



Published in final edited form as:

*J Abnorm Child Psychol.* 2014 July ; 42(5): 845–859. doi:10.1007/s10802-013-9831-z.

## Delineating Selection and Mediation Effects among Childhood Personality and Environmental Risk Factors in the Development of Adolescent Substance Abuse

Brian M. Hicks<sup>1</sup>, Wendy Johnson<sup>2</sup>, C. Emily Durbin<sup>3</sup>, Daniel M. Blonigen<sup>4</sup>, William G. Iacono<sup>5</sup>, and Matt McGue<sup>5</sup>

<sup>1</sup>Department of Psychiatry, University of Michigan, Ann Arbor, MI, USA

<sup>2</sup>Department of Psychology, University of Edinburgh, Edinburgh, United Kingdom

<sup>3</sup>Department of Psychology, Michigan State University, East Lansing, MI, USA

<sup>4</sup>Department of Veterans Affairs, Palo Alto Health Care System, Palo Alto, CA, USA

<sup>5</sup>Department of Psychology, University of Minnesota, Minneapolis, MN, USA

### Abstract

Utilizing the large, longitudinal Minnesota Twin Family Study ( $N = 2510$ ; 96% European American ancestry), we examined the influence of several person-environment transactions on adolescent substance abuse. We focused on the two childhood personality traits found to be most predictive of substance abuse in this sample—*socialization* (willingness to follow rules and endorse conventional values) and *boldness* (social engagement and assurance, stress resilience, thrill seeking)—and the environmental variables of antisocial and prosocial peers, academic engagement, parent-child relationship quality, and stressful life events. Path analysis revealed that low socialization had a *selection* effect for each environmental risk factor, that is, socialization at age 11 predicted environmental risk at age 14, after controlling for the stability of the environmental variables from ages 11 to 14. Antisocial peers and academic engagement at age 14 then *mediated* some of the risk of low socialization on substance abuse at age 17, but the majority of risk for substance abuse was accounted for by the stability of socialization from age 11 to 14. Boldness at age 11 also increased risk for substance abuse, but did so primarily via a direct effect. The findings help to parse the nature of person-environment transactions across multiple personality traits and contextual risk factors that contribute to adolescent substance abuse.

### Keywords

substance abuse; personality; environmental risk; longitudinal

---

The misuse of alcohol, nicotine, and illicit drugs accounts for some of the most significant and preventable public safety, health, and mortality problems (World Health Organization,

---

Address correspondence to: Brian M. Hicks, Department of Psychiatry, University of Michigan, 4250 Plymouth Rd, Ann Arbor, MI 48109. brianhic@umich.edu. Phone and fax numbers are 734-232-0215 and 734-998-7992.

None of the authors report any biomedical financial interests or potential conflicts of interest.

2008, 2011). Notably, adolescent substance abuse (heavy use and symptoms of abuse and dependence) is the strongest predictor of a severe and persistent course of substance use disorders (SUDs), and concomitant psychosocial impairment that have long-term consequences including school failure and disengagement, employment difficulties, early parenthood, high-risk sexual behavior, and legal problems (Hicks, Iacono, & McGue, 2010; Tapert, Aarons, Sedlar, & Brown, 2001; Viner & Taylor, 2007). Therefore, understanding the origins of adolescent substance abuse can help to reduce a substantial portion of the public health burden associated with SUDs.

The strongest predictors of adolescent substance abuse are a pattern of early and persistent antisocial behavior (Armstrong & Costello, 2002; Zucker, 2006), and environmental risk factors related to family, peer, school, and neighborhood contexts (Hawkins, Catalano, & Miller, 1992; Zucker, 2006). Consistent with a developmental cascade model, there is a typical sequence of interplay between child characteristics and environmental influences such that exposure to one risk factor often increases risk for another, the effects of which accumulate and contribute to an early initiation of use and rapid escalation to abuse by late adolescence (Granic & Patterson, 2006). Specifically, high-risk rearing environments characterized by poor parent-child relationships, harsh and inconsistent discipline, and inadequate monitoring are associated with conduct problems, particularly when paired with an undercontrolled child temperament (aggressiveness, impulsivity). Conduct problems then increase the risk for academic failure and disengagement and rejection by prosocial peers. Lack of attachment to these socializing agents increases feelings of hostility and depression as well as affiliation with deviant peers. Deviant peer affiliation then facilitates adolescent problem behavior including delinquency, precocious sexual behavior, and substance use (Jessor & Jessor, 1977).

Given the interdependence between child traits and environmental risk factors, parsing the mechanisms of risk for adolescent substance abuse is challenging. An advantage to studying SUDs relative to many other disorders, however, is the necessity of the discrete event of initiation of use, which demarcates risk present prior to initiation from exposure to risk that is confounded with substance use. Identifying the early expressions of person-level risk and tracking their interplay with environmental risk then can help to delineate mechanisms of risk via person-environment transactions in the development of substance abuse.

### **Childhood Person-level Risk**

To leverage the strengths of focusing on pre-morbid risk, Hicks, Iacono, and McGue (in press) used the extensive assessments and longitudinal SUD outcomes of the Minnesota Twin Family Study (MTFS; Iacono, Carlson, Taylor, Elkins, & McGue, 1999) to identify the behaviors, traits, and attitudes present prior to initiation that best predicted adolescent and young adult substance abuse. Working with the most predictive items, Hicks et al. (in press) developed scales that assessed two independent personality traits called socialization and boldness that accounted for the majority of person-level risk present prior to initiation of use. *Socialization* was defined by an individual's willingness to conform to rules, accept adult supervision, and endorse conventional values. Though the term "socialization" is commonly used to refer to the process by which individuals acquire the skills necessary to

effectively participate in and achieve a society's valued outcomes, here, we use it to refer to a trait construct defined by a collection of correlated behaviors and attitudes. The second trait was called *boldness* and was defined by items related to social assurance and dominance, resilience to stress, and thrill seeking (see Table 1).

Socialization included content that accounted for the association between childhood externalizing behaviors and later substance abuse. For example, socialization at age 11 was highly correlated with concurrent symptoms of attention deficit hyperactivity disorder ( $r = -.62$ ), conduct disorder ( $r = -.66$ ), and oppositional defiant disorder ( $r = -.62$ ), as well as internalizing distress ( $r = -.32$ ), the latter indicative of an association with mental health problems in general. Socialization was also correlated with parental externalizing disorders ( $r = -.22$  and  $-.26$  for father and mother symptoms, respectively), and had a large correlation with a composite of environmental risk factors ( $r = -.67$ ) that included deviant peers, parent-child relationship problems, lack of academic engagement, and stressful life events. In contrast, boldness at age 11 was unrelated to concurrent childhood disruptive behavior disorders and parental externalizing disorders (mean  $r = .05$ ), had a small but significant negative association with the environmental risk composite ( $r = -.16$ ), and was associated with less internalizing distress ( $r = -.35$ ). Heritability analyses were consistent with the differential patterns of environmental correlates for socialization and boldness; specifically, socialization exhibited both moderate additive genetic (.45) and shared environmental (.30) influences while boldness was highly heritable (.71) with no shared environmental influences. In terms of incremental validity, both socialization and boldness at age 11 predicted SUD outcomes at age 17 over and above childhood disruptive behavior disorders, parental externalizing disorders, and a composite of environmental risk. Results were also replicated in an independent sample.

The socialization and boldness measures have a number of advantages to investigating person-environment transactions in the development of SUDs relative to other close constructs such as externalizing and internalizing. One is that socialization and boldness are independent, and exhibit distinct patterns of external correlates. As such, the two traits index distinct domains of risk for SUDs. Another is that the items were originally selected to maximize prediction of SUD rather than assess an a priori hypothesized construct. As such, the socialization and boldness measures provide a more efficient organization of content relevant to pre-morbid risk for SUDs. This is especially true for boldness, which seems to assess much of the childhood risk for SUDs "left over" after accounting for externalizing-related content. That is, boldness provides a more efficient organization of the risk for SUDs associated with (low) internalizing and extraversion/positive emotionality, bringing together multiple facets embedded in these broad measures into a coherent personality construct with ties to the child development (low behavioral inhibition; Fox, Henderson, Marshall, Nichols, & Ghera, 2005; Kagan, 1994) and psychopathology (psychopathy; Patrick, Fowles, & Krueger, 2009) literatures. Though socialization also incorporates a relatively diverse content, its conceptual emphasis on an underlying trait related to the internalization of normative values and behavior helps to focus theory building. Finally, socialization is keyed toward adjustment rather than pathology, and so has the potential to inform both adaptive and maladaptive outcomes, an attribute missing from most symptom measures. Together

then, socialization and boldness provide an efficient assessment of risk for SUDs present prior to initiation of use, and substantial utility in delineating person-environment transactions during late childhood and adolescence, when substance use begins and problem use first emerges.

