Toward a Bioecological Model of School Engagement: A Biometric Analysis of Gene and Environmental Factors

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School disengagement is associated with poor academic achievement, dropout, and risk behaviors such as truancy, delinquency, and substance use. Despite empirical research identifying risk correlates of school disengagement across the ecology, it is unclear from which domain these correlates arise. To redress this issue, the current study used intraclass correlation and DeFries-Fulker analyses to longitudinally decompose variance in three domains of engagement (academic, behavioral, and emotional) using data from the National Longitudinal Study of Adolescent Health. Findings suggest that nonshared environmental factors (that is, environmental contexts and experiences that are unique to each sibling) account for approximately half of the variance in indicators of school disengagement when controlling for genetic influences, and that this variance increases as adolescents grow older and rely less on their immediate family. The present study contributes new evidence on the biosocial underpinnings of school engagement and highlights the importance of interventions targeting factors in the nonshared environment.

KEY WORDS: *academic performance; behavior genetics; prevention; school attachment; school engagement*

School engagement has received significant attention during the past two decades, as researchers have produced compelling evidence of its role in developmental outcomes and academic achievement for students across grade levels. Likewise, educators, social workers, counselors, and families have increasingly recognized the importance of school engagement, as it resonates with their own observations and experiences with students (Furlong et al., 2003). Although definitions of school engagement vary, the construct of school engagement broadly relates to students' participation in, feelings about, and connection to school and the school community, which encompasses teachers, peers, and after-school activities.

The importance of school engagement has been established as a result of a growing body of research that has found low school engagement to be associated with poor school achievement, dropout, and risk behaviors such as truancy, delinquency, antisocial behavior, and substance use (Green et al., 2012; Henry, Knight, & Thornberry, 2012; Hirschfield & Gasper, 2011; Vaughn et al., 2011). In the body of research related to dropout, engagement has emerged as one of the strongest predictors of dropout, irrespective of how engagement is measured (Rumberger, 2011). Moreover, the strength of the evidence linking dropout and engagement has led to engagement being used as a primary theoretical model for understanding and preventing school dropout (Appleton, Christenson, & Furlong, 2008). Given the significant negative individual and social implications, problematic behaviors, and negative developmental trajectories associated with low school engagement, resources continue to be invested to examine and better understand school engagement and to develop interventions for its improvement.

In response to this increased awareness, significant attention has been devoted to examining factors that may directly or indirectly affect students' levels of school engagement. This body of research points to a number of factors in various domains associated with school engagement. Individual factors (such as autonomy, self-efficacy and goal orientation, positive affect, intrinsic motivation, and antisocial behaviors), peer factors (such as peer support, perceptions of peer academic values, and peer group membership), and family factors (such as socioeconomic status (SES), authoritative parenting, parental involvement, and parental educational attainment) have been found to be associated with

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school engagement (Caraway, Tucker, Reinke, & Hall, 2003; Fullerton, 2002; Furlong et al., 2003; Miller-Cribbs, Cronen, Davis, & Johnson, 2002; Patrick, Skinner, & Connell, 1993; Schlee, Mullis, & Shriner, 2009; Shin, Daly, & Vera, 2007; Steinberg, Lamborn, Dornbusch, & Darling, 1992). School- and classroom-level factors (such as positive learning environments, positive interactions and relationships with teachers, cooperative learning, school size, and positive school climate) have also been found to be associated with school engagement (Finn & Voelkl, 1993; McNeely, Nonnemaker, & Blum, 2002; Ryan & Patrick, 2001).

Although many factors across multiple domains have been identified, little attention has been given to the examination of genetic influences in relation to contextual factors on school engagement. Given the mounting evidence that genetics influences all behavioral outcomes (Dick & Rose, 2002; Plomin & Asbury, 2005; Turkheimer, 2000) and the importance of understanding the differential impacts of individual and contextual factors on school engagement to better inform intervention and advance research, it is surprising that genetic research is sparse in this area. To redress this gap, we used biometric analysis to assess the relative impact of genetic and environmental influences, both shared and nonshared, on school engagement over time. The goal of our study was to use Bronfenbrenner's bioecological theory (Bronfenbrenner & Ceci, 1994) and a multidimensional construct of school engagement as theoretical frameworks to put together a more comprehensive and developmentally informed model of school engagement that could better inform intervention and prevention efforts.

A MULTIDIMENSIONAL CONSTRUCT OF SCHOOL ENGAGEMENT

Although most practitioners and researchers believe that school engagement is important, few agree as to what school engagement is or how best to measure it. The terminology and constructs used to define, describe, and study school engagement have evolved during the past 25 years. Definitions and conceptualizations of school engagement have become more complex and multidimensional as the body of knowledge in this area has expanded. Although there is no one definition of school engagement to which everyone subscribes, there appears to be agreement that school engagement is a multidimensional construct.

The multidimensionality of school engagement has been conceptualized as comprising two to four components, including behavioral, affective, cognitive, and academic engagement subtypes (Appleton et al., 2008; Fredricks, Blumenfeld, & Paris, 2004; Jimerson, Campos, & Grief, 2003). The affective (also referred to as emotional or psychological) dimension of engagement generally encompasses students' positive and negative feelings about teachers, peers, and school, and is often measured by using self-report surveys about students' feelings about school and their relationships with teachers and peers (Fredricks et al., 2004; Jimerson et al., 2003). The cognitive dimension of school engagement relates to students' perceptions and beliefs related to school, psychological investment in learning, and the use of cognitive and learning strategies and problem-solving skills (Fredricks et al., 2004; Jimerson et al., 2003). The behavioral dimension of school engagement encompasses student actions and participation in the classroom, school and extracurricular activities, attendance, misbehavior, attention, preparation, and completion of homework (Jimerson et al., 2003). Indicators of academic engagement include academic performance, time on task, and credit completion (Appleton et al., 2008).

