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Moderating Effects of Personality on the Genetic and Environmental Influences of School Grades Helps to Explain Sex Differences in Scholastic Achievement

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Abstract

Girls consistently achieve higher grades than boys despite scoring lower on major standardized tests and not having higher IQs. Sex differences in non-cognitive variables such as personality might help to account for sex differences in grades. Utilizing a large sample of 17 year-old twins participating in the Minnesota Twin Family Study (MTFS), we examined the roles of Achievement Striving, Self-Control, and Aggression on sex differences in grade point average (GPA). Each personality trait was a significant predictor of GPA, with sex differences in Aggression accounting for one-half the sex difference in GPA and genetic variance accounting for most of the overlap between personality and GPA. Achievement Striving and Self-Control moderated the genetic and environmental influences on GPA. Specifically, for girls but not boys, higher Achievement Striving and Self-Control were associated with less variability in GPA and greater genetic and environmental overlap with GPA. For girls, certain personality traits operate to shape a context yielding uniformly higher GPA, a process that seems absent in boys.

Keywords

grade point average; personality; sex differences; gene-environment interactions and correlations

Girls get better school grades than boys. This is true in all subjects throughout elementary, middle, and high school, and even into college (American Association of University Women, 1998; Mau & Lynn, 2001; Perkins et al., 2004; Pomerantz et al., 2002; Willingham & Cole, 1997). Girls, however, do not have higher IQ's, and they do not score as well on some of the major standardized tests (American Association of University Women, 1998; Deary et al., 2007; Mau & Lynn, 2001). This has meant, in particular, that standardized test scores do not have the same predictive validity for college grades in men and women. For example, Stricker et al. (1993) found that a regression equation predicting college freshman grade point average on a 4.0 scale using Scholastic Aptitude Test (SAT) scores under-predicted women's first-semester grades by .10 and over-predicted those of men by .11.

To understand the reason for sex differences in the association between ability and school performance requires delineating the factors that contribute to both the under-prediction of

girls' grades and the over-prediction of boys'. Historically, however, most research efforts have been devoted to understanding the male advantage in standardized test scores, with an eye to understanding the under-prediction of female grades, particularly in the areas of math and science. Varied explanations have been offered. For example, some have suggested that girls may take easier courses than boys and engage in fewer activities outside of the classroom that develop intellectual skills that are, directly or indirectly, measured by standardized tests (Entwisle et al., 1994; Lever, 1978; Loewen et al., 1988; Pallas & Alexander, 1983). Others have suggested that stereotype threat may impede female but not male test performance, particularly in math-related areas (e.g., Steele, 1997). Test-taking strategies have also been implicated. Willingham and Cole (1997) noted that boys tend to do better on the multiple-choice test format that is used in many standardized tests, while girls tend to do better on free-response tests. Additionally, Kimball (1989) suggested that female students may be less confident than male students about answering the kinds of novel problems often presented on standardized tests.

Personality Traits and Academic Achievement: Achievement Striving, Self-Control, and Aggression

These explanations do not, however, help us to understand why female students get better grades than male students. One hypothesis concerns the contribution personality makes to academic achievement, and that sex differences in personality might help account for the gender gap in grades. Drawing connections between personality and academic achievement is not new: Whipple (1922) noted that academic success required more than 'native intelligence' (p. 262) and Webb (1915) attributed intellectual performance at least partly to persistence of motivation, or what might now be termed conscientiousness or striving for achievement. Consistent with these speculations, the broad personality trait of Conscientiousness of the Five Factor Model (FFM) of personality has been repeatedly linked to greater academic achievement even when controlling for intelligence and previous grades (Duckworth & Seligman, 2005; Nofle & Robins, 2007; Wagerman & Funder, 2007). Finer grained analyses have demonstrated that greater academic achievement is specifically associated with the achievement striving, persevering, and self-control facets of Conscientiousness (Nofle & Robins, 2007).

