially important. This project will also shed light on competing theories regarding the role of SES in alcohol use: the diathesis stress and social control models.

In prior research using the current sample, differences in family SES did not explain rural moderation of genetic influences on alcohol use among adolescent females (Davis et al., 2017). Genetic influences on alcohol involvement were lower for females in rural areas compared with females living in urban areas. Although those living in rural areas were more disadvantaged than those in urban areas, significant differences in the heritability of alcohol involvement between rural and urban females could not be explained by the SES gap between groups (Davis et al., 2017). Despite the fact that differences in SES did not account for this interaction, SES might moderate genetic or environmental influences on alcohol use.

Method

Participants

The sample consisted of same-sex twin pairs who completed the 1962 NMSQT, a test largely taken by college-bound high school students (Loehlin & Nichols, 1976). Among the twin pairs who were recruited, 1,188 (79%) responded and completed a questionnaire that included questions regarding personality, behavior, and alcohol involvement. Among the respondents were 509 monozygotic (MZ; 293 female and 216 male) and 330 dizygotic (DZ; 195 female and 135 male) twin pairs. Participants were approximately 17 years old, and the sample was overwhelmingly (98%) White, with females slightly overrepresented (58.2%). In addition to the twins' participation, a parent, stepparent, or guardian provided information about the family environment. In almost all cases (92.9%), the twins' mother provided this information. Eighty-eight percent of twin pairs were from intact families. Of the 12% whose parents were no longer together, the majority were from divorced, separated, or remarried families (95%). The remainder reported having a deceased parent.

Measures

Alcohol involvement. Ten items from the twin questionnaire pertained to drinking behaviors (Davis et al., 2017). As these items included a variety of normative and problem-drinking behaviors, exploratory and confirmatory factor analyses were conducted to assess whether items could be summed. Results of the factor analyses in Mplus (Muthén & Muthén, 2010) suggested that a single factor was the most parsimonious solution. Therefore, the ten items were summed to obtain an alcohol composite score (Cronbach's $\alpha = .79$). Alcohol composite scores were pro-rated to account for missing items, and resulting scores were log transformed. Following transformation, skewness and kurtosis were 1.06 and 0.46, respectively.

Parental education. Parental education level was assessed by asking, "What is each parent's highest educational attainment?" Information was obtained for the mother's and father's education. Response options ranged from "8th grade or less" to "graduate or professional degree beyond the bachelor's degree" (Table 1). To create a single parental education variable, the average of the mother's and father's reported educational attainment was calculated. If only one parent's education level was provided, that parent's information was used for the parental education variable. Parental education was treated as a six-level ordinal variable. Seventeen (2%) twin pairs were missing parental education information. For context, in 1962, 28.3% of adults had completed high school, 9.1% had completed some college, 5.9% had completed a 4-year degree, and 3.1% had some post-bacca-

TABLE 1. Characteristics of the 1962 National Merit Twin Study sample

Variable	Prevalence %
Family income	
<\$5,000	11.8
\$5,000–7,499	25.7
\$7,500–9,999	21.4
\$10,000–14,999	23.6
\$15,000–19,999	9.4
\$20,000–24,999	3.0
≥\$25,000	5.1
Maternal education	
8th grade or less	6.6
Part high school	12.8
High school graduate	37.2
Part college/junior college	23.8
College graduate	15.1
Graduate/professional degree	4.5
Paternal education	
8th grade or less	11.0
Part high school	12.0
High school graduate	26.0
Part college/junior college	21.8
College graduate	15.0
Graduate/professional degree	14.1

laureate education (U.S. Department of Commerce, 1963b). Parents of the current sample were more educated on average than the general population.

Family income. Family income was assessed by asking, “What is the family’s income before taxes?” Response options ranged from “less than \$5,000 per year” to “\$25,000 and over” (Table 1). Family income was treated as a seven-level ordinal variable. Of the twin pairs, 62 (7.4%) were missing family income information. More than one tenth (11%) of the sample reported incomes below \$5,000, whereas almost a quarter (23.8%) reported incomes in the range of \$5,000 to \$7,499. At the time of data collection, the average family income in the United States was \$6,000, with 39% of families having incomes over \$7,000 (U.S. Department of Commerce, 1963a). More than half (62.5%) of the current sample had incomes at or above \$7,500, suggesting that high SES families were overrepresented.