Although conceptualizing school engagement along multiple dimensions seems to be helpful in better understanding school engagement and bringing together related lines of research, scholars continue to disagree on the number and types of engagement components, and there is overlap and variation in how the components are operationalized and measured. Moreover, despite the general acceptance that school engagement is complex and multidimensional, engagement researchers often examine only one or two dimensions of engagement; most engagement "research has not capitalized on the potential of engagement as a multidimensional construct that encompasses behavior, emotion and cognition" (Fredricks et al., 2004, p. 83).

Although the different types of school engagement are conceptualized to be related and to compose a broader theoretical construct of students' participation and connection to school, each type of school engagement comprises clusters of variables that are conceivably differentially affected by biological and environmental factors and processes. For example, academic engagement may have a stronger genetic component than behavioral engagement, which may be more strongly influenced by shared or nonshared environmental factors. Thus, it is important to examine the role of genetic and environmental factors for multiple constructs of school engagement to identify variation in genetic, shared, and nonshared factors between the types of school engagement—up to this point, this role has been ignored. To redress these gaps in the literature and to build a more nuanced understanding of school engagement, in the present study we examine genetic and environmental factors related to behavioral, emotional, and academic engagement.

BIOECOLOGICAL MODEL

Because school engagement is complex and found to be influenced by individual factors as well as environmental factors at various levels within the ecology, bioecological theory (Bronfenbrenner & Ceci, 1994) was selected to guide this study. Bioecological theory provides a framework that accounts for biological and ecological factors that can be used to examine and better understand the complex processes and contexts that affect school engagement. Bioecological theory asserts that "human development takes place through processes of progressively more complex reciprocal interaction between an active, evolving biopsychological human organism and the persons, objects, and symbols in its immediate external environment" (Bronfenbrenner & Morris, 1998, p. 996). The bioecological model considers the biologically based characteristics and genetics that influence proximal processes and developmental outcomes (Bronfenbrenner & Ceci, 1994; Bronfenbrenner & Morris, 1998). The environment can be deficient or plentiful in conditions and experiences that inhibit or assist biological factors to be realized. Likewise, biological factors and evolutionary processes set limits on development and "impose imperatives regarding the environmental conditions and experiences required for the realization of human potential" (Bronfenbrenner & Morris, 1998, p. 997).

The bioecological model is especially well suited as a framework for this study. It allows for the examination of complex developmental outcomes and can account for biological and genetic factors in addition to environmental factors at various levels within the ecology. As we examined the role of genetics and shared and nonshared environments in school engagement, a theoretical framework that allowed for the consideration of biological and environmental factors across various contexts was essential. In addition, the bioecological theory provides for the consideration of time, which is an important factor during adolescence. Taking into account findings from developmental genetics research that point to genetic influence on cognitive abilities across the life span (Plomin, Owen, & McGuffin, 1994), along with well-studied developmental and relational changes experienced throughout adolescence (Larson, Richards, Moneta, Holmbeck, & Ducket, 1996), it is reasonable to expect, and important to examine, whether differential variance between genetic, shared, and nonshared environments changes as adolescents grow older.

BEHAVIOR GENETICS AND BIOMETRIC ANALYSIS

Behavior genetics is a highly interdisciplinary field of study that examines the role of genetics in behavior. The field of behavior genetics and the body of research that has grown out of the field have provided substantial evidence that "everything is heritable" (Turkheimer, 2000, p. 160). Although psychopathology, personality, and cognitive abilities are among the best-studied areas, twin and adoption studies across almost all behavioral domains converge to show that "nearly all behaviors that have been studied show moderate to high heritability" (McGuffin, Riley, & Plomin, 2001, p. 1232; see also Plomin, 1990; Plomin et al., 1994). More specifically, behavior genetics research examining genetic and environmental contributions to adolescent behavior has provided evidence that genes account for significant variance in adolescent behavioral outcomes, including antisocial behavior, conduct disorder, problem and aggressive behaviors, internalizing problems, and prosocial attitudes (DiLalla, 2002; Edelbrock, Rende, Plomin, & Thompson, 1995; Jacobson & Rowe, 1999; Moffit, 2005; Rhee & Waldman, 2002; Rushton, 2004; Slutske et al., 1997). Although genes do not cause behaviors, genes do produce certain proteins that play a central role in many important biological processes and shape physiological functioning, including those in the brain and nervous system that are involved in thinking, behavior, and personality (Plomin, DeFries, McClearn, & McGuffin, 2008; Raine, 2013). Evidence has shown that genes influence behavioral outcomes, but genetics research also provides evidence for the importance of noninheritable factors—genetic factors usually account for only about half of the variance for behavioral disorders (Plomin et al., 1994). What is not clear, however, is the extent to which genetic variances account for variation in specific behavioral outcomes, as opposed to how much can be attributed to environmental factors.

In biometric analyses, samples of sibling pairs, usually twins, are analyzed to decompose variance in a variable or scale into three different components: a heritability component, a shared environmental component, and a nonshared environmental component. The heritability component captures the proportion of variance that is the result of genetic influences. The shared environmental component captures the proportion of variance that is the result of environmental factors that make siblings similar. The shared environment encompasses the environmental experiences that twins and siblings have in common, such as their family, neighborhood, and school. The nonshared environmental component captures the proportion of variance that is due to environmental factors that siblings do not share and that can contribute to dissimilarity between siblings. The nonshared environment can be conceived of as environmental contexts and experiences that are unique to each sibling (Plomin et al., 2008), such as peer group, classes, teachers and mentors, and nonshared extracurricular activities.

As previously noted, school engagement has been linked to factors that are biological or genetic in nature (individual factors) and factors that can be found within the shared environment (family and school factors) and the nonshared environment (peer group, classroom, and other experiences unique to the individual). Despite empirical research that has identified numerous correlates of school performance, school problems, and school engagement, it is unclear which domain—shared, nonshared, or genetic—has the greatest impact. To our knowledge, only one behavior genetics study has been conducted to explore genetic and environmental factors related to school connectedness. Using the National Longitudinal Study of Adolescent Health (known as Add Health), Jacobson and Rowe (1999) examined the genetic and environmental influences of the family and school environment and depressed mood with 2,302 adolescent sibling pairs. Their results revealed that a measure of school connectedness was influenced largely by genetic (45%) and nonshared environmental (48%) factors for girls. For boys, nonshared environmental factors also explained most of the variance (59%); genetic factors explained approximately 17% of the variance. The Jacobson and Rowe (1999) study provided some initial evidence of the genetic and environmental correlates of school connectedness—a factor related to school engagement.