The distinction between achievement striving and self-control deserves special consideration as it relates to academic achievement and sex differences. In the FFM, Conscientiousness has been broadly conceptualized as having "proactive" aspects that relate to goal orientation and task persistence and "inhibitive" aspects that relate to behavioral restraint, cautiousness, and planning (Costa et al., 1991). This conceptualization was supported by a recent analysis of 36 Conscientiousness-related scales, which delineated a hierarchical structure of Conscientiousness with Proactive and Inhibitive factors composing the second (broadest) level of the hierarchy. In contrast, Tellegen's (in press) 3-factor model of personality locates the proactive aspects of Conscientiousness (assessed via the Achievement scale¹) within the Positive Emotionality (PEM; one's sensitivity to positive emotions) factor emphasizing the positive affective component of task engagement. On the other hand, the inhibitive aspects of Conscientiousness (embodied in the Control scale¹) form the core of Tellegen's Constraint (CON) factor that emphasizes the behavioral and cognitive control needed to complete tasks and modulate behavior as appropriate for a given context. Shiner (1998, 2000) also makes this distinction in her review and empirical analyses of childhood personality, identifying the traits of Mastery Motivation and Academic Conscientiousness as roughly corresponding to the

¹To be consistent with the broader literature and to avoid confusion between academic achievement and the Achievement scale from Tellegen's Multidimensional Personality Questionnaire (MPQ; Tellegen, in press), we will use the names "Achievement Striving" and "Self-Control" to refer to the MPQ scales of Achievement and Control, respectively.

proactive and inhibitive aspects of the adult Conscientiousness construct. Both Mastery Motivation and Academic Conscientiousness exhibited cross sectional associations with school grades in childhood as well as prospective links with academic attainment and work performance 10 years later even after controlling for IQ (Shiner, 2000). Of note, men tend to score slightly higher on measures of achievement striving while women score slightly higher on self-control, a difference that widens from late adolescence to young adulthood (Blonigen et al., in press; Roberts et al., 2001). These differences in personality then might help account for gender differences in grades.

In addition to achievement striving and self-control, externalizing or aggressive behavior is another non-cognitive individual differences trait that exhibits both a strong association with academic achievement (see Hinshaw, 1992 for a review and Johnson et al., 2005, 2006 for associations in the MTFS) and a large gender difference (Moffitt et al., 2001). While it is fairly clear that externalizing behavior often results in poorer academic performance indirectly due to the disruption of order, task persistence, and learning processes, it is also notable that some of the gender gap in externalizing behavior is attributable to the male preponderance of neuropsychological deficits directly related academic achievement including attention problems, low verbal IQ, and learning disabilities (for a review see Moffitt et al., 2001). While historically conceptualized as distinct from personality, externalizing behavior exhibits high levels of stability as well as strong personality correlates. Specifically, the personality correlates of externalizing behavior occupy an intermediate vector between low Agreeableness and low Conscientiousness in the FFM (Miller et al., 2003) and high Negative Emotionality (NEM; one's sensitivity to negative emotions) and low CON in Tellegen's 3 factor model (Krueger et al., 1994; Krueger et al., 1996). In particular, the Aggression scale (a marker of the NEM factor) of Tellegen's MPQ has exhibited especially strong associations with delinquency, crime, antisocial personality disorder, and substance use disorders in adolescence and early adulthood (Krueger et al., 1994; Krueger et al., 1996). Aggression also exhibits a large gender difference, which might in turn help to account for gender differences in academic achievement (Blonigen et al., in press; Roberts et al., 2001).

The Roles of Genetic and Environmental Influences in the Association Between Personality and School Performance

That genetic influences contribute to personality is well established (Krueger & Johnson, 2007), and no longer surprising. Across a wide variety of personality measures and samples, 40-60% of individual differences in personality can be attributed to genetic variation (Bouchard & Loehlin, 2001). But school performance also shows genetic influences, a fact that still generates some surprise because studies examining it are less common. For example, Johnson et al. (2005, 2006) observed that about 70% of the variation in school grades could be attributed to genetic influences in an adolescent sample. At an overall population level, there do not appear to be sex differences in the magnitudes of genetic and environmental influences that contribute to either personality or school performance, but this conclusion relies on the assumption that genetic and environmental influences are independent of each other and constant across the ranges of environmental circumstances or other traits. It is becoming increasingly clear that these assumptions are often violated (Johnson, 2007).