### **Person-Environment Transactions: Selection and Mediation**

The differences in heritability and environmental correlates suggest that the risk for substance abuse conferred by socialization and boldness may operate via different mechanisms of person-environment interplay. To investigate this, Hicks, Johnson, Durbin, Blonigen, Iacono, et al. (2013) tested (1) whether socialization and boldness at age 11 predicted greater exposure to environmental risk at age 14, that is, had *selection* effects, and (2) whether environmental risk at age 14 mediated the effects of socialization and boldness on substance abuse at age 17. Low socialization at age 11 was associated with selection into high-risk environments in mid-adolescence; that is, socialization predicted exposure to environmental risk at age 14, even after accounting for stability in environmental risk from age 11 to 14. Also, environmental risk at age 14 had a partial mediation effect, that is, socialization increased risk for substance abuse indirectly via greater exposure to high-risk environments. This indirect effect was primarily due to genetic influences indicative of an active gene-environment correlation (Scarr & McCartney, 1983). In contrast, boldness was uncorrelated with the composite measure of environmental risk at age 14, and conferred a direct and entirely heritable risk for substance abuse at age 17.

There were two important limitations of the analyses in Hicks et al. (2013). The first was the use of a composite measure of environmental risk. While the aggregation of risk factors has the advantage of parsimony and may capture a higher portion of risk variance, composites can obscure differential associations across contextual factors and, so may be less meaningful for understanding mechanisms underlying this risk. The second limitation was that Hicks et al. did not incorporate the stability of personality from age 11 to 14, limiting inferences regarding the extent to which environmental risk at age 14 mediated the influence of personality at age 11 on substance abuse at age 17. That is, some (or all) of the mediation attributed to environmental risk at age 14 could be due to the stability of personality from age 11 to age 14. Also, similar to selection effects for personality, contextual variables may have *shaping* effects on personality. That is, environmental variables at age 11 might predict personality at age 14, even after controlling for the stability of personality from age 11 to 14. Therefore, to help elucidate these associations, we examined how the selection, shaping, and mediation effects among boldness, socialization, and several environmental risk factors during the transition from childhood to mid-adolescence contributed to substance abuse in late adolescence.

### **Do people select their environments? Or, does the environment shape the person?**

The risk and protective factors we refer to as environmental variables represent experiences in the social environments of family, school, peers, and contextual stressors. Though a common assumption is that environmental variables represent an external influence on a

child's behavior and personality, a more accurate conceptualization is that contexts involve interactions between individuals and their environments. An interesting question then is, what is the relative influence that personality plays in selecting environments versus the impact environments have in shaping an individual's personality? The strength of selection effects seems to depend upon how much a context is influenced by the child's behavior (Scarr & McCartney, 1983). For example, relationships (e.g., parent-child, peers) are a function of an individual's behavior and the reactions of others to that behavior and vice versa, and so are strongly influenced by a child's personality. Other contexts such as family-level stressors (parental discord and family money, legal, and mental health problems) may influence the child, but exposure to such stressors is relatively independent of a child's behavior (i.e., little or no selection effects). Also, individuals often select environments consistent with their existing traits (Roberts & Caspi, 2003; Roberts & Wood, 2006). For example, antisocial children tend to have more antisocial friends. As these children gain greater autonomy in selecting their friends during adolescence, their peer groups often become even more deviant, embedding these children in a culture that reinforces norm violation and increases risk for substance use (Dishion, Capaldi, Spracklen, & Li, 1995; Dishion & Owen, 2002; Dishion, Spracklen, Andrews, & Patterson, 1996; Piehler, Veronneau, & Dishion, 2012). The reciprocal influences among person-level characteristics and environments continue over time, potentiating the cumulative risk for outcomes such as substance abuse.

To delineate these processes, we used longitudinal data from the MTFS to examine selection and shaping effects between socialization, boldness, and five environmental variables between age 11 and 14, and how the dynamics among these variables contributed to substance abuse at age 17. Given its cross-sectional associations with environmental risk factors, we predicted that low socialization would have selection effects for all types of high-risk environments, which in turn would at least partially mediate the effects of low socialization on substance abuse. In contrast, as boldness has small to null associations with environmental risk, we predicted it would exhibit few selection effects, and primarily increase risk for substance abuse via a direct effect. Additionally, as personality exhibits moderate stability during this age range (estimated population correlation = .47; Roberts & DelVecchio, 2000), we also predicted that personality at age 14 would mediate some of the effect of childhood personality on later substance abuse. Finally, because children gain greater autonomy in selecting their environments during the transition from childhood to adolescence, we predicted that selection effects would be stronger than shaping effects. Again, given their cross-sectional correlates, we also predicted that any shaping effects would be stronger for socialization than for boldness.

## Method

### Sample

Participants were male and female twins ( $N = 2510$ ) from the age 11 cohort of the MTFS (Iacono et al., 1999; Keyes, Malone, Elkins, Legrand, McGue, et al., 2009). All twins were same-sex pairs born in the state of Minnesota. Families were identified using public birth records for the years 1977–1984 and 1988–1994, and located using public databases.

Among eligible families, 90% were located and over 80% agreed to participate in an intake assessment the year the twins turned 11. Families were required to live within a day's drive of the University of Minnesota, with neither twin having a physical or mental disability that would interfere with participating in the daylong assessment. Parents were representative of the Minnesota population of the target birth years in education, socioeconomic status, and history of mental health treatment. Ninety-six percent of the sample was of European American ancestry, consistent with the demographics of Minnesota for the target birth years. Though the sample lacks racial and ethnic diversity, it covers a wide range of the socioeconomic spectrum (Iacono et al., 1999), includes a mix of families living in urban (65%) and rural settings (35%; urban defined as >10,000 residents; Legrand, Keyes, McGue, Iacono, & Krueger, 2008), and is gender balanced (51% female). Informed consent from parents and assent from the twins was obtained prior to data collection, and all study protocols were evaluated by an institutional review board. Participants were informed that confidentiality would only be broken under conditions of eminent danger to self or others, or knowledge of the ongoing abuse of a minor child or vulnerable adult. Confidentiality was not broken regarding current or past substance use. After the intake assessment, twins were invited to participate in follow-up assessments every 3–5 years. Here, we used data from the age 11 intake assessment ( $M = 11.8$  years,  $SD = 0.43$  years), and the first and second follow-ups at the target ages of 14 ( $M = 14.9$  years,  $SD = 0.55$ ) and 17 ( $M = 18.1$  years,  $SD = 0.63$ ). Retention rates were excellent for both the completed age 14 (93.0%) and the ongoing age 17 assessments (80.5% of total sample; 91.6% retention for all those who have reached the target age).

## Assessment

**Child personality traits at age 11 and 14: boldness and socialization**—Items assessing socialization and boldness are listed in Table 1. These are the items at the age 11 assessment that yielded the strongest prediction for a composite of substance abuse at age 17 (see below) in the MTFS (Hicks et al., in press). The original socialization scale included 20 items ( $\alpha = .80$ ) from teacher, child, and mother reports of personality, oppositional and antisocial behavior, and academic attitudes. High scorers on socialization willingly conform to rules and adult supervision and endorse conventional moral and ethical values. The boldness scale included 9 teacher-rated items ( $\alpha = .80$ ) of personality traits and behaviors, with high scorers being sociable, socially assured and dominant, stress resilient, lacking anxiety, and thrill seeking. Scale scores for socialization and boldness were calculated by taking the mean z-score across the items of their respective scales. Socialization and boldness were uncorrelated,  $r = -.01$ , ns. The same items were used to calculate socialization and boldness scores at age 11 and 14. For socialization, however, two items of mother-rated personality were not available at age 14, and so were excluded from scale score at both ages. Further, to reduce criterion contamination with the academic engagement variable (see below), academic-related items were also excluded from the socialization scale score (15-items;  $r = .97$  with the original scale).

**Environmental risk factors at age 11 and 14**—Each MTFS assessment covers several environmental variables associated with adolescent substance abuse including peer, family, and school contexts and stressful life events. These measures have been used in several

previous published reports, and exhibit substantial validity and reliability (e.g., Hicks, South, DiRago, Iacono, & McGue, 2009; Hicks, Carlson, Blonigen, Patrick, Iacono, et al., 2012).