Data analysis

Descriptive analyses were conducted using IBM SPSS Statistics for Windows, Version 23 (IBM Corp., Armonk, NY). Structural equation modeling was conducted in Mplus using maximum likelihood estimation (Muthén & Muthén, 2010) to determine proportions of variance in alcohol involvement accounted for by additive genetic (A), shared environmental (C), and unique environmental influences (E; Figure 1). As shown in Figure 1, correlations between additive genetic influences were set to 1.0 for MZ twins and 0.5 for DZ. As shared environmental influences are aspects of the environment twins share, correlations were set to 1.0. Unique environmental influences were uncorrelated. Support

for a gene–environment interaction was evidenced by significant moderation (β_a , β_c , and β_e in Figure 1) of estimates of the *a*, *c*, and *e* paths by SES (Figure 1). Models were fit using both the log-transformed and original alcohol composite; results were consistent across the two sets of analyses. To rule out gene–environment correlation, we regressed out variance in alcohol involvement due to family income or parental education (Purcell, 2001). This removed potential genetic effects shared between alcohol involvement and income/parental education (Purcell, 2002). Models were fit allowing MZ and DZ twins’ regression weights of alcohol involvement on SES to differ (van der Sluis et al., 2012).

Initial models were fit using the full sample and controlling for the effect of sex to have maximal power. Further models were fit to examine whether estimates differed for males and females. Because of scarcity at the upper ends of the distribution, sex-specific models were conducted combining the two highest levels of income or parental education. Wald chi-square tests were conducted to test whether moderation parameters were significant.

Power analyses

Researchers have called for the need to conduct power analyses to aid in the interpretation of findings from gene–environment interaction studies (Hanscombe et al., 2012; Salvatore et al., 2017; van der Sluis et al., 2012). Therefore, we conducted power analyses using OpenMx (Neale et al., 2015) and umx packages (Bates et al., 2016b) within R (R Development Core Team, 2013). Data were simulated with a shared environment component of .3 and a unique environmental component .3. Power analyses consisted of 1,000 simulations with the *p* value set at .05. Power to detect small and large moderation effects was calculated. A small moderation effect was defined as the genetic component ranging from 0.43 to 0.57, whereas a large moderation effect was defined as ranging from 0.3 to 0.7 (Bates et al., 2016a). Calculations indicated that there was inadequate power to detect a gene–environment interaction for the full sample (parental education: large effect = 48%, small effect = 9%; family income: large effect = 45%, small effect = 11%); power was lower in sex-specific models.

Results

Descriptive statistics

Almost two thirds of participants (61.4%) reported alcohol use. Family income was significantly correlated with alcohol involvement ($r = .09$, $p = .002$), but parental education was not ($r = .01$, $p = .63$). Maternal and paternal education were significantly correlated ($r = .56$, $p < .0001$). In addition, average parental education was significantly correlated with income ($r = .41$, $p < .001$). Single parenthood was associ-

FIGURE 1. Path diagram for the full moderation model. SES represents the parental education or family income moderator. SES = socioeconomic status; A = additive genetic variation; C = shared environmental variation; E = unique environmental variation; MZ = monozygotic twins, DZ = dizygotic twins. β_a , β_c , and β_e are the moderation effects of SES on a , c , and e paths, respectively.

ated with lower family incomes ($r = -.26$, $p < .0001$), lower average parental education ($r = -.12$, $p = .001$), and lower paternal education ($r = -.12$, $p = .001$), but was not significantly correlated with alcohol involvement ($r = .06$, $p = .09$) or maternal education ($r = -.07$, $p = .07$).

Gene–environment interaction models

Parental education. Full sample analyses controlled for sex, which was significantly correlated with alcohol involvement ($r = -.37$, $p = .01$). Findings suggested no evidence of moderation of genetic or environmental influences on alcohol involvement by average parental education levels, $\chi^2(3) = 0.42$, $p = .94$. To be thorough, models were fit examining highest level of parental education, maternal education, and paternal education as moderators as well; results were similar across these analyses. An alternative model including nonlinear moderation effects did not significantly improve model fit, $\Delta\chi^2(3) = 2.22$, $p = .53$.

Figure 2 (Panel A) presents a graphical depiction of the A, C, and E components of variance across levels of average parental education based on the moderation model. All components of variance were similar across levels of SES. In the sex-specific model, an omnibus Wald test of all moderation parameters was not significant, $\chi^2(6) = 4.79$, $p = .57$. Although there was no evidence of significant sex differences in moderation parameters, $\chi^2(3) = 4.34$, $p = .23$, estimates of genetic and environmental influences differed significantly for males and females, $\chi^2(3) = 13.71$, $p = .003$.

(Further information on the sex-specific models can be found in supplementary materials.)