That is, we are beginning to understand that the relative and absolute magnitudes of genetic and environmental influences often vary systematically with measured levels of environmental circumstances or other traits. Moreover, because even environmental circumstances often also carry genetic influence (Plomin & Bergeman, 1991), the same genetic influences may contribute strongly to two (or more) ostensibly different traits in some situations but not in others. The same kinds of observations can sometimes be made about environmental influences: they may vary with measured levels of other traits, and the same environmental

influences may contribute only sometimes to different traits. Measuring these kinds of transactions between genetic and environmental influences involving pairs of traits can be very helpful in uncovering the causal patterns involved in the association between the traits, and new statistical modeling approaches make this possible (Purcell, 2002). For example, Johnson and Krueger (2006) used this approach to observe that environmental variance in life satisfaction decreased with increasing financial resources, making genetic influences on life satisfaction more important in the presence of plentiful financial resources, and less important when financial resources were tight. They interpreted this to indicate that environmental shocks were less likely to disrupt life satisfaction in good financial circumstances, likely because it is possible for people in such circumstances to buy their ways out of the attendant difficulties and inconveniences.

In the current study, we employ a similar approach to examine the nature of the transactions between genetic and environmental influences on school grades and the MPQ scales of Achievement Striving, Self-Control, and Aggression in population representative sample of 17-year old male and female twins. These scales were selected due to their empirical and theoretical associations with academic achievement, and because each scale is associated with a different higher-order factor, providing an index of the impact on GPA of the distinct affective, cognitive, and behavioral characteristics associated with each major dimension of personality.

We employed 3 analytic approaches. First, we used correlational and mediation analyses (i.e., hierarchical regression) to determine if the associations between personality and GPA differed for boys and girls, and whether mean-level sex differences in personality could account for the gender gap in GPA. We predicted that sex differences in mean-levels of certain personality traits (e.g., Aggression) would account for at least some of the gender gap in GPA. Next, we examined the genetic and environmental contributions to the covariance between personality and GPA and whether this differed by gender. Finally, we fit Gene $\times$ Environment ($G \times E$) interaction models to determine whether sex differences existed in the dynamics of gene-environment interplay between personality and GPA. We predicted that sex differences would be detected in the gene-environment interplay between personality and GPA, which would also help account for greater academic achievement in girls. Specifically, we predicted that certain personality traits would function as a moderator such that higher levels of the trait (e.g., Achievement Striving) would result in uniformly higher and less variable GPA in girls but not boys.

Method

Sample

Participants were male and female twins taking part in the ongoing Minnesota Twin Family Study (MTFS). The MTFS is epidemiological-longitudinal study of the parents and same-sex twin pairs born in Minnesota (Iacono et al., 1999; Iacono & McGue, 2002). The MTFS utilizes an accelerated longitudinal design and so is composed of a younger (age 11) and older (age 17) cohort. Twins and their parents were located using publicly available birth records and databases and recruited into the study the years the twins turned either 11 or 17 years old. Twins return every 3-4 years for follow-up assessments. For the older cohort, the target birth years were 1972-1978 for male twins and 1975-1979 for female twins. The target birth years for the younger cohort were 1977-1982 for male twins and 1981-1984 and 1988-1990 for female twins. The study was able to locate over 90% of eligible twin families for each target birth year. Families were then invited to participate in a day-long, in-person assessment at the University of Minnesota provided the family lived within a day's drive to our Minneapolis laboratories and neither twin had a significant mental or physical handicap that would preclude their participation in the assessment. Seventeen percent of eligible families declined participation.

Consistent with the demographics of those born in Minnesota in the targeted years, 98% of the participants were Caucasian.