**Antisocial and prosocial peers**—Children rated the proportions of their friends (*all my friends to none of my friends*) that engaged in various types of antisocial (get in fights, skip school, steal, drink alcohol, smoke cigarettes;  $\alpha = .85$ ) and prosocial (get good grades, liked by other kids;  $\alpha = .85$ ) behaviors using a 19-item questionnaire (Walden, McGue, Iacono, Burt, & Elkins, 2004). Teachers completed similar ratings (inter-rater reliability  $r = .71$ ). Four antisocial peer items related to substance use. To avoid criterion contamination with the outcome measure of adolescent substance abuse, these items were excluded from the antisocial peer score ( $r = .95$  with the original score). The mean z-score of the twin and teacher ratings were used for the measures of antisocial and prosocial peers.

**Parent-child relationship quality**—The Parental Environment Questionnaire (Elkins, McGue, & Iacono, 1997; McGue, Elkins, Walden, & Iacono, 2005) is a 50-item questionnaire covering several aspects of the parent-child relationship (conflict, involvement, positive regard;  $\alpha$ 's  $.82$  to  $.69$ ). Children and mothers completed ratings for both the mother-child and father-child relationship. An overall measure of parent-child relationship quality was calculated using the mean z-score for ratings of the child and mother; ratings were then averaged for the mother-child and father-child relationship ( $r = .67$  and  $.60$  at age 11 and 14, respectively, for mother-child and father-child relationship quality).

**Academic engagement**—A composite of each child's academic context was calculated using child and mother ratings for the following measures (Johnson, McGue, & Iacono, 2005, 2006): a 7-item ( $\alpha = .83$ ) scale of the child's attitudes about school (good attitude about school, enjoys attending school), cumulative grade point average (GPA), and expectation of educational attainment (e.g., high school, bachelor degree). The academic engagement composite was calculated by taking the mean z-score for academic attitudes, GPA, and expectations averaged across the child and mother informants ( $r = .77$ ). Although these measures are often conceptualized as individual differences measures, they can provide at least an indirect measure of a child's subjective experience of the school environment.

**Stressful life events**—A structured interview was used to assess the experience of stressful life events (Bemmels, Burt, Legrand, Iacono, McGue, 2008). We selected 16 events related to family-level functioning including parental discord and divorce and family money, legal, and mental health problems. Stressful life events at age 14 referred to events that occurred over the past 3 years. As these family-level events should be concordant across members a twin pair, the intraclass correlations (ICC) between twin reports provided estimates of reliability: ICC =  $.81$  and  $.85$  at ages 11 and 14, respectively.

**Substance abuse at age 17**—An expanded version of the Substance Abuse Module of the Composite International Diagnostic Interview (Robins, Babor, & Cottler, 1987) was used to assess substance use and SUD symptoms at age 17. We calculated a composite measure of adolescent substance abuse using 10 measures of alcohol, nicotine, and

marijuana use and symptoms of abuse/dependence. The composite included *DSM-IV* symptoms of alcohol, nicotine, and marijuana abuse and dependence; past 12-month frequency of alcohol, nicotine, and marijuana use; quantity measures including average number of drinks per occasion, maximum number of drinks consumed in 24 hours, average number of cigarettes smoked per day, and number of lifetime marijuana uses. A  $\log(x+1)$  transformation was applied to all variables to reduce positive skew. The mean z-score across the 10 measures (mean  $r = .58$ ) was used as the substance abuse composite score at age 17 (skew = 1.29, kurtosis = .91). Due to the illicit nature substance use in adolescence, 25.7% of the sample had not yet initiated use by the age 17 assessment.

## Data analysis

We began by examining mean-level changes and rank-order stability in socialization, boldness, and the environmental measures from ages 11 to 14. Linear mixed models were used to adjust statistics for the correlated twin observations. Next, we used path analysis to examine the interplay between child personality and environmental risk factors on adolescent substance abuse. Figure 1 provides conceptual illustrations of the different models we tested. Panel A depicts the independent stability and full mediation model. In this model, personality traits and environmental variables were correlated at age 11, but none of the variables predicted the others at age 14, after controlling for the stability of each variable from age 11 to 14. Also, the age 14 variables fully mediated the effects of the age 11 variables on substance abuse at age 17. This was the most parsimonious model, and excluded all selection and shaping effects of the age 11 variables on the age 14 variables, and the direct effects for age 11 variables. We also tested a partial mediation variant of this model, wherein the direct effects from the age 11 variables to substance abuse at age 17 were included (not depicted in the figure). Panel B depicts the shaping model wherein the environmental variables at age 11 predicted the personality variables at age 14, after controlling for stability in the personality variables from age 11 to 14. Panel C depicts the selection model wherein the personality variables at age 11 predicted the environmental variable at age 14, after controlling for stability in the environmental variable from age 11 to 14. Panel D depicts a model that incorporates all possible selection and shaping effects of the age 11 variables on the age 14 variables. Finally, we removed all non-significant paths from this last model to identify a final best fitting model.

Mplus 5.1 (Muthen & Muthen, 2007) was used to fit all path analysis models, including estimation of the direct and indirect effects, using the MLR estimator and COMPLEX type to adjust the standard errors for the correlated twin observations. Model fit was evaluated using the  $\chi^2$  fit statistic, the comparative fit index (CFI; values  $> .95$  indicate a good fit), the root mean square error of approximation (RMSEA; values  $< .05$  indicate a good fit) and the standardized root mean residual (SRMR; values  $< .05$  indicate a good fit). Comparisons between nested models were tested using an adjusted chi square difference test as required when using the MLR estimator. Mediated or indirect effects were calculated by multiplying the effect of an age 11 variable on an age 14 variable by the effect of the age 14 variable on substance abuse at age 17. Though the sample size was relatively large, the models were complex with numerous statistical tests, making it difficult to accurately assess power and type II error rate. Therefore, we emphasized effect size using Cohen's conventions for direct



and indirect effects, and only effects with a  $p$ -value  $< .001$  were described as statistically significant. For the direct effects, beta coefficients of .10 were considered small, .24 medium, and .37 large effects (Cohen, 1988). For the indirect effects, product terms of .01 were considered small, .09 medium, and .25 large effects (Cohen & Cohen, 1983).

## Results

### Mean-level change and rank-order stability in personality and environmental variables from age 11 to 14

The means and standard deviations for boldness, socialization, and the environmental variables at ages 11 and 14 are provided in Table 2. There was a small mean-level decrease in socialization scores from age 11 to 14, but no significant mean-level change for boldness scores. From ages 11 to 14, exposure to environmental risk increased as evidenced by increased antisocial peer affiliation and declining prosocial peer affiliation, parent-child relationship quality, and academic engagement. There was a small decline in the number of stressful life events. All variables exhibited medium to high rank-order stability (range  $r = .37$  to  $.65$ , all  $p$ 's  $< .001$ ).

### Correlations among the variables

Correlations among all study variables are provided in Table 3, and all correlations described below were significant at  $p < .001$ . Socialization ( $r = -.43$ ) and boldness ( $r = .21$ ) at age 11 had a large negative and medium positive association with substance abuse at age 17, respectively. Associations with substance abuse at age 17 were stronger for socialization at age 14 ( $r = -.58$ ), but unexpectedly weaker for boldness at age 14 ( $r = .13$ ). Boldness at age 11 had small to medium positive associations with prosocial and antisocial peers at ages 11 and 14, and with academic engagement at age 11. Boldness at age 14 had small to medium associations with prosocial peers and academic engagement at ages 11 and 14, and antisocial peers at age 11. Socialization at age 11 had medium to large associations with each environmental variable at ages 11 (mean  $r = |.44|$ ) and 14 (mean  $r = |.39|$ ). Socialization at age 14 had medium to large associations with each environmental variable at age 14 (mean  $r = |.48|$ ), and small to medium associations with each environmental variable at age 11 (mean  $r = |.31|$ ). Substance abuse at age 17 had small to medium associations with each environmental variable at age 11 (mean  $r = |.23|$ ), and medium to large associations with each environmental variable at age 14 (mean  $r = |.35|$ ). All the correlations among the environmental variables were also significant with the magnitude increasing from age 11 (mean  $r = |.27|$ ) to age 14 (mean  $r = |.37|$ ).