Family income. Findings suggested significant moderation of genetic and environmental influences on alcohol involvement by family income, $\chi^2(3) = 21.86$, $p < .0001$. Wald tests of the individual parameters of moderation were conducted, with moderation of genetic, $\chi^2(1) = 5.97$, $p = .01$; shared environmental, $\chi^2(1) = 6.98$, $p = .01$; and unique environmental influences all reaching significance, $\chi^2(1) = 6.57$, $p = .01$. An alternative moderation model including nonlinear effects did not significantly improve model fit, $\Delta\chi^2(3) = 4.19$, $p = .24$.

Figure 2 (Panel B) presents a graphical depiction of the change in A, C, and E components across levels of income. Among those with the lowest family income, genetic factors accounted for half of the variation in alcohol involvement, whereas genetic factors accounted for almost none (2%) of the variation in alcohol involvement for twins with the highest family income. The shared environmental component accounted for approximately a fourth (26%) of the variance in alcohol involvement at the lowest level of family income, whereas at the highest level, the environment accounted for about two thirds (67%) of the variance. The unique environmental component remained relatively consistent. An omnibus Wald test of all the moderation parameters in the sex-specific analyses was not significant, $\chi^2(6) = 4.18$, $p = .65$. Unlike the results for parental education, the main effects, $\chi^2(3) = 1.41$, $p = .70$, and moderation parameters did not significantly differ across sex, $\chi^2(3) = 1.73$, $p = .63$. For both males and females, the additive genetic component

FIGURE 2. Results for the full sample $G \times E$ models. Panel A shows results from the full sample $G \times E$ model for average parental education. This model showed no evidence of significant moderation. Panel B shows results from the full sample $G \times E$ model for family income. This model showed evidence of significant moderation of A, C, and E components of variance. Error bars indicate standard error. *Note:* Sample size provided on figure is the number of twin pairs included in each category.

decreased as levels of income increased. (Additional information on the sex-specific models can be found in supplementary materials.)

Discussion

This study examined whether SES moderated genetic and environmental influences on alcohol involvement among adolescents. Evidence of significant moderation by family income was found, with genetic influences on alcohol involvement decreasing and shared environmental influences increasing with increases in family income. The significant moderation finding provides support for the diathesis stress model, similar to results by Hamdi et al. (2015), suggesting that a low-income environment activates genetic predispositions to alcohol use among adolescents, whereas a high-income environment might protect against genetic predispositions to use. The similarity of the findings in our sample of adolescents assessed in 1962 to the previous study of adults assessed in 1995–1996 (Hamdi et al., 2015) suggests that this may be a robust phenomenon.

The diathesis-stress model posits that genetic influences on alcohol involvement will be greater in a high-risk envi-

ronment, such as a low SES environment (Vendliniski et al., 2011). However, this model also predicts a negative association between SES and alcohol involvement, whereas our study found a small positive association. This is consistent with prior work in the area, which has also found greater genetic influences on alcohol use in lower SES environments and a small positive association between alcohol use and SES (Hamdi et al., 2015).

However, moderation effects found are inconsistent with some prior studies that examined education as a moderator of genetic and environmental influences on alcohol use. Two prior studies conducted using young adult samples found evidence for moderation of environmental influences on alcohol use, rather than genetic influences (Barr et al., 2016; Latvala et al., 2011). Other research comparing same age college and non-college-attending peers found evidence for greater genetic contributions to quantity of use among students (Timberlake et al., 2007). However, these studies were conducted among young adults and examined the individuals' own level of education rather than that of their family of origin.

There was no evidence of significant moderation by parental education levels. However, in the sex-specific analyses,

estimates of genetic and environmental contributions were significantly different for males and females. The pattern of effects among females was in line with the social control model, whereas among males, the opposite pattern emerged. Among males, a low SES environment might provide additional pressure that triggers genetic diathesis to use alcohol, whereas among females, a low SES environment might act as a conservative one in which the opportunity to engage in alcohol use is limited. Research has found that stress-reduction motives for drinking are more important among males than among females (Rutledge & Sher, 2001). Prior research with the current sample examining the impact of rural residency on etiologic influences on alcohol involvement found evidence for the social control model among females (Davis et al., 2017). This might suggest that females living in low income and/or rural environments were subjected to restrictive monitoring on their alcohol use.