Participating families were generally representative of the Minnesota population for the targeted birth years. The average Hollingshead (1957) occupational status of families was roughly 4 on a 7-point scale (lower scores indicating higher status) with a standard deviation of slightly less than 2. The full ranges of occupational and educational levels were represented in the sample. Parents included persons with graduate degrees and professional credentials working in professional occupations as well as persons who were unemployed or working in unskilled jobs with less than a high school education, with most falling in between. The “average” family included parents working in jobs at the skilled “blue collar” level with about 2 years of post-secondary education. To examine any ascertainment bias, over 80% of eligible families who did not participate completed a brief mail or telephone survey assessing occupational and educational status and a screen of mental health history. Participating parents achieved an average .3 years more of education than non-participating parents (a statistically significant but substantively minor difference), but did not differ in terms of self-reported mental health.

The total sample included 1329 twin pairs with the following zygosity and sex breakdown: 426 monozygotic (MZ) and 210 dizygotic (DZ) male twin pairs, and 440 MZ and 253 DZ female twin pairs. Data for the current investigation was collected at the intake assessment for the 17 year-old cohort and the second follow-up (age 17) assessment for the 11 year-old cohort. The age 11 cohort (237 MZ and 110 DZ male twin pairs, 217 MZ and 139 DZ female twin pairs) is slightly larger than the age 17 cohort (188 MZ and 101 DZ male twin pairs, 223 MZ and 114 DZ female twin pairs). The mean age of the total sample at the time of assessment was 17.8 years ($SD = .67$ years) with the mean age of the age 11 cohort ($M = 18.1$ years, $SD = .67$ years) being slightly greater and more variable than the age 17 cohort ($M = 17.5$ years, $SD = .46$ years). The greater number of MZ twin pairs is a function of a greater number of MZ compared to DZ twins in the population from which the sample was drawn (Hur, McGue, & Iacono, 1995) as well as a slightly greater participation rate from families of MZ twins. Zygosity was determined by the agreement of separate reports from parents and MTFS staff regarding the physical resemblance of the twin pairs and an algorithm assessing the similarity of twins on ponderal and cephalic indices and fingerprint ridge counts. A serological analysis was performed if these estimates did not agree.

Measures

Grade point average (GPA)—Rather than collecting data on actual grades (e.g., report cards), the MTFS asks twins and their mothers to rate the grades they typically receive in language arts, math, social studies, and science classes by indicating if the grades were much better than average (A's = 4), above average (B's = 3), average (C's = 2), below average (D's = 1), or much below average (failed class = 0). This approach was taken to provide a standardized assessment of grades and mitigate comparison problems due to participants attending different school districts that employed different grading formats, procedures, and standards. The participants' average rating across class subjects was used for the GPA variable. The validity of this approach was tested by collecting 67 school transcripts from a random sample of the age 11 cohort. The resulting correlation between actual school grades and the MTFS GPA variable was .89. Participants who failed to complete high school still provided grade reports at age 17, either because they were still in school at the time or by reporting grades for the last year they attended school. The GPA variable was available for 88.8% ($n = 2359$) of participants.

Personality—The 198-item version of the Multidimensional Personality Questionnaire (MPQ; Tellegen & Waller, 1992) was used to assess personality. The MPQ is a self-report questionnaire (4-point response format from “Definitely true” to “Definitely false”) that yields 11 primary scales organized around a 3-factor structure of Positive Emotionality (PEM; sensitivity to positive emotions), Negative Emotionality (NEM; sensitivity to negative emotions), and Constraint (CON; behavioral inhibition).

We examined the association between GPA and personality using three primary trait scales: Achievement Striving, Aggression, and Self-Control. Achievement Striving refers to a person's mastery motivation, that is, the tendency to experience positive emotions by engaging in challenging tasks, being persistent, and having high standards and ambitious goals. Aggression refers to a person's tendency to be angry and vindictive, exhibit a willingness to harm others for selfish purposes, and to enjoy physical violence. Self-Control refers to a person's tendency to be contemplative, organized, cautious, and responsible. Each scale is composed of 18 items with internal consistency reliability as measured by Cronbach's alpha ranging from .84 to .90 (Blonigen et al., in press). Personality data were available for 91.1% ($n = 2422$) of participants.