### Path analysis models of person-environment effects in the development of adolescent substance abuse

As the model that included all the variables was complex, we began by fitting a series of models that included only a single environmental variable along with boldness and socialization at ages 11 and 14 to predict substance abuse at age 17 to gain a greater understanding of the associations among the variables. We briefly summarize key findings from these models here (all effects described below were significant at  $p < .001$ ). For each model, boldness ( $\beta = .12$  to  $.13$ ) and socialization ( $\beta = -.09$  to  $-.13$ ) at age 11 had small

direct effects on substance abuse at age 17. Boldness at age 11 also consistently predicted socialization and prosocial peers at age 14. Socialization at age 11 had selection effects for each environmental variable at age 14. Each environmental variable at age 11 (except prosocial peers) also predicted socialization at age 14, though the effects were small ( $\beta = .12$  to  $|.13$ ). For each model, socialization at age 14 predicted substance abuse at age 17. Antisocial peers, academic engagement, and parent-child relationship quality at age 14 had small effects on substance abuse at age 17.

Next, we incorporated all the environmental variables and boldness and socialization at ages 11 and 14 into a model predicting substance abuse at age 17, and fit a series of models to test hypotheses regarding selection, shaping, and mediation. For each model, the direct effects for all the age 14 variables on substance abuse at age 17 were included so that the indirect effects of the age 11 variables could be calculated.

Model fit statistics are provided in Table 4 with a description of each model. First, we fit the independent stability and full mediation model that excluded all selection and shaping effects, and all direct effects from the age 11 variables to substance abuse at age 17 (Figure 1 Panel A). This model provided a poor overall fit to the data. Second, we added the direct effects of the age 11 variables on substance abuse at age 17. Though a significant improvement in fit  $\chi^2(7) = 52.77$ , this model also provided a poor overall fit. Third, we fit a model that included all possible shaping effects, that is, each environmental variable at age 11 was allowed to predict socialization and boldness at age 14 (Figure 1 Panel B). While a significant improvement over the first model,  $\chi^2(10) = 102.00, p < .001$ , this model still provided a mediocre fit to the data. Fourth, we fit a model that included all possible selection effects (Figure 1 Panel C), that is, boldness and socialization at age 11 were allowed to predict each environmental variable at age 14. This model yielded a much better fit than the first model,  $\chi^2(10) = 321.74, p < .001$ , as well as a good overall fit to the data. Fifth, we fit a model that included all possible paths from the age 11 to the age 14 variables (Figure 1 Panel D). This model provided a good overall fit to the data and a significantly better fit than the selection model,  $\chi^2(10) = 62.40, p < .001$ . This model, however, included a number of non-significant paths indicative of model overfit. Therefore, we fit a more parsimonious model by cutting the non-significant paths and using information from the modification indices and results from the models that included only one environmental variable.

The final model is depicted in Figure 2. After adjusting for the other variables at age 11, boldness, socialization, academic engagement, parent-child relationship quality, and stressful life events had medium to large stability coefficients from age 11 to 14, while antisocial and prosocial peers had small and medium stability coefficients, respectively. Boldness was the only variable at age 11 that had a direct effect on substance abuse at age 17. Boldness at age 11 also had small selection effects for prosocial and antisocial peers. Surprisingly, boldness at age 11 also predicted socialization at age 14. Socialization at age 11 had medium to large selection effects for antisocial and prosocial peers and academic engagement, and small selection effects for parent-child relationship quality and stressful life events. Prosocial peers at age 11 had a small shaping effect ( $\beta = .09, p < .001$ ) on boldness at age 14, and stressful life events at age 11 had a small shaping effect ( $\beta = -.06, p$

< .001) on socialization at age 14. Among the age 14 variables, socialization had a medium effect and antisocial peers and academic engagement small effects on substance abuse at age 17.

Table 5 provides the direct, indirect, and total effects for boldness, socialization, and the environmental variables at age 11 on substance abuse at age 17. Academic engagement at age 11 had a small indirect effect via academic engagement at age 14. None of the other environmental variables at age 11 had a significant direct or indirect effect on substance abuse at age 17. Boldness at age 11 had a significant total indirect via boldness (33% of indirect of effect), antisocial peers (16%), and socialization (52%) at age 14, though only the indirect effect via socialization was statistically significant. Socialization at age 11 had a significant total indirect effect primarily via socialization (62% of indirect effect), antisocial peers (17%), and academic engagement (15%) at age 14.

### Supplemental analyses: Influence of aggregated environmental risk

Given that we detected small but consistent shaping effects on socialization at age 14 when only one age 11 environmental variable was included in the model, we were concerned that the lack of shaping effects in the full model might be due to controlling for the overlapping variance among the different environmental measures rather than to an actual lack of environmental influences on socialization. That is, though no single environmental variable at age 11 had a large shaping effect on socialization at age 14, there may have been a notable general or cumulative shaping effect of the environmental variables on socialization.

To examine this possibility, we calculated an environmental risk composite at ages 11 and 14 by taking the mean z-score across the five environmental variables (coded in the direction of greater risk; see Hicks et al., 2013 for details), and included the composites in a model with socialization and boldness at ages 11 and 14 to predict substance abuse at age 17 ( $\chi^2[6] = 17.55, p = .008, CFI = .996, RMSEA = .028, SRMR = .020; p < .001$  for all effects described below). Interestingly, the environmental risk composite at age 11 had medium ( $\beta = -.23$ ) and small ( $\beta = -.09$ ) shaping effects on socialization and boldness at age 14, respectively. Socialization at age 11 also had a selection effect ( $\beta = -.20$ ) on the environmental risk composite at age 14. Socialization ( $\beta = -.35$ ) and the environmental risk composite ( $\beta = -.30$ ) at age 14 and boldness at age 11 ( $\beta = .14$ ) all had significant effects on substance abuse at age 17 ( $R^2 = .388$ ). Each variable at age 11 also had a significant indirect effect on substance abuse at age 17. For socialization ( $\beta = -.20$ ), 71% of its indirect effect was due its stability from age 11 to 14, with the remaining 29% attributable to its effect on environmental risk at age 14. For the environmental risk composite ( $\beta = .22$ ), 67% of its indirect effect was due to its stability from age 11 to 14, with remaining 33% attributable to its effect on socialization at age 14. For boldness ( $\beta = .09$ ), 59% of its indirect effect was due to its effect on socialization at age 14 with the remaining 41% attributable to its stability from age 11 to 14.

## Discussion

Utilizing longitudinal MTFS data, we examined how the interplay among the personality traits of socialization and boldness and several environmental variables contributed to

adolescent substance abuse. We found consistent evidence of selection effects for childhood socialization on environments in mid-adolescence. The environmental variables then mediated some of the influence of childhood socialization on adolescent substance abuse. However, the stability of socialization from age 11 to 14 accounted for the majority of the effect of socialization at age 11 on substance abuse at age 17. In contrast, there was less consistent evidence for shaping effects of any single environmental variable on personality. When the different environmental variables were aggregated into a composite, however, we detected a notable shaping effect on socialization, suggesting a non-specific or cumulative influence of childhood environments on at least some aspects of personality in mid-adolescence. Boldness had only small prospective associations with the environmental variables, and was the only variable at age 11 to have a direct effect on substance abuse at age 17. When all the variables were incorporated into one model, socialization had a large effect and boldness, antisocial peers, and academic engagement had small effects.

### **Interplay between Socialization and Environmental Risk**

Previously, we showed that socialization (conformity to rules and endorsement of conventional values) at age 11 had a selection effect on a composite of environmental risk at age 14, and that this environmental risk composite mediated some, but not all of the effect of socialization at age 11 on substance abuse at age 17 (Hicks et al., 2013). Here, we extended these findings in a number of ways. First, socialization's selection effects were ubiquitous, that is, socialization predicted each type of environmental context, over above their temporal stability and the other environmental variables at age 11. Second, the magnitude of the selection effects varied across the environmental variables. Results were generally consistent with our prediction that the magnitude of the selection effects would vary as a function of the influence of the child's behavior in shaping the different contexts. Specifically, selection effects were strongest for antisocial peers, prosocial peers, and academic engagement—all of which are malleable and sensitive to person-level traits. The selection effect for antisocial peers actually exceeded its stability coefficient, suggesting socialization plays a key role in creating a deviant peer network in mid-adolescence that then increases risk for later substance abuse. Socialization tended to reflect and then accentuate existing environmental contexts. Put another way, children low in socialization affiliated with more antisocial peers in childhood, continued to do so in adolescence, and acquired more antisocial peers over time. Selection effects were weaker for stressful life events—unsurprising as these events were mostly independent of the child behavior—and parent-child relationship quality. The weak selection effect for parent-child relationship quality was somewhat unexpected, given its interactive nature and the robust cross-sectional associations with socialization. One reason may be that parent-child relationships are more stable than peer relationships with the influence of child personality already established. Alternatively, other factors besides child personality may be more influential during this age range, for example, a shift to spending more with peers and less time with parents.