These findings suggest that income and education might have different effects on etiological influences on alcohol use. Researchers investigating health inequalities have argued for the importance of distinctions between income and education, as they likely have unique impacts on health (Geyer et al., 2006; Noble et al., 2015). In the case of alcohol use, higher levels of family income might act to decrease restrictions on alcohol use, as adolescents whose families have more disposable income would have access to money to purchase alcohol. Additionally, some prior research has found that adolescents from more advantaged families are at increased risk for alcohol use and dependence, and this association is hypothesized to be the result of increased pressure to achieve and isolation from parents (Luthar et al., 2018). On the other hand, parents with higher education might be better equipped to educate children about effects of alcohol and reduce their use. Research has consistently found that higher parental education is associated with better health outcomes for children (Boyle et al., 2006; Gakidou et al., 2010).

Limitations and future directions

Although the use of data from 1962 United States provided a test of moderation of genetic influences on alcohol use by SES in a novel context, the focus on a sample born around 1945 has limitations. Changes that have occurred since these data were collected might reduce generalizability to today's adolescents, who may face different environments or restrictions on alcohol use as a result of family SES. For example, income inequality has increased, and this may have implications for understanding the impact of SES on genetic and environmental factors related to alcohol use. Research suggests that income inequality at the national and neighborhood level is associated with increased frequency of alcohol use (Galea et al., 2007), increased alcohol consumption (Elgar et al., 2005), and increased alcohol-related mortality (Dietze et al., 2009).

In addition, there have been changes in access to higher education. The sample primarily consisted of high-achieving, White adolescents. It is important to note that around the time of data collection, more than a quarter of individuals (27.2%) dropped out of high school (Snyder et al., 2016). Twins who participated would have been those who had not dropped out and were likely planning to attend college. The relative affluence of this sample may limit generalizability to the less affluent. Changes in drinking norms, particularly for adolescent girls, have also occurred since these data were collected. These differences between adolescents born in 1945 and current adolescents likely do not simply affect rates of alcohol use and the proportion of individuals attending college, but also the relationships between them, including $G \times E$ effects. These changes may influence heritability estimates of alcohol phenotypes, which are in part a function of the restrictiveness of the environment.

However, evidence from a recent meta-analysis on the moderating effect of SES on genetic and environmental contributions to variability in general intelligence (Tucker-Drob & Bates, 2016) suggests that these effects may still be relevant to today's adolescents. The meta-analysis was prompted by the search for key study differences that might account for discrepant findings. They found that site of the study (United States vs. Europe and Australia), but not when the study was conducted, explained the inconsistent findings. The authors speculated that this may be attributable to wider social class differences in access to education, health care, and social welfare in the United States compared with Australia and Western Europe. Of particular relevance is that one of the studies included in the meta-analysis was also based on the 1962 National Merit Twin Study data (Harden et al., 2007), and estimates from that study were consistent with estimates obtained from more recent studies. The synthesis of the different studies in different contexts led to greater resolution on the phenomenon than a single study could have. The present study contributes a critical unique data point toward a better understanding of the relation between SES and individual differences in genetic and environmental contributions to alcohol involvement.

Additionally, although used in previous studies (Legrand et al., 2008; Loehlin, 2010; Polderman et al., 2015), an alcohol composite does not provide information about specific behaviors like quantity or frequency of use. Prior research has found that SES has different moderation effects on various aspects of alcohol use (Hamdi et al., 2015), and the use of an alcohol composite measure did not allow us to detect such effects. The alcohol composite measure was also limited, as most participants had low levels of involvement, and many items (e.g., "I have drunk before breakfast" or "I have gone on the wagon") were endorsed infrequently. Although it would have been better to include only participants who endorsed alcohol involvement, prior research has included non-alcohol-involved participants (Hamdi et al., 2015).

Furthermore, there was not sufficient power to include only alcohol-involved participants. However, post hoc analyses excluding non-alcohol-involved participants yielded roughly similar results (see supplemental materials).

Despite these limitations, this study is the first, to our knowledge, to examine multiple indicators of family SES as moderators of influences on alcohol use among adolescents. Future studies should compare the impact of social status and financial resources on alcohol use. For example, although the current study had too few single-parent families ($n = 98$) to explore the potential moderating effect of this characteristic, single parenthood, which was correlated with lower family incomes and lower paternal education, is likely an important factor to consider when developing a more complete picture of SES. Studies examining this effect in the future should make use of specific alcohol measures to better pinpoint effects of the moderator on alcohol involvement. An important direction for future research will be to examine how income disparity may moderate etiological influences on alcohol use. In addition, researchers should explore this phenomenon in contexts other than the United States, which may vary in the extent to which access to education, health care, and social welfare differs across the socioeconomic spectrum (Tucker-Drob & Bates, 2016).

Conflict of Interest Statement

Christal N. Davis and Wendy S. Slutske declare no conflicts of interest.

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Ethical approval: This article does not contain any studies with human participants performed by any of the authors.

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