Phenotypic and Behavioral Genetic Analyses—First, we examined mean-level sex differences in the GPA and personality variables. Linear mixed models as implemented in SPSS were used to adjust for the non-independence of the twin observations. Second, we employed hierarchical regression analyses to determine the extent to which mean-level sex differences in personality could account for the mean-level sex difference in GPA. This was accomplished by entering participant sex in step 1, followed by a single personality variable (e.g., Aggression) and its interaction with participant sex (e.g., Sex $\times$ Aggression) on the second step. The magnitude of the decrease in the beta coefficient for participant sex from step 1 to step 2 indicates the extent to which mean-level differences in personality can account for the gender gap in GPA. Additionally, a significant interaction between participant sex and personality would indicate that the association between the personality trait and GPA is significantly different across gender (e.g., the correlation between Aggression and GPA might be greater in boys than in girls). Regression analyses were carried out in *Mplus 3* (Muthen & Muthen, 2003) using the complex sampling analysis option that utilizes a maximum-likelihood estimator with robust standard errors (MLR) that adjusts parameter estimates for the non-independence of observations due to cluster sampling (i.e., twin observations).

Finally, we also took advantage of our twin sample to investigate the genetic and environmental influences underlying the link between GPA and personality. This methodology is based on the assumption that the variance of a trait can be decomposed into three independent sources: additive genetic (A), shared environment (C), and nonshared environment (E). Estimates of the ACE variance components are derived by comparing the similarity of members of MZ twin pairs relative to DZ twin pairs. Classical twin methodology includes the additional assumptions of no assortative mating, no $G \times E$ interactions or correlations (r_{GE}), and that shared environmental effects do not differ for MZ and DZ twins (Plomin, DeFries, McClearn, & McGuffin, 2001). Given that MZ twins share all their genes and DZ twins share on average 50% of their segregating genes, a correlation between MZ twins on a given trait that is twice the correlation for DZ twins indicates that twin similarity is primarily due to additive genetic effects. A DZ correlation greater than one-half the MZ correlation indicates shared environmental contributions to a trait. Nonshared environmental effects (including measurement error) contribute to differences between members of a twin pair. Twin correlations less than 1.0 indicate nonshared environmental contributions to a trait.

This model can be extended to the bivariate case by employing a Cholesky decomposition to estimate the genetic and environmental contributions to the covariance between traits. Figure 1 provides a graphical depiction of this model for Achievement Striving and GPA. The model

includes ACE effects that overlap across the two traits and ACE effects that are unique to each trait. Factors $A_1C_1E_1$ account for the genetic and environmental effects on Achievement Striving, including those effects that overlap with GPA. Factors $A_2C_2E_2$ are the residual genetic and environmental effects that are unique to GPA. The amount of genetic overlap between the traits is estimated by calculating the genetic covariance, which is the product of the $a_{11} \times a_{22}$ paths. Standardizing the genetic covariance by the genetic variance of each trait yields the genetic correlation (r_G), which varies from 1.0 to -1.0 and provides an index of the amount genetic overlap between the two traits. Similar analytic procedures can be employed to calculate shared (r_C) and nonshared environmental (r_E) correlations.

These models provide estimates of ACE variance components for the population on average and are assumed to be constant throughout that population (i.e., no $G \times E$ interactions) and independent of each other (i.e., no r_{GE}). More sophisticated quantitative genetic models, however, allow these assumptions to be relaxed such that one trait (e.g., Achievement Striving) can moderate the magnitude of the genetic and environmental influences on another trait (e.g., GPA). For example, the heritability (i.e., the proportion of genetic variance relative to total phenotypic variance) of GPA could increase or decrease as a linear function of Achievement Striving such that the heritability of GPA is greater at higher levels of Achievement Striving (or vice versa). This would be an example of a $G \times E$ interaction, which can be conceptualized as either differential environmental sensitivity or as differential genetic expression in different environments. Additionally, the genetic and environmental correlations, or variations in environmental exposure with genetic background, can vary as functions of the moderator. For example, the r_G between Achievement Striving and GPA could be greater at higher levels of Achievement Striving (or vice versa).