A third way we extended our earlier report was to incorporate the stability of socialization from age 11 to 14. This was important because socialization's indirect effects through the environmental variables at age 14 could have reflected changes in socialization that were correlated with changes in the environmental variables. In fact, we found that socialization

at age 14 accounted for about two thirds of the association between childhood socialization and adolescent substance abuse (the direct effect of socialization at age 11 on substance abuse at age 17 was also no longer significant after adjusting for socialization at age 14). Over and above stability, however, we detected significant indirect effects for socialization at age 11 via antisocial peers and academic engagement at age 14. These two contexts then may be crucial points of intervention by which to reduce risk for adolescent substance abuse.

By including personality at age 14, we were also able to examine shaping effects, that is, the effects of environmental contexts in childhood on personality in mid-adolescence. Interestingly, the strength of shaping effects depended on the level of specificity used to measure environmental risk. When differentiated into distinct domains, we detected few significant effects of childhood environments on personality in mid-adolescence (over and above the stability of personality), suggesting a dominant role for the person in selecting environments. When aggregated into a composite, however, there was a robust effect for the environmental measures at age 11 in predicting socialization at age 14; in fact, the shaping effect was on par with the selection effect. Because the environmental variables and socialization at age 11 all had medium to large correlations with each other, however, there was likely little measure-specific variance remaining to establish *unique* associations between the different environmental variables and socialization in the full model. These findings suggest a non-specific effect of childhood environments that is present across different domains and has a cumulative effect on personality. Environmental risk factors in childhood then had an indirect effect on later substance abuse by helping to shape personality in mid-adolescence.

### **Boldness, Environmental Risk, and Substance Abuse**

Another novel contribution of this analysis was examining the role of boldness and its associations with environmental risk in the development of adolescent substance abuse. Boldness (social dominance, stress resilience, and thrill seeking) primarily increased risk for substance abuse directly, and mostly independent of the environmental variables, thus representing a highly person-driven risk factor. Boldness at age 11 did have small selection effects for prosocial and antisocial peers at age 14, but these selection effects did not result in significant indirect effects on substance abuse at age 17. Unexpectedly, boldness at age 11 also predicted socialization at age 14, even after controlling for the environmental variables and stability of socialization. To help understand the nature of this association, we examined the correlations between boldness at age 11 and the socialization items at age 14. We found that boldness exhibited the strongest associations with items reflecting specific antisocial behaviors. Therefore, a mechanism by which childhood boldness increases risk for later substance abuse is via involvement in antisocial behavior in mid-adolescence.

Another unexpected finding was that boldness at age 11 had a stronger association with substance abuse at age 17 than boldness at age 14. Boldness was the only variable that exhibited this pattern, which is unusual given the greater temporal proximity of the age 14 measurement. This raised concerns that the boldness items may be functioning differently at ages 11 and 14. However, boldness exhibited similar internal consistency reliability and factor structure ages 11 and 14, and its rank-order stability is consistent with other

personality constructs during this age range (Roberts & Del Vecchio, 2000). Further, after examining a larger pool of potential boldness items, we found that the correlations with substance abuse at age 17 tended to decline for all boldness items, rather than correlations decreasing for the original set of items but increasing for other potential boldness items. This suggests that bold traits in childhood—rather than in adolescence—may be particularly predictive of substance use problems. However, an alternative methodological explanation is that boldness relied solely on teacher reports. Because teachers spend more time with individual students in the elementary relative to middle school grades, the teacher reports at age 14 may be less valid than those at age 11.

Boldness also had robust correlations with prosocial peers and small but significant correlations with academic engagement. This suggests that boldness may influence selection into both positive and negative environmental contexts, contributing to adaption in some circumstances and exposure to risk in others. Prosocial peers at age 11 also had a shaping effect on boldness at age 14, suggesting that boldness may be a positive trait that a positive environmental context helps to accentuate. Conceptually, boldness is similar to low behavioral inhibition, a trait defined in young children by low social and object fear and ease in novel, uncertain, and potentially frightening situations (Fox et al., 2005), that has also been linked to the interpersonal facets of psychopathy associated with reduced fear-potentiated startle (Patrick et al., 2009; Vaidyanathan, Hall, Patrick, & Bernat, 2011). Given the social and somewhat novel and deviant nature of adolescent substance use, it is plausible that the confluence of social assurance and engagement, lack of fear in new and uncertain situations, and thrill seeking increases risk for substance abuse. However, boldness may do so “in the moment”, that is, via the immediate decision to use substances—perhaps a consequence of reduced fear reactivity and a bias toward reward in risky situations—rather than by increasing exposure to various types of contextual risk.

## Conclusions

Our results were generally consistent with other studies that have examined the influence of multiple person-level and environmental variables in both community (Wills & Cleary, 1999; Wills, Cleary, Filer, Shinar, Mariani, & Spera, 2001; Willis, Windle, & Cleary, 1998) and high-risk samples (Chassin et al. 1993; Stice, Barrera, & Chassin, 1998). Most notably there is a consistent pattern for the importance of person-level traits operationalized as externalizing, self-control, novelty seeking, and tolerance for deviance that have both a direct effect on adolescent substance use and an indirect via peer substance use. Also, peer substance use is typically the strongest predictor of concurrent substance use, even when controlling for other personality and environmental variables. Our results for boldness are also consistent with small but significant direct effects for low harm avoidance and risk taking (Wills et al., 2001, 1998).

We extended these findings in a number of ways. First, all the predictors of adolescent substance abuse were prospective, that is, all the predictors were measured 3 to 6 years prior to the outcome, providing stronger support for a causal influence. Second, while many previous studies examined peers' substance use, we removed items referring to substance use from our prospective measure of antisocial peers to avoid criterion contamination.

Despite this additional control, we still detected effects for antisocial peers at age 14, which was also a key mediating variable for the effects of childhood personality on substance abuse. While the controls of using prospective predictors and removing substance use items from the antisocial peer measure reduced the variance accounted for relative to cross-sectional studies without these controls ( $R^2 > .55$ ; Chassin et al., 1993; Wills et al., 2001, 1998), we still accounted for a notable portion of variance in adolescent substance ( $R^2 = .39$ ) and have more confidence in the causal influence of antisocial peer affiliation. Additionally, few other studies have been able parse the mechanisms by which childhood personality increases risk for adolescent substance abuse via direct effects and indirect effects through multiple environmental risk factors, while controlling for stability of personality and environmental risk.

The study has some limitations. One is the sample's lack of racial/ethnic diversity. It remains to be seen if the person-environment associations in risk for substance abuse will generalize to samples of differing demographic characteristics. An additional limitation was that our initial assessment was at age 11 when substantial person-environment transactions have already occurred. Ideally, one would begin to track person-environment transactions at earlier ages. Another limitation was that the measures of socialization and boldness at age 11 were designed to maximize prediction with substance abuse and antisocial behavior at age 17 (Hicks et al., in press), and here are being used to test hypotheses about those constructs. As such, it is especially important to replicate the current findings in other samples. Further, while socialization incorporated information from teacher, parent, and child reports, boldness relied solely on teacher reports. Finally, there are alternatives to our conceptualizations of the environmental risk variables. For example, measurement of the school environment could have relied more heavily on institutional characteristics such as average test scores and number of disciplinary problems. Also, stressful life events could be conceptualized as a moderating rather than mediating variable.

To conclude, we gained valuable insights into the person-environment transactions between childhood personality traits and environmental risk factors that contribute to adolescent substance abuse. Notably, this was one of the few longitudinal studies to examine the differential influences of multiple personality traits and environment risk factors, by focusing on delineating selection, shaping, and mediation effects in the development of adolescent substance abuse. Specifically, there was an overall increase in exposure to environmental risk factors for substance abuse during the transition from childhood to mid-adolescence. This increase was partially due to socialization's selection effects—most importantly for antisocial peers and academic disengagement—that then increased risk for substance abuse. Further, environmental risk in childhood had a non-specific and cumulative shaping effect on the socialization trait that then contributed to risk for substance abuse. These selection and shaping effects were consistent with a developmental cascade or accentuation model, whereby pre-existing traits and environments reinforce one another and compound risk over time. In contrast, boldness had a direct effect, and represented a person-driven risk for substance abuse that was mostly independent of contextual factors. Future work should continue to examine the mechanisms of person-environment transactions that contribute to substance abuse, and begin to tailor prevention and intervention efforts based

on these individual differences factors and the mechanisms of their transactions with environmental risk factors (Conrod, Castellanos-Ryan, & Mackie, 2011).