THE PRESENT STUDY

One of the often-overlooked and strongest advantages of a biometric analysis is the ability to move toward a better specification of the environment because the genetic factor is held constant. From a behavior genetics perspective, this is especially salient if there is sufficient variance in the nonshared environment—the environmental component where school-based prevention strategies can potentially have the greatest impact. The present study builds on and extends Jacobson and Rowe's (1999) study by using intraclass correlations and DeFries-Fulker (DF) analyses to longitudinally decompose variance in different facets of school engagement—behavioral, academic, and affective—based on data from Add Health. Examining the proportion of variance in each of the three dimensions of school engagement accounted for by genetic, shared, and nonshared factors and how they change over time can provide substantial insights into better understanding school engagement, to specify environmental components and more precisely target areas for intervention. For example, if we know that a greater share of variation related to school engagement stems from environmental factors outside of the home, it may be prudent to target intervention resources toward school-based, rather than family-based, services.

The goal of the present study was to use biometric analysis to assess the relative impact of biological, genetic, and environmental factors—shared and nonshared—on three dimensions of school engagement (academic, behavioral, and emotional) and to examine the extent to which the relative impact of genetic and environmental factors changes over time during the middle and high school years. This study makes four significant contributions to the literature. First, we used biometric analysis to assess the degree to which genetic and environmental factors account for the variance in school engagement. To our knowledge, this study is the first to assess the behavior genetics of school engagement, advancing knowledge in this area. Second, this study used a multidimensional model of school engagement, allowing for examination of the differential impact of genetic and environmental variables on each of these components and providing a more nuanced understanding school engagement. Third, we used a longitudinal approach to examine change over time. Because of changes occurring between early and late adolescence in peer and family relationships and roles (for example, the tendency for socialization to occur more outside of the family as adolescents age and differentiate from their parents), along with adolescents' increased capacity to select into an expanding range of environments as they get older (Bergen, Gardner, & Kendler, 2007; Larson et al., 1996), we hypothesized that variance in nonshared environmental factors increases as adolescents grow older. Fourth, we used data from a national sample of adolescents, addressing the need for a nationally representative sample from which results can be generalized. Up to this point, much of the school engagement research has been conducted with local, nonrepresentative samples.

METHOD

Participants

Data for the current study are from the National Longitudinal Study of Adolescent Health, a three-wave nationally representative sample of American youths enrolled in 132 middle and high schools during the 1994–1995 academic school year (Harris et al., 2003; Udry, 2003). Data collection began when students enrolled at these schools were administered a self-report survey during a specified school day. More than 90,000 students completed the wave 1 in-school surveys. A subsample of youths and their primary caregivers were then selected to be reinterviewed at home (that is, the wave 1 in-home component of Add Health). Approximately one to two years later, the second round of surveys was administered. Because relatively little time had lapsed since wave 1, most of the respondents were still adolescents. Between 2001 and 2002, the third wave of data was collected.

The Add Health study oversampled sibling pairs. A detailed description of the sibling-pairs sample of the Add Health has been published (Harris, Halpern, Smolen, & Haberstick, 2006). Briefly, during wave 1 interviews, adolescents were asked whether they lived with a co-twin, a half-sibling, a stepsibling, or a cousin. If they did, and if their sibling was between the ages of eight and 11, their sibling was also included in the sample. A probability sample of full siblings was also included in the sample (Jacobson & Rowe, 1999). A total of 3,139 respondents were included in the sibling-pairs sample.

This study only looked at monozygotic (MZ) and same-sex dizygotic (DZ) twin pairs because it is necessary to use kinship pairs to estimate genetic and environmental influences and because twins are the most widely examined type of kinship pair. The sample sizes used in the analyses vary as a function of missing data but range between $N = 426$ and $N = 912$. Recent research has revealed almost no differences on variables between the twin and nontwin samples of the Add Health data (Barnes & Boutwell, 2013), which suggests that the sample being analyzed is similar to the nationally representative sample of adolescents.

Measures

Academic Engagement. During wave 1 and wave 2 interviews, students were asked to indicate their most recent grades in four different subjects: English or language arts, mathematics, history or social studies, and science. Responses were originally coded as follows: A = 1, B = 2, C = 3, and D or lower = 4. These items were reverse coded such that A = 4, B = 3, C = 2, and D or lower = 1. All four of the items were then subjected to principal components factor analysis to assess whether they loaded together and could be used as a single indicator of academic performance. The results of this procedure and of internal consistency reliability analysis indicated that the four items "hung together." Consequently, the grades for each subject were summed together to create the wave 1 academic performance scale ($\alpha = .75$) and wave 2 academic performance scale ($\alpha = .76$). Higher values for these academic performance scales indicate higher grades. Table 1 contains the descriptive statistics for the academic engagement scale as well as the other measures used in the analyses.

Behavioral Engagement. During wave 1 and wave 2 interviews, adolescents were asked a series of questions about their school problems. Specifically, adolescents were asked how often they had trouble getting along with teachers, getting along with other students, paying attention, and finishing their homework. Responses to these questions were coded as follows: 0 = never, 1 = just a few times, 2 = about once a week, 3 = almost every day, and 4 = every day. Using similar procedures as with the

Table 1: Descriptive Statistics for the Add Health Study Variables Used in the Final Analytic Sample

Measures	*M*	*SD*	Minimum–Maximum
Wave 1			
Academic engagement	11.52	2.99	4–16
Behavioral engagement	3.96	3.08	0–16
Emotional engagement	18.51	3.78	6–25
Wave 2			
Academic engagement	11.80	2.86	4–16
Behavioral engagement	3.68	2.86	0–15
Emotional engagement	18.56	3.67	5–25

academic performance scale, these items were factor analyzed, and the results of the analyses indicated that the four variables loaded on a single construct. As a result, all four of the items were summed together to create the wave 1 behavioral engagement scale ($\alpha = .70$) and wave 2 behavioral engagement scale ($\alpha = .66$). Higher values on these scales represent more school problems.