We adopted the standard quantitative gene-environment interplay model shown in Figure 2 (Purcell, 2002). Moderating effects can be of two types: moderation of the common variance between the two traits or moderation of the variance unique to the trait of primary interest, in this case GPA. Comparing Figures 1 and 2, the primary difference between the Cholesky model and the gene-environment interplay model is that moderating terms have been added to the path coefficients on GPA of the form $x + b \cdot M$, where the x terms are the regression coefficients linking the ACE factors to GPA (e.g., a_{21} and a_{22}), M is the level of Achievement Striving, and the b terms are regression coefficients stipulating the direction (+ or -) and magnitude of any moderation effects.

Models were fit to the raw data using full information maximum likelihood estimation as implemented in the computer program *Mx* (Neale, Boker, Xie, & Maes, 2002). This approach uses all available information under the assumption that data are missing at random (Little & Rubin, 1987). Because we were interested in sex differences, models were fit separately for male and female twins. The current gene-environment interplay models do not allow for a direct test of sex differences in parameter estimates. However, we were able to test for sex differences by using the parameter estimates obtained in one gender to fit models in the other gender. The extent to which model fit declined due to using parameter estimates obtained from the opposite sex sample was used as an index of sex differences in the $G \times E$ interaction models. Though the age range was relatively modest, we followed standard behavior genetic analytic procedures by regressing the variables on age and age² prior to analyses (McGue & Bouchard, 1984). The variables were then standardized on the mean and standard deviation of the female twin sample to ease interpretation of results across boys and girls.

Model fit was evaluated using $-2 \cdot \log\text{likelihood}$ ($-2LL$), Akaike's Information Criterion (AIC; Akaike, 1983), and the sample size adjusted Bayesian Information Criterion (BIC_{adj} ; Schwartz, 1978; Sclove, 1987). AIC and the BIC are information theoretic fit statistics that incorporate parsimony (i.e., the number of parameters in the model) when determining model fit. AIC is

computed as $-2LL - 2df$, and BIC_{adj} is computed as $-2LL - df \ln N^*$ where df is the degrees of freedom of the model and $N^* = (N + 2)/24$ where N is the sample size. Such indices provide objective measures of the amount of information needed to most efficiently represent the data. If the full gene-environment interplay model yielded lower AIC and BIC_{adj} values than the Cholesky model, it indicated that moderation effects were present and that the gene-environment interplay model better represented the data than the simpler Cholesky model. Additionally, if the gene-environment interplay model fit better than the Cholesky model, non-significant moderation terms were dropped from the full model in order to focus on the most significant moderating effects.

Results

Mean-level sex differences, correlation/regression analyses, and mediation analyses

Descriptive statistics and effect sizes (Cohen's d) for the mean-level sex differences for GPA and personality traits are provided in Table 1. Consistent with previous reports, girls achieved higher mean GPA ($F = 87.9$, $df = 1$, 1213.38 , $p < .001$) and scored higher on Self-Control, ($F = 14.4$, $df = 1$, 1250.88 , $p < .01$) while boys scored higher on Achievement Striving ($F = 24.6$, $df = 1$, 1250.32 , $p < .001$) and Aggression ($F = 288.7$, $df = 1$, 1248.63 , $p < .001$). The magnitudes of the effect sizes for the sex differences were small for Achievement Striving and Self-Control, medium for GPA, and large for Aggression.

Table 2 presents the correlations among the study variables, separately for boys and girls. Achievement Striving and Self-Control were positively correlated and Aggression negatively correlated with GPA. Each personality trait exhibited a small to moderate association with GPA. The correlations between GPA and Achievement Striving and Self-Control were slightly greater for girls compared to boys. Self-Control was moderately correlated with both Achievement Striving and Aggression, while the correlation between Achievement Striving and Aggression was relatively modest.

Results of the hierarchical regression analyses of personality on sex differences in GPA are presented in Table 3. Participant sex had a moderate association with GPA. Both Achievement Striving and the Sex $\times$ Achievement Striving interaction were significant predictors of GPA. The significant interaction term indicated that the association (i.e., correlation) between Achievement and GPA was stronger for girls. Achievement Striving, however, failed to account for any of the sex difference on GPA (i.e., the beta coefficient for participant sex did not decline after inclusion of Achievement Striving and its interaction with participant sex in step 2a). Both Control and Aggression were also significant predictors of GPA, but the interaction terms with sex were not, indicating that the association between these traits and GPA did not differ for boys and girls. Sex differences in Control accounted for a modest portion of the sex difference in GPA as evidenced by a reduction in the beta coefficient for sex in step 2b. As reported in step 2c, however, the sex difference on Aggression accounted for nearly one-half the sex difference in GPA (Sobel test $z = 7.96$, $p < .001$). That is, controlling for the mean-level difference between boys and girls on Aggression resulted in a notable narrowing of the gender gap on GPA.