## Acknowledgments

This work was supported by grants from the National Institute of Drug Abuse U01 DA024417 (W.G.I.), R37 DA005147 (W.G.I.), R01 DA013240 (W.G.I.), K01 DA025868 (B.M.H.), National Institute of Alcohol Abuse and Alcoholism R01 AA09367 (M.M.), a Career Development Award-2 from the VA Office of Research and Development (D.M.B.), and a Research Council of the United Kingdom fellowship (W.J.).

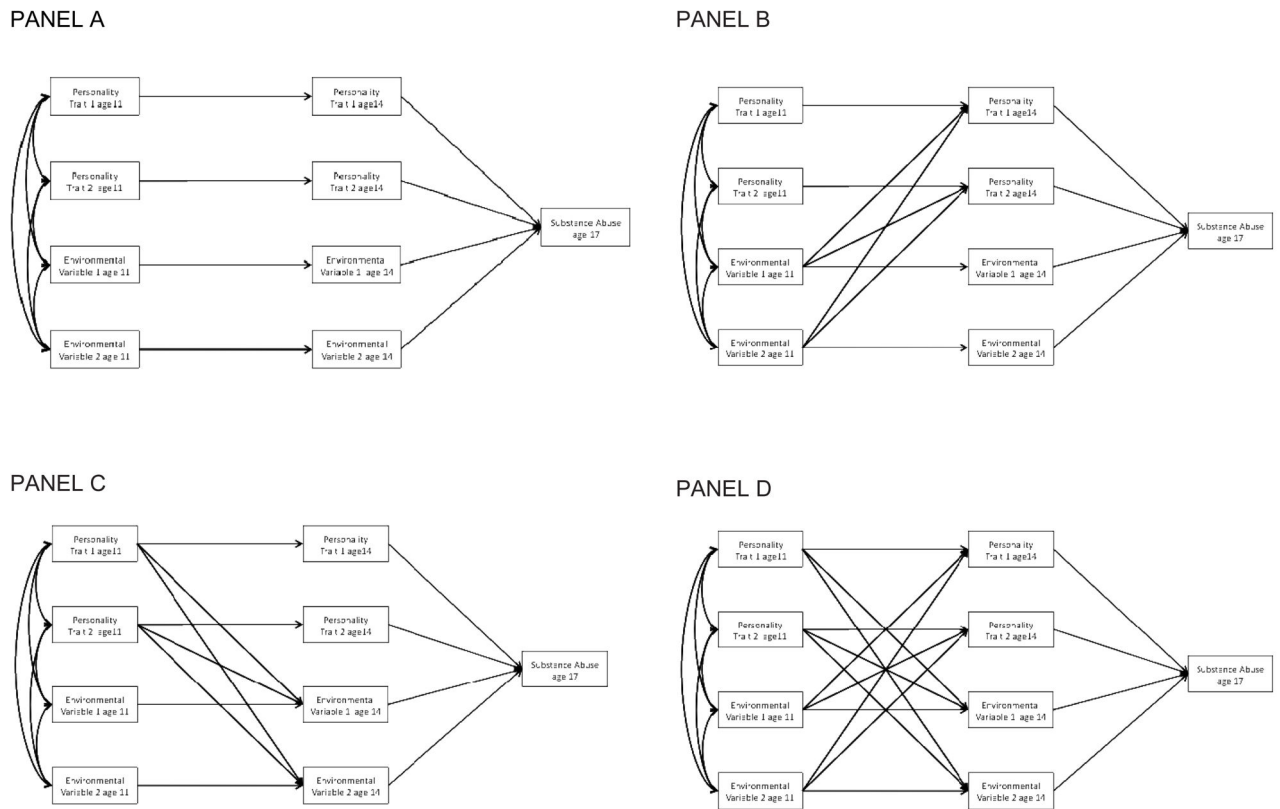
## References

- Armstrong TD, Costello EJ. Community studies on adolescent substance use, abuse, or dependence and psychiatric comorbidity. *Journal of Consulting and Clinical Psychology*. 2002; 70:1224–1239. [PubMed: 12472299]
- Bemmels HR, Burt SA, Legrand LN, Iacono WG, McGue M. The heritability of life events: An adolescent twin and adoption study. *Twin Research and Human Genetics*. 2008; 11:257–265. [PubMed: 18498204]
- Chassin L, Pillow DR, Curran PJ, Molina BSG, Barrera M. Relation of parental alcoholism to early adolescent substance use: A of three mediating mechanisms. *Journal of Abnormal Psychology*. 1993; 102:3–19. [PubMed: 8436697]
- Cohen, J. *Statistical power analysis for the behavioral sciences*. Hillsdale, NJ: Erlbaum; 1988.
- Cohen, JC.; Cohen, P. *Applied multiple regression/correlation analysis for the behavioral sciences*. 2. Hillsdale, NJ: Erlbaum; 1983.
- Conrod PJ, Castellanos-Ryan N, Mackie C. Long-term effects of a personality-targeted intervention to reduce alcohol use in adolescents. *Journal of Consulting and Clinical Psychology*. 2011; 79:296–306. [PubMed: 21500886]
- Cukrowicz KC, Taylor J, Schatschneider C, Iacono WG. Personality differences in children and adolescents with attention deficit/hyperactivity disorder, conduct disorder, and controls. *Journal of Child Psychology and Psychiatry*. 2006; 47:151–159. [PubMed: 16423146]
- Dishion TJ, Capaldi D, Spracklen KM, Li FZ. Peer ecology of male adolescent drug use. *Development and Psychopathology*. 1995; 7:803–824.
- Dishion TJ, Owen LD. A longitudinal analysis of friendships and substance use: Bidirectional influence from adolescence to adulthood. *Developmental Psychology*. 2002; 38:480–491. [PubMed: 12090479]
- Dishion TJ, Spracklen KM, Andrews DW, Patterson GR. Deviancy training in male adolescent friendships. *Behavior Therapy*. 1996; 27:373–390.
- Elkins IJ, McGue M, Iacono WG. Genetic and environmental influences on parent-son relationships: Evidence for increasing genetic influence during adolescence. *Developmental Psychology*. 1997; 33:351–363. [PubMed: 9147842]
- Fox NA, Henderson HA, Marshall PJ, Nichols KE, Ghera MM. Behavioral inhibition: Linking biology and behavior within a developmental framework. *Annual Review of Psychology*. 2005; 56:235–262.
- Granic I, Patterson GR. Toward a comprehensive model of antisocial development: A dynamic systems approach. *Psychological Review*. 2006; 113:101–131. [PubMed: 16478303]
- Hawkins JD, Catalano RF, Miller JY. Risk and protective factors for alcohol and other drug problems in adolescence and early adulthood: Implications for substance abuse prevention. *Psychological Bulletin*. 1992; 112:64–105. [PubMed: 1529040]
- Hicks BM, Carlson MD, Blonigen DM, Patrick CJ, Iacono WG, McGue M. Psychopathic personality traits and environmental risk factors: Differential correlates, gender, and genetic mediation. *Personality Disorders: Theory, Research, & Treatment*. 2012; 3:209–227.
- Hicks BM, Iacono WG, McGue M. Consequences of an adolescent onset and persistent course of alcohol dependence in men: Adolescent risk factors and adult outcomes. *Alcoholism-Clinical and Experimental Research*. 2010; 34:819–833.