Emotional Engagement. During wave 1 and wave 2 interviews, adolescents were asked a number of questions to measure school attachment. Specifically, respondents were asked to indicate whether they felt close to people at their school, whether they felt like they were part of their school, whether they were happy to be at their school, whether the teachers at their school treated students fairly, and whether they felt safe in their school. Responses to these questions were coded as follows: 1 = strongly agree, 2 = agree, 3 = neither agree nor disagree, 4 = disagree, and 5 = strongly disagree. The responses were reverse-coded, and as with the academic performance and behavioral engagement scales, the items were subjected to principal components analysis. The results revealed that all five variables loaded on a single construct. As a result, the items were summed together to create the wave 1 emotional engagement scale ($\alpha = .76$) and wave 2 emotional engagement scale ($\alpha = .66$). Higher values on both of these scales reflect greater levels of emotional engagement.

Analysis Plan

The analysis for this study was conducted in a series of interlocked steps. First, intraclass correlation coefficients (ICCs) were estimated for the wave 1 and wave 2 academic engagement, behavioral engagement, and emotional engagement scales. ICCs index the degree of similarity between twins (from the same twin pair) for each of the measures and are simply estimated by correlating the variable for twin 1 with that same variable for the co-twin. An ICC of .8, for instance, would indicate that twins tend to score similarly on that measure. ICCs were estimated for the full sample of twins and separately for DZ twins and MZ twins. In general, a larger ICC for MZ twins in comparison with DZ twins would provide evidence that the measure is under genetic influence. The reason for this inference is that DZ twins share 50% of their DNA, and MZ twins share 100% of their DNA. However, DZ and MZ twin pairs share similar environments—that is, they have the same parents, typically attend the same school, and live in the same neighborhood. The only reason that a pair of MZ twins should be more similar to each other on a particular measure is that they share more genetic material. Comparing the ICC for MZ twins to the ICC for DZ twins provides initial evidence indicating whether genetic influences are salient to the measure.

Estimating ICCs is an important first step in genetic analysis, but ICCs do not reveal the precise proportion of variance in the measure that is due to genetic factors, shared environmental influences, and nonshared environmental factors. A different analytic strategy is needed to estimate these variance components; in this study, we used DF analysis (DeFries & Fulker, 1985), which has been widely used in a range of disciplines, including psychology and criminology. DF analysis is a variant of ordinary least squares regression that was designed to be used with samples of kinship pairs to estimate the proportion of variance in a measure that is explained by genetic factors. The results of DF analysis provide direct estimates of the proportion of variance accounted for by genetic factors and shared environmental factors. The variance that is left unexplained by these two factors is thus due to nonshared environmental influences and error. Together, genetic influences, shared environmental influences, and nonshared environmental influences account for 100% of the variance in any variable or scale.

When using DF analysis, which twin (from each twin pair) to use as the dependent variable and which twin (from each twin pair) to use as the independent variable becomes an issue, but this can be easily resolved by double-entering twins, such that each twin acts as both the independent and dependent variables (Kohler & Rodgers, 2001; Rodgers, Rowe, & Li, 1994). When twins are double-entered, however, the observations are no longer independent, which could result in deflated standard errors and biased tests of statistical significance. To correct for the nonindependence in observations, all DF models were estimated by using the more robust Huber/White correction for standard errors.

RESULTS

The analysis for this study began by estimating ICCs for each of the school engagement measures in the full twin sample as well as separately for DZ and MZ twins. As can be seen in Table 2, all of the ICCs were statistically significant, indicating that there was at least some similarity between the twins' scores on the school engagement measures. A close inspection of the numbers shows, however, that the ICCs for MZ twins are all larger than the ICCs for DZ twins. This pattern of results, where MZ ICCs are greater than DZ ICCs, provides initial evidence that all of the school engagement measures are influenced, in part, by genetic factors. To provide precise estimates of how much of the variance in the school engagement measures is attributable to genetic factors and how much is attributable to shared and nonshared environmental factors, we next analyzed the school engagement measures by using DF analysis.

Variance Estimates of School Engagement

Table 3 presents the results of the DF models, using the wave 1 measures. The first column displays the variance estimates for the academic engagement scale. As can be seen, genetic factors, shared environmental influences, and nonshared environmental factors each explain approximately one-third of the variance. For the behavioral engagement scale, most of the variance (60%) is due to nonshared environmental factors and none of the variance is accounted for by shared environmental factors. For the emotional engagement scale, genetic and nonshared environmental factors each explain approximately 50% of the variance. Similar to the previous model, the shared environment explains none of the variance.

Table 2: Intraclass Correlations for the School Measures

Measure	Full Twin ICC (*N*)	DZ Twin ICC (*N*)	MZ Twin ICC (*N*)
Wave 1			
Academic engagement	.59* (600)	.51* (278)	.66* (322)
Behavioral engagement	.31* (912)	.19* (192)	.40* (234)
Emotional engagement	.39* (910)	.28* (422)	.47* (488)
Wave 2			
Academic engagement	.58* (426)	.50* (192)	.67* (234)
Behavioral engagement	.24* (716)	.16* (388)	.29* (378)
Emotional engagement	.38* (716)	.25* (338)	.49* (378)

Note: ICC = intraclass correlation; DZ = dizygotic; MZ = monozygotic.
*$p < .05$, two-tailed tests.

Variance Estimates over Time

To assess the consistency in the findings and to examine whether these variance estimates change across time, we replicated the DF models presented previously by using the wave 2 school engagement measures. The results of these models are also contained in Table 3. The academic engagement values are similar to those in wave 1. The behavioral engagement scale shows that only 30% of the variance in behavioral engagement is attributable to genetic factors and that the remaining 70% of the variance is due to nonshared environmental factors. The shared environment explains none of the variance in behavioral engagement. Last, about one-half of the variance in the emotional engagement scale is due to genetic factors, and the other half is explained by nonshared environmental factors. Once again, the shared environment explains none of the variance.