In step 3, all significant predictors from the step 2 regression models were entered into a single model. Each personality trait remained a significant predictor of GPA, indicating that each trait indexed unique characteristics associated with achieving higher GPA. The Sex $\times$ Achievement Striving interaction also remained statistically significant. Participant sex and the three personality traits exhibited a medium to large effect size in accounting for GPA (multiple $R = .42$, $p < .001$), and personality added substantially to participant sex in predicting GPA ($\Delta R^2 = .121$, $p < .001$). Together, the three personality traits accounted for only one-fourth the sex difference in GPA, which is actually less than Aggression alone. One possible reason for

this is the presence of a suppressor effect between Achievement Striving and participant sex such that higher mean-level Achievement Striving scores for boys help to narrow the gender gap on GPA. If so, controlling for sex differences in Achievement Striving would result in a widening of the gender gap and increase the beta coefficient for participant sex.

Twin Correlations, Univariate, and Bivariate Behavioral Genetic Analyses

Table 4 presents the MZ and DZ twin correlations for GPA and personality traits. The high MZ correlation for GPA indicated the highly familial nature of the trait, and the much higher MZ relative to DZ twin correlations indicated a substantial genetic contribution to variance in GPA. The MZ correlations for the three personality traits were slightly lower than for GPA, indicative of moderate heritability. The much lower DZ correlations relative to MZ correlations indicated little to no shared environmental contribution to either GPA or personality.

Results of the univariate biometric modeling were consistent with the twin correlations. GPA was highly heritable, with virtually no shared environmental influence for boys and a modest shared environmental contribution for girls. For both boys and girls, the three personality traits were moderately heritable with virtually no shared environmental contributions. Nonshared environmental effects were relatively modest for GPA and relatively large for personality. Heritability estimates did not differ between boys and girls for any of the study variables, $\Delta\chi^2(1) = .001$ to 1.91.

Results of the bivariate Cholesky models indicated substantial genetic overlap between GPA and Achievement Striving and Self-Control (especially for girls), as evidenced by the moderate to large genetic correlations. The genetic correlation between GPA and Aggression was also significant though somewhat lower. Nonshared environmental correlations were small. None of the genetic or nonshared environmental correlations were significantly different across boys and girls, $\Delta\chi^2(1) = .168$ to 1.65. Because there was so little shared environmental variance in each trait, estimation of shared environmental correlations encountered problems with boundary conditions, which resulted in estimates of 1.00 or -1.00 , making such correlations difficult to interpret. Genetic variance accounted for 72% to 94% of the covariance between GPA and each personality trait.

Quantitative G $\times$ E Moderation Models of GPA and Personality

We next investigated whether the genetic and environmental variance components of GPA were moderated as functions of personality by fitting quantitative G $\times$ E moderation models. Table 5 provides fit statistics for the G $\times$ E moderation models of personality effects on GPA. For Achievement Striving, for both boys and girls, the full G $\times$ E moderation model fit better than the no moderation model, as evidenced by lower AIC and BIC_{adj} values and a significant likelihood ratio test (LRT). For Self-Control, the full G $\times$ E moderation model fit better than the no moderation model for girls, but for boys the no moderation model fit better than the G $\times$ E moderation model. For Aggression, there was no evidence of moderation for boys. For Aggression in girls, the full G $\times$ E moderation model yielded a slightly lower AIC value than the no moderation model, and there was a marginally significant LRT between the full and no G $\times$ E interaction model. However, the BIC_{adj} value (which employs a slightly greater weight for parsimony than AIC) was lower for the no moderation model, and follow-up analyses failed to yield interpretable moderation effects of any substantive consequence. Therefore