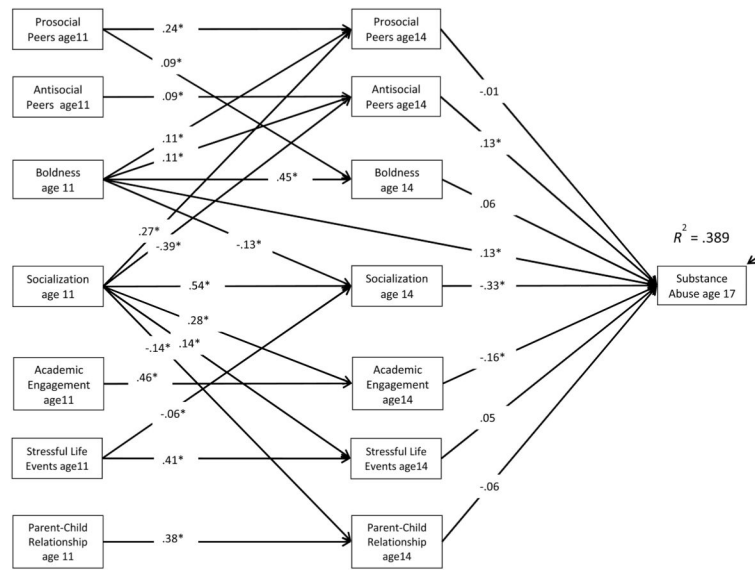


- Hicks BM, Iacono WG, McGue M. Identifying childhood characteristics that underlie pre-morbid risk for substance use disorders: Socialization and boldness. *Development and Psychopathology*. in press.
- Hicks BM, Johnson W, Durbin CE, Blonigen DM, Iacono WG, McGue M. Gene-environment correlation in the development of adolescent substance abuse: Selection effects of child personality and mediation via contextual risk factors. *Development and Psychopathology*. 2013; 25:119–132. [PubMed: 23398757]
- Hicks BM, South SC, DiRago AC, Iacono WG, McGue M. Environmental adversity and increasing genetic risk for externalizing disorders. *Archives of General Psychiatry*. 2009; 66:640–648. [PubMed: 19487629]
- Iacono WG, Carlson SR, Taylor J, Elkins IJ, McGue M. Behavioral disinhibition and the development of substance use disorders: Findings from the Minnesota Twin Family Study. *Development and Psychopathology*. 1999; 11:869–900. [PubMed: 10624730]
- Iacono WG, Malone SM, McGue M. Behavioral disinhibition and the development of early-onset addiction: Common and specific influences. *Annual Review of Clinical Psychology*. 2008; 42:325–348.
- Jessor, RJ.; Jessor, SL. *Problem behavior and psychosocial development*. New York: Academic Press; 1977.
- Johnson W, McGue M, Iacono WG. Disruptive behavior and school grades: Genetic and environmental relations in 11-year olds. *Journal of Educational Psychology*. 2005; 97:391–405.
- Johnson W, McGue M, Iacono WG. Genetic and environmental influences on academic achievement trajectories during adolescence. *Developmental Psychology*. 2006; 42:514–532. [PubMed: 16756442]
- Kagan, J. *Galen's prophecy: Temperament in human nature*. New York: Basic Books; 1994.
- Keyes MA, Malone SM, Elkins IJ, Legrand LN, McGue M, Iacono WG. The Enrichment Study of the Minnesota Twin Family Study: Increasing the yield of twin families at high risk for externalizing psychopathology. *Twin Research and Human Genetics*. 2009; 12:489–501. [PubMed: 19803776]
- Legrand LN, Keyes M, McGue M, Iacono WG, Krueger RF. Rural environments reduce the genetic influence on adolescent substance use and rule-breaking behavior. *Psychological Medicine*. 2008; 38:1341–1350. [PubMed: 17903338]
- McGue M, Elkins I, Walden B, Iacono WG. Perceptions of the parent-adolescent relationship: A longitudinal investigation. *Developmental Psychology*. 2005; 41:971–984. [PubMed: 16351340]
- Muthen, LK.; Muthen, BO. *Mplus User's Guide*. 5. Los Angeles: Muthen & Muthen; 2007.
- Patrick CJ, Fowles DC, Krueger RF. Triarchic conceptualization of psychopathy: Developmental origins of disinhibition, boldness, and meanness. *Development and Psychopathology*. 2009; 21:913–938. [PubMed: 19583890]
- Piehler TF, Veronneau MH, Dishion TJ. Substance use progression from adolescence to early adulthood: Effortful control in the context of friendship influence and early onset use. *Journal of Abnormal Child Psychology*. 2012; 40:1045–1058. [PubMed: 22527607]
- Roberts, BW.; Caspi, A. The cumulative continuity model of personality development: Striking a balance between continuity and change in personality traits across the life course. In: Staudinger, RM.; Lindenberger, U., editors. *Understanding Human Development: Lifespan Psychology in Exchange with Other Disciplines*. Dordrecht, NL: Kluwer Academic Publishers; 2003. p. 183-214.
- Roberts BW, DelVecchio WF. The rank-order consistency of personality traits from childhood to old age: A quantitative review of longitudinal studies. *Psychological Bulletin*. 2000; 126:3–25. [PubMed: 10668348]
- Roberts, BW.; Wood, D. Personality development in the context of the neo-socioanalytic model of personality. In: Mroczek, DK.; Little, TD., editors. *Handbook of personality development*. Mahwah, NJ: Erlbaum; 2006. p. 11-39.
- Robins, LM.; Babor, T.; Cottler, LB. *Composite international diagnostic interview: Expanded substance abuse module*. St. Louis: Author; 1987.
- Scarr S, McCartney K. How people make their own environments: A theory of genotype-environment effects. *Child Development*. 1983; 54:424–435. [PubMed: 6683622]

- Stice E, Barrera M, Chassin L. Prospective differential prediction of adolescent alcohol use and problem use: Examining the mechanisms of effect. *Journal of Abnormal Psychology*. 1998; 107:616–628. [PubMed: 9830249]
- Tapert SF, Aarons GA, Sedlar GR, Brown SA. Adolescent substance use and sexual risk-taking behavior. *Journal of Adolescent Health*. 2001; 28:181–189. [PubMed: 11226840]
- Taylor J, McGue M, Iacono WG, Lykken DT. A behavioral genetic analysis of the relationship between the socialization scale and self-reported delinquency. *Journal of Personality*. 2000; 68:29–50. [PubMed: 10820680]
- Vaidyanathan U, Hall JR, Patrick CJ, Bernat EM. Clarifying the role of defensive reactivity deficits in psychopathy and antisocial personality using startle reflex methodology. *Journal of Abnormal Psychology*. 2011; 120:253–258. [PubMed: 20973594]
- Viner RM, Taylor B. Adult outcomes of binge drinking in adolescence: findings from a UK national birth cohort. *Journal of Epidemiology and Community Health*. 2007; 61:902–907. [PubMed: 17873228]
- Walden B, McGue M, Iacono WG, Burt SA, Elkins IJ. Identifying shared environmental contributions to early substance use: The respective roles of peers and parents. *Journal of Abnormal Psychology*. 2004; 113:440–450. [PubMed: 15311989]
- Welner Z, Reich W, Herjanic B, Jung K, Amado H. Reliability, validity, and parent-child agreement studies of the Diagnostic Interview for Children and Adolescents (DICA). *Journal of the Academy of Child & Adolescent Psychiatry*. 1987; 26:649–653.
- Wills TA, Cleary SD. Peer and adolescent substance use among 6<sup>th</sup>–9<sup>th</sup> graders: Latent growth analyses of influence versus selection mechanisms. *Health Psychology*. 1999; 18:453–463. [PubMed: 10519461]
- Wills TA, Cleary S, Filer M, Shinar O, Mariani J, Spera K. Temperament related to early-onset and substance use: Test of a developmental model. *Prevention Sciences*. 2001; 2:145–163.
- Wills TA, Windle M, Cleary SD. Temperament and novel seeking in adolescent substance use: Convergence of dimensions of temperament with constructs from Cloninger's theory. *Journal of Personality and Social Psychology*. 1998; 74:387–406. [PubMed: 9491584]
- World Health Organization. WHO report on the global tobacco epidemic, 2008: The MPOWER package. Geneva: Author; 2008.
- World Health Organization. Global status report on alcohol and health. Geneva: Author; 2011.
- Zucker, RA. Alcohol use and the alcohol use disorders: A developmental-biopsychosocial systems formulation covering the life course. In: Cohen, DCaDJ., editor. *Developmental Psychopathology* (2nd ed.), vol. 3: Risk, Disorder, and Adaption. New York: Wiley; 2006. p. 620-656.



**Figure 1.** Panel A depicts the independent stability and mediation model. That is, correlated personality and environmental variables at age 11 do not predict each other at age 14, and the age 14 variables mediate the effects of the age 11 variables on substance abuse at age 17. Panel B depicts the shaping model, that is, environmental variables at age 11 predict (or shape) personality variables at age 14, after controlling for the stability of the personality variables from age 11 to 14. Panel C depicts the selection model, that is, personality variables at age 11 predict (or select) environmental variables at age 14, after controlling for the stability of the environmental variables from age 11 to 14. Panel D depicts a model that includes all possible selection and shaping effects.



**Figure 2.** Best fitting model using boldness, socialization, and the environmental variables at ages 11 and 14 to predict substance abuse at age 17.  $R^2$  for the age 14 variables were as follows: boldness (.25), socialization (.34), antisocial peers (.21), prosocial peer (.21), academic engagement (.42), parent-child relationship quality (.21), stressful life events (.22). The correlations among the age 11 variables were also not depicted, but are provided in Table 3. Correlations among the residuals for the age 14 variables were not depicted, but can be obtained from B. M. Hicks.