DISCUSSION

Scholars have firmly established the importance of school engagement as a construct that deserves ongoing attention to examine and explain various developmental trajectories and student outcomes, particularly academic achievement and dropout (Fredricks et al., 2004). Improving school engagement is increasingly viewed as a means to improve academic achievement and reduce dropout, resulting in numerous interventions designed to positively affect school engagement. A significant area of research that has been largely ignored, however, is the examination of genetic influences in relation to contextual factors that contribute to school engagement, or lack thereof. Although it is well established that one's genetic makeup and environmental factors influence behaviors, social workers have not adequately integrated social and biological

Table 3: DeFries-Fulker Analysis of Wave 1 and Wave 2 School Measures			
Variance Components	**Academic Engagement[a] (*N* = 600)**	**Behavioral Engagement[a] (*N* = 912)**	**Emotional Engagement[a] (*N* = 910)**
Wave 1			
Heritability	32	40	49
Shared environment	35	00	00
Nonshared environment	33	60	51
Variance Components	**Academic Engagement (*N* = 426)**	**Behavioral Engagement (*N* = 716)**	**Emotional Engagement (*N* = 716)**
Wave 2			
Heritability	34	30	49
Shared environment	32	00	00
Nonshared environment	34	70	51

[a]Percentage of variance decomposed.

research to better understand the etiology of specific behaviors to improve prevention and intervention efforts (McCutcheon, 2006). As studies across several fields have converged to identify genetic effects and the importance of nonshared environmental effects on many behaviors, the sparse attention on genetic effects and lack of distinction between shared and nonshared environmental factors in social work research is a serious deficiency.

To redress this gap in the literature, the present study used biometric analysis to assess the relative impact of genes and environmental factors on school engagement. To our knowledge, the present investigation is the first to assess the behavior genetics of school engagement. Understanding the differential impact of genetic and contextual factors on the three dimensions of school engagement provides additional insights and a more nuanced understanding of school engagement to better inform intervention and prevention efforts.

The findings of the present study reveal that genetic factors account for approximately one-third to one-half of the variance and that nonshared environmental factors account for one-third to two-thirds of the variance in the three school engagement domains measured in this study. Overall, our finding that nonshared environmental factors are particularly salient is consistent with extant behavior genetics studies and meta-analyses of adolescent behavior (Jacobson & Rowe, 1999; Pike & Plomin, 1996; Plomin & Asbury, 2005; Plomin, Asbury, & Dunn, 2001). Turkheimer and Waldron (2000) conducted a meta-analysis of studies in which an aspect of the nonshared environment was measured, finding that upward of 50% of the total variance in outcomes was attributed to the nonshared environment. Likewise, nonshared environmental factors accounted for a substantial amount of variance for self-control (Beaver et al., 2009), perceptions of self-worth and competence (McGuire, Neiderhiser, Reiss, Hetherington, & Plomin, 1994), conduct disorder (Slutske et al., 1997), and a range of other behavioral problems (Eaves et al., 1997). Genes do account for some of the variance in behavior, but nonshared environmental factors account for a substantial amount of variance, often more than genes and shared environmental factors. According to Turkheimer (2011), reducing the nature–nurture debate to a contest between genetic effects and familial environments, cultural contexts, and socioeconomic variables is inadequate. The nonshared environment is particularly important, as it is where more potent causes of developmental outcomes can be found (Plomin & Daniels, 1987). Nonshared environmental factors are important because they are under an individual's control and are amenable to change; genes and upbringing are not (Turkheimer, 2011).

Although prior behavior genetics studies make it not altogether surprising that we found genetic and nonshared environmental factors to account for most of the variance in the three school engagement domains, it is interesting that shared environmental factors explained none of the variance in the behavioral and emotional engagement domains at wave 1 and wave 2. In prior studies of adolescent internalizing and externalizing behaviors, shared environmental factors were found to account for 0% to

30% of the variation in the behaviors examined. Burt (2009) examined 490 twin studies assessing shared environmental effects on child and adolescent internalizing and externalizing psychopathology and found that the shared environment accounted for between 10% and 19% of the variance in a broad range of behaviors, including oppositional defiant disorder, depression, anxiety, conduct disorder, and broad internalizing and externalizing disorders. Evidence of significant shared environmental effects was not found for conduct disorder, aggression, oppositional defiant disorder, self-control, attention deficit/hyperactivity disorder (ADHD), and adolescent adjustment across several studies (Beaver et al., 2009; DiLalla, 2002; Eaves et al., 1997; McGue, Sharma, & Benson, 1996; Slutske et al., 1997). Although shared environmental factors are often found to be weaker than genetic and nonshared environmental factors for a range of adolescent behaviors, there is some evidence of significant shared environmental influence in childhood and adolescence. With IQ, for example, shared environmental effects have been found to explain 25% to 30% of the variance (McGue, Bouchard, Iacono, & Lykken, 1993). Thus, even though the differences in the amount of variance explained by shared environmental factors in the domain of academic engagement (33%) compared with behavioral and emotional engagement (0%) are interesting, these findings nonetheless seem to be consistent with prior behavior genetics research in areas that are conceptually similar to the variables measured in each of the three engagement domains.

Because adolescence is marked by numerous changes in peer and familial roles and relationships, emerging environmental opportunities, and changes in cognitive development and functioning as adolescents age, we expected some change in the amount of variance explained by genes and shared and nonshared environmental factors over time. Our results indicate that the genetic effects increased negligibly in the academic engagement domain, decreased 10% in the behavioral engagement domain, and remained unchanged in the emotional engagement domain from wave 1 to wave 2.

Findings from prior research examining patterns of heritability across time in longitudinal behavior genetics studies have been mixed across various phenotypes. A meta-analysis examining heritability of behavioral phenotypes across adolescence and young adulthood found a general pattern of increased heritability across time for externalizing behavior, anxiety symptoms, depressive symptoms, IQ, and social attitudes, but not for alcohol consumption, nicotine initiation, and ADHD (Bergen et al., 2007). Another meta-analysis examining shared environmental influences in twin and adoption studies of internalizing and externalizing psychopathology prior to adulthood also found mixed results of longitudinal change in heritability of various phenotypes (Burt, 2009). Little to no change in heritability was found for externalizing behaviors and anxiety, inconsistent results were found for internalizing and conduct problems, and some evidence was found of increased genetic influences for depression.