Table 1

## Items of the Socialization and Boldness scales.

Item	Informant	Response Format	Instrument
<b>Socialization</b>			
<i>Rate the personality of the student comparing him or her to the other students in class</i>			
Truthful, trustworthy Law abiding Values a good reputation, endorses strictness, respects authority	Teacher	1 = Lowest 5% 2 = Lower 30% 3 = Middle 30% 4 = Higher 30% 5 = Highest 5%	Teacher Rating Form (Johnson et al., 2005)
<i>How characteristic is each behavior of the student</i>			
Needs a lot of supervision (r) Difficulty following instructions (r) Motivated to earn good grades *		1 = Not at all 2 = Just a little 3 = Pretty much 4 = Very much	
Turn in homework on time * Have a good attitude about school *	Child	1 = Definitely false 2 = Probably false 3 = Probably true 4 = Definitely true	Academic History Questionnaire (Johnson et al., 2005)
Stolen without confrontation (r) Cruel to animals (r) Often argues with adults (r) Often defies adults' requests (r)		0 = absent 1 = subthreshold 2 = full threshold	DICA-R Child CD (Welner et al., 1987) DICA-R Child ODD
Stealing from small stores (r) Rides bicycle recklessly (r) Set off fireworks in the street (r) Littering by smashing bottles, tipping garbage cans, etc.		0 = no 1 = yes	Delinquent Behavior Inventory (Taylor et al., 2000)
Often lies (r) Often swears or uses obscene language	Mother	0 = absent 1 = subthreshold 2 = full threshold	DICA-R Parent CD DICA-R Parent ODD
Aggressive (r) ** Endorses strictness **		1 = Definitely low 2 = Probably low 3 = Probably high 4 = Definitely high	Parental Rating of Child's Personality (Cukrowicz et al., 2006)
<b>Boldness</b>			
Persuasive, dominant, socially visible Charming with the opposite sex Entertaining, funny Thrill-seeking, adventurous, risk-taking	Teacher	1 = Lowest 5% 2 = Lower 30% 3 = Middle 30% 4 = Higher 30% 5 = Highest 5%	Teacher Rating Form
Seldom talks or plays with others (r) Passive and withdrawn (r) Easily hurt by criticism (r) Worries about many things (r) Often engages in physically dangerous activities		1 = Not at all 2 = Just a little 3 = Pretty much 4 = Very much	

Note. r = reverse keyed; DICA-R = Diagnostic Interview for Children and Adolescents Revised; CD = Conduct disorder; ODD = Oppositional defiant disorder.

\* These items overlapped with the academic engagement variable and so were excluded from the socialization total score.

\*\* These items were not available at age 14 and so were not included in the calculation of socialization scores at age 11 or 14.

**Table 2**

Descriptive statistics mean-level change over time, rank-order stability, and gender differences for contextual variables.

Variable	Mean (SD)		Mean-level Change ( <i>d</i> )	Rank-order Stability ( <i>r</i> )
	Age 11	Age 14	Age 14 – Age 11	Age 11 to 14
Boldness	50.0 (10.0)	50.7 (9.3)	.07	.49
Socialization	50.0 (10.0)	47.1 (14.0)	-.24	.56
Antisocial Peers	50.0 (10.0)	55.3 (12.9)	.46	.37
Prosocial Peers	50.0 (10.0)	46.0 (10.1)	-.40	.41
Academic Engagement	50.0 (10.0)	47.4 (12.8)	-.23	.65
Parent-child Relationship Quality	50.0 (10.0)	45.7 (11.9)	-.39	.48
Stressful Life Events	50.0 (10.0)	48.3 (9.5)	-.17	.47

Note. *d* refers to Cohen's  $d = M_1 - M_2 / (SD_1^2 + SD_2^2)/2$ . All *d*'s and *r*'s  $> |.10|$  are significant at  $p < .001$ . To ease interpretation, all scores were converted to a T-score metric, standardized on the age 11 variable.

Table 3

Correlations among study variables.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
1. Substance Abuse age 17	1.0													
2. Boldness age 11	.21	1.0												
3. Boldness age 14	.13	.49	1.0											
4. Socialization age 11	-.43	-.01	-.01	1.0										
5. Socialization age 14	-.58	-.12	-.07	.56	1.0									
6. Antisocial peers age 11	.35	.20	.08	-.53	-.40	1.0								
7. Antisocial peers age 14	.49	.13	.12	-.47	-.66	.37	1.0							
8. Prosocial peers age 11	-.12	.40	.28	.37	.17	-.26	-.17	1.0						
9. Prosocial peers age 14	-.28	.18	.33	.37	.42	-.21	-.46	.41	1.0					
10. Academic engagement age 11	-.24	.14	.18	.53	.36	-.29	-.32	.40	.38	1.0				
11. Academic engagement age 14	-.44	.07	.15	.52	.58	-.34	-.51	.33	.49	.65	1.0			
12. Parent-child relationship quality age 11	-.21	.07	.09	.44	.32	-.22	-.26	.26	.26	.37	.33	1.0		
13. Parent-child relationship quality age 14	-.30	.08	.08	.33	.40	-.18	-.37	.23	.37	.29	.42	.48	1.0	
14. Stressful life events age 11	.22	-.02	-.07	-.33	-.29	.21	.24	-.21	-.23	-.23	-.23	-.31	-.23	1.0
15. Stressful life events age 14	.23	-.02	-.02	-.26	-.32	.16	.27	-.15	-.26	-.17	-.21	-.24	-.29	.47

Note. Correlations greater than  $|\pm .10|$  are significant at  $p < .001$ .

Table 4

Model fit statistics for personality and environmental variables at age 11 and 14 predicting substance abuse at age 17.

Model description	$\chi^2$	df	CFI	RMSEA	SRMR
<b>1. Independent Stability and Full Mediation</b> (Figure 1, panel A) Only stability coefficients from age 11 to age 14 variables; age 14 variables mediate the effects of all age 11 variables on substance abuse at age 17	620.07	54	.897	.065	.104
<b>2. Independent Stability and Partial Mediation</b> Add direct effects from age 11 variables to substance abuse at age 17	564.72	47	.906	.066	.102
<b>3. Shaping only</b> (Figure 1, panel B) All environmental variables at age 11 predict personality variables at age 14	517.41	44	.914	.065	.093
<b>4. Selection only</b> (Figure 1, panel C) Personality variables at age 11 predict all environmental variables at age 14	263.43	44	.960	.045	.045
<b>5. Selection and Shaping</b> (Figure 1, panel D) Personality variables at age 11 predict all environmental variables at age 14, and all environmental variables at age 11 predict personality variables at age 14	201.12	34	.970	.044	.038
<b>6. Best fitting model</b> (Figure 2) Retain only significant effects for age 11 to age 14 variables, include direct effect for boldness at age 11	200.43	43	.972	.038	.040

Note. df = degrees of freedom; CFI = comparative fit index; RMSEA = root mean square error of approximation; SRMR = standardized root mean residual. Figure 1 provides conceptual illustrations for models 1 (Panel A), 3 (Panel B), 4 (Panel C), and 5 (Panel D). Model 6 is depicted in Figure 2.



**Table 5**

Direct, Indirect, and Total Effects of Childhood Personality and All Environmental Variables at ages 11 and 14 on Substance Abuse at age 17 when estimated in the Same Model.

Variable	Effects on Substance Abuse at age 17		
	Direct Effect	Indirect Effect	Total Effect
<u>Age 11 environmental variables</u>			
Antisocial peers age 11	0	.012	.012
Academic engagement age 11	0	-.074*	-.074*
Parent-child relationship quality age 11	0	-.024	-.024
Prosocial peers age 11	0	.004	.004
Specific indirect effects			
Prosocial peers age 14		-.002	
Boldness age 14		.006	
Stressful life events age 11	0	.040	.040
Specific indirect effects			
Stressful life events age 14		.019	
Socialization age 14		.021	
<u>Age 11 personality variables</u>			
Boldness age 11	.133*	.085*	.218*
Specific indirect effects			
Boldness age 14		.028	
Antisocial peers age 14		.014	
Prosocial peers age 14		-.001	
Socialization age 14		.044*	
Socialization age 11	0	-.293*	-.293*
Specific indirect effects			
Socialization age 14		-.181*	
Antisocial peers age 14		-.050*	
Academic engagement age 14		-.044*	
Parent-child relationship quality age 14		-.009	
Prosocial peers age 14		-.002	
Stressful life events age 14		-.006	

Note.

\*  $p < .001$ . All coefficients are standardized coefficients. A value of 0 for a direct effect indicates this parameter was not included in the model.