The change in variance over time in the behavioral engagement domain observed in the present study could indicate that the items composing the behavioral engagement measure may be more susceptible to nonshared environmental factors than items in the academic or emotional engagement domain. Any differences in variance across time may also be an artifact of the way in which the school engagement constructs were operationalized and measured in this study. Future research could expand on this study by examining variance in genetic, shared, and nonshared factors over time, using different measures aligned with alternative conceptualizations of school engagement.

Implications

The present study confirms that the nonshared environmental component is the most salient, accounting for a substantial amount of variance in school engagement across all domains. This is good news for school personnel, school social workers, counselors, and others who work with youths because the nonshared environment has the greatest potential to be affected by interventions. To extend our findings to implications for intervention, we mapped our findings onto Bronfenbrenner and Ceci's (1994) bioecological theory. The theory specifies that development is the result of a complex process that occurs through the interaction of the biologically based characteristics and genetics of the person within and between various levels of one's ecology through time. Our results indicate that genetics (the person in the bioecological theory) do influence school engagement domains to some extent; however, nonshared environmental factors account for a substantial amount of the variance, and shared environmental factors account for none or little variance, depending on the school engagement domain being examined.

Using the bioecological model as our framework, the macrosystem and exosystem comprise environmental contexts that are likely part of the shared environment; siblings share the aspects of the environment related to culture, SES, neighborhood, and parents' work environment. The microsystem comprises environments in which adolescents spend much of their time, such as home, school, and peer groups; the mesosystem is the interrelation between the microsystem environments. Thus, nonshared factors are more likely to be found in the microsystem and mesosystem. Within the microsystem are environments that siblings share, such as family and school, as well as environments that siblings do not share, such as classes, peer groups, teachers, and possibly extracurricular activities. In addition, proximal processes, interactions between students and others in their environment, also qualify as a nonshared environment. Thus, interventions may be most indicated in the environments and proximal processes within and between the microsystem and mesosystem that are unique to siblings (that is, peer group, teachers, mentors, and extracurricular activities).

Although the results of this study do not specify the exact microsystem or the proximal processes to target for intervention, the findings suggest that there is room for interventions to affect school engagement processes, particularly in schools. The proximal processes that occur within schools, such as relationships and interactions with teachers, peer groups, and school activities, may be particularly salient. In addition, although the family environment is considered a shared environment, the proximal processes between adolescents and their parents are in the realm of the nonshared environment; the interactions between students and parents are unique to that dyad or subgroup. Thus, family interventions should not be dismissed as an inappropriate strategy. Targeting aspects of the parent–adolescent relationship and interactions that may be amenable to change and affect school engagement could be an appropriate strategy to improve students' engagement with school. However, given our findings, along with findings from extant behavior genetics research that as participants get older, more variance is explained by nonshared environmental factors rather than family and other shared factors (Rhee & Waldman, 2002), family interventions may be less relevant in high school than in elementary and middle school.

Prevention and Intervention in the Nonshared Environment

The findings of the present study suggest that targeting nonshared environmental factors can potentially have a significant impact on school engagement, as school engagement factors are less likely to be dependent on family influence or genes than on amenable factors—which can be positively influenced by social workers, counselors, and school personnel. Unfortunately, some in the general public, including policymakers, parents, and perhaps even educators, may explain adolescents' struggles by "placing blame" on genetic or family influences. As a result, some may find reasons to excuse themselves from intervening, assuming that their efforts may be futile. The findings from this study, however, suggest that interventions in the nonshared environment will affect students' success. Thus, this study and similar research provide compelling arguments against the claim of skeptics of school services that it is too late to remediate these students.

Although schools function within a definite policy context and no doubt face important decisions about where to devote resources and how to balance competing educational initiatives, this study provides an argument that it would indeed be beneficial to devote resources to prevention and intervention in the nonshared environment for adolescents who continue to struggle academically and with school disengagement. School-based services play an important role in limiting individual barriers to academic success and in keeping youths engaged in school. However, evidence-based dropout prevention interventions are sparse. Targeting nonshared environmental factors and processes within the school environment has promise, but more research is needed to identify specific pathways and processes involved in school engagement and disengagement and to develop effective policies and interventions.

Limitations

The interpretation of this study's results should take into account two main limitations. First, the measures of school engagement are based on self-reported data and are not augmented by school administrative data; thus, they are open to the usual criticisms of self-reported data. Whether the results reported here would be replicable with different measures of school engagement remains an empirical issue awaiting future research. There are also limitations to our measurement approach, which are common with extant files from nationally representative data that often sacrifice depth of measurement for generalizability. Unfortunately, there is little consensus or consistency in the way school engagement is defined, operationalized, and measured; however, in our view, we selected engagement variables from the data set that aligned with a multidimensional model of school engagement.

Moreover, twin pairs from the Add Health data may not be representative of all twins or of samples of singletons. However, it is important to point out that the Add Health sample is much larger and much more representative of the population than the samples typically used in genetic analysis. Further, prior researchers have compared the sample of siblings, including twins, from Add Health with the nationally representative sample of Add Health respondents. The results of these studies revealed no substantive differences in a wide range of measures (Beaver, 2008). Still, replication studies that use different samples and use behavior genetics strategies are needed to test the relative proportion of variance in the nonshared environment.

Conclusion

Despite its limitations, the present study contributes new evidence on the biosocial underpinnings of school engagement and highlights the potential importance of interventions targeting factors in the nonshared environment. Although this study represents a first step to understanding the relative importance of genetic and shared and nonshared environmental factors that contribute to school engagement, future research is needed to examine whether these results are replicable with different samples and with different measures and definitions of school engagement. In addition, more nuanced investigations examining specific genes and shared and nonshared environmental factors as well as gene–environment interaction would be natural next steps to better elucidate and disentangle which factors and interactions are most salient in predicting and preventing school disengagement. By better specifying genetic as well as shared and nonshared environmental effects, we can begin to more effectively identify individual risks and needs across the ecology to improve prevention and intervention efforts in this area. **SWR**

REFERENCES

Appleton, J., Christenson, S. L., & Furlong, M. J. (2008). Student engagement with school: Critical concept and methodological issues of the construct. *Psychology in the Schools, 45*, 369–386.

Barnes, J. C., & Boutwell, B. B. (2013). A demonstration of the generalizability of twin-based research on antisocial behavior. *Behavior Genetics, 43*(2), 120–131.

Beaver, K. M. (2008). Nonshared environmental influences on adolescent delinquent involvement and adult criminal behavior. *Criminology, 46*, 341–370.

Beaver, K. M., Schlutt, J. E., Boutwell, B. B., Ratchford, M., Roberts, K., & Barnes, J. C. (2009). Genetic and environmental influences on levels of self-control and delinquent peer affiliation: Results form a longitudinal sample of adolescent twins. *Criminal Justice and Behavior, 36*, 41–60.

Bergen, S. E., Gardner, C. O., & Kendler, K. S. (2007). Age-related changes in heritability of behavioral phenotypes over adolescence and young adulthood: A meta-analysis. *Twin Research and Human Genetics, 10*, 423–433.

Bronfenbrenner, U., & Ceci, S. J. (1994). Nature-nurture reconceptualized in developmental perspective: A bioecological model. *Psychological Review, 101*, 568–586.

Bronfenbrenner, U., & Morris, P. A. (1998). The ecology of developmental processes. In W. Damon & R. M. Lerner (Eds.), *Handbook of child psychology, Volume 1: Theoretical models of human development* (5th ed., pp. 993–1028). Hoboken, NJ: John Wiley & Sons.

Burt, S. A. (2009). Rethinking environmental contributions to child and adolescent psychopathology: A meta-analysis of shared environmental influences. *Psychological Bulletin, 135*, 608–637.

Caraway, K., Tucker, C. M., Reinke, W. M., & Hall, C. (2003). Self-efficacy, goal orientation, and fear of failure as predictors of school engagement in high school students. *Psychology in the Schools, 40*, 417–427.

DeFries, J. C., & Fulker, D. W. (1985). Multiple regression analysis of twin data. *Behavior Genetics, 15*, 467–473.

Dick, D. M., & Rose, R. J. (2002). Behavior genetics: What's new? What's next? *Current Directions in Psychological Science, 11*, 70–74.

DiLalla, L. F. (2002). Behavior genetics of aggression in children: Review and future directions. *Developmental Review, 22*, 593–622.

Eaves, L. J., Silberg, J. L., Meyer, J. M., Maes, H. H., Simonoff, E., Pickles, A., et al. (1997). Genetics and developmental psychopathology: 2. The main effects of genes and environment on behavioral problems in the Virginia twin study of adolescent behavioral development. *Journal of Child Psychology and Psychiatry, 38*, 965–980.

Edelbrock, C., Rende, R., Plomin, R., & Thompson, L. E. (1995). A twin study of competence and problem behavior in childhood and early adolescence. *Journal of Psychology and Psychiatry, 36*, 775–785.

Finn, J. D., & Voelkl, K. E. (1993). School characteristics related to school engagement. *Journal of Negro Education, 62*, 249–268.

Fredricks, J. A., Blumenfeld, P. C., & Paris, A. H. (2004). School engagement: Potential of the concept, state of the evidence. *Review of Educational Research, 74*, 59–109.

Fullerton, S. (2002). *Student engagement with school: Individual and school-level influences* [Longitudinal Surveys of Australian Youth research report No. 27]. Camberwell,

Victoria: Australian Council for Educational Research. Retrieved from http://research.acer.edu.au/lsay_research/31
Furlong, M. J., Whipple, A. D., St. Jean, G., Simental, J., Soliz, A., & Punthuna, S. (2003). Multiple contexts of school engagement: Moving toward a unifying framework for educational research and practice. *California School Psychologist, 8*, 99–113.
Green, J., Liem, G.A.D., Martin, A. J., Colmar, S., Marsh, H. W., & McInerney, D. (2012). Academic motivation, self-concept, engagement, and performance in high school: Key processes from a longitudinal perspective. *Journal of Adolescence, 35*, 1111–1122.
Harris, K. M., Florey, F., Tabor, J., Bearman, P. S., Jones, J., & Udry, J. R. (2003). *The National Longitudinal Study of Adolescent Health: Research design*. Chapel Hill: Add Health, Carolina Population Center, University of North Carolina at Chapel Hill. Retrieved from http://www.cpc.unc.edu/projects/addhealth/design
Harris, K. M., Halpern, C. T., Smolen, A., & Haberstick, B. C. (2006). The National Longitudinal Study of Adolescent Health (Add Health) twin data. *Twin Research and Human Genetics, 9*, 988–997.
Henry, K. L., Knight, K. E., & Thornberry, T. P. (2012). School disengagement as a predictor of dropout, delinquency and problem substance use during adolescence and early adulthood. *Journal of Youth and Adolescence, 41*, 156–166.
Hirschfield, P. J., & Gasper, J. (2011). The relationship between school engagement and delinquency in late childhood and early adolescence. *Journal of Youth and Adolescence, 40*, 3–22.
Jacobson, K. C., & Rowe, D. C. (1999). Genetic and environmental influences on the relationship between family connectedness, school connectedness, and adolescent depressed mood: Sex differences. *Developmental Psychology, 35*, 926–939.
Jimerson, S. R., Campos, E., & Grief, J. L. (2003). Toward an understanding of definitions and measures of school engagement and related terms. *California School Psychologist, 8*, 7–27.
Kohler, H.-P., & Rodgers, J. L. (2001). DF-analyses of heritability with double-entry twin data: Asymptotic standard errors and efficient estimation. *Behavior Genetics, 31*, 179–191.
Larson, R. W., Richards, M. H., Moneta, G., Holmbeck, G., & Ducket, E. (1996). Changes in adolescents' daily interactions with their families from ages 10–18: Disengagement and transformation. *Developmental Psychology, 32*, 744–754.
McCutcheon, V. V. (2006). Toward an integration of social and biological research. *Social Service Review, 80*, 159–178.
McGue, M., Bouchard, T. J., Iacono, W. G., & Lykken, D. T. (1993). Behavioral genetics of cognitive ability: A life-span perspective. In R. Plomin & G. E. McClearn (Eds.), *Nature, nurture, and psychology* (pp. 59–76). Washington, DC: American Psychological Association.
McGue, M., Sharma, A., & Benson, P. (1996). The effect of common rearing on adolescent adjustment: Evidence from a U.S. adoption cohort. *Developmental Psychology, 32*, 604–613.
McGuffin, P., Riley, B., & Plomin, R. (2001). Toward behavioral genomics. *Science, 291*, 1232–1233.
McGuire, S., Neiderhiser, J. M., Reiss, D., Hetherington, E. M., & Plomin, R. (1994). Genetic and environmental influences on perceptions of self-worth and competence in adolescence: A study of twins, full siblings, and step-siblings. *Child Development, 65*, 785–799.
McNeely, C. A., Nonnemaker, J. M., & Blum, R. W. (2002). Promoting school connectedness: Evidence from the National Longitudinal Study of Adolescent Health. *Journal of School Health, 72*, 138–146.
Miller-Cribbs, J. E., Cronen, S., Davis, L., & Johnson, S. D. (2002). An exploratory analysis of factors that foster school engagement and completion among African American students. *Children & Schools, 24*, 159–174.
Moffit, T. E. (2005). The new look of behavioral genetics in developmental psychopathology: Gene-environment interplay in antisocial behaviors. *Psychological Bulletin, 131*, 533–554.
Patrick, B. C., Skinner, E. A., & Connell, J. P. (1993). What motivates children's behavior and emotion? Joint effects of perceived control and autonomy in the academic domain. *Journal of Personality and Social Psychology, 65*, 781–791.
Pike, A., & Plomin, R. (1996). Importance of nonshared environmental factors for childhood and adolescent psychopathology. *Journal of the American Academy of Child & Adolescent Psychiatry, 35*, 560–570.
Plomin, R. (1990). The role of inheritance in behavior. *Science, 248*, 183–188.
Plomin, R., & Asbury, K. (2005). Nature and nurture: Genetic and environmental influences on behavior. *Annals of the American Academy of Political and Social Science, 600*, 86–98.
Plomin, R., Asbury, K., & Dunn, J. (2001). Why are children in the same family so different? Nonshared environment a decade later. *Canadian Journal of Psychiatry, 46*, 225–233.
Plomin, R., & Daniels, D. (1987). Why are children in the same family so different from one another? *Behavioral and Brain Science, 10*, 1–60.
Plomin, R., DeFries, J. C., McClearn, G. E., & McGuffin, P. (2008). *Behavioral genetics* (5th ed.). New York: Worth.
Plomin, R., Owen, M. J., & McGuffin, P. (1994). The genetics of complex human behavior. *Science, 264*, 1733–1739.
Raine, A. (2013). *The anatomy of violence*. New York: Pantheon Books.
Rhee, S. H., & Waldman, I. D. (2002). Genetic and environmental influences on antisocial behavior: A meta-analysis of twin and adoption studies. *Psychological Bulletin, 128*, 490–529.
Rodgers, J. L., Rowe, D. C., & Li, C. (1994). Beyond nature versus nurture: DF analysis of nonshared influences on problem behaviors. *Developmental Psychology, 30*, 374–384.
Rumberger, R. W. (2011). *Dropping out: Why students drop out of high school and what can be done about it*. Cambridge, MA: Harvard University Press.
Rushton, J. P. (2004). Genetic and environmental contributions to pro-social attitudes: A twin study of social responsibility. *Proceedings of the Royal Society B: Biological Sciences, 271*, 2583–2585.
Ryan, A. M., & Patrick, H. (2001). The classroom social environment and changes in adolescents' motivation and engagement during middle school. *American Educational Research Journal, 28*, 437–460.
Schlee, B. M., Mullis, A. K., & Shriner, M. (2009). Parents social and resource capital: Predictors of academic achievement during early childhood. *Children and Youth Services Review, 31*, 227–234.
Shin, R., Daly, B., & Vera, E. (2007). The relationships of peer norms, ethnic identity, and peer support to school engagement in urban youth. *Professional School Counseling, 10*, 379–388.
Slutske, W. S., Heath, A. C., Dinwiddie, S. H., Madden, P.A.F., Bucholz, K. K., Dunne, M. P., et al. (1997).

Modeling genetic and environmental influences in the etiology of conduct disorder: A study of 2,682 adult twin pairs. *Journal of Abnormal Psychology, 106*, 266–279.
Steinberg, L., Lamborn, S. D., Dornbusch, S. M., & Darling, N. (1992). Impact of parenting practices on adolescent achievement: Authoritative parenting, school involvement, and encouragement to succeed. *Child Development, 63*, 1266–1281.
Turkheimer, E. (2000). Three laws of behavior genetics and what they mean. *Current Directions in Psychological Science, 9*, 160–164.
Turkheimer, E. (2011). Genetics and human agency: Comment on Dar-Nimond and Heine (2011). *Psychological Bulletin, 137*, 825–828.
Turkheimer, E., & Waldron, M. (2000). Nonshared environment: A theoretical, methodological, and quantitative review. *Psychological Bulletin, 126*, 78–108.
Udry, J. R. (2003). The National Longitudinal Study of Adolescent Health (Add Health), Waves I and II, 1994–1996; Wave III, 2001–2002 [Data file and documentation]. Chapel Hill, NC: Carolina Population Center.
Vaughn, M. G., Wexler, J., Beaver, K. M., Perron, B. E., Roberts, G., & Fu, J. (2011). Psychiatric correlates of behavioral indicators of school disengagement in the United States. *Psychiatric Quarterly, 82*, 191–206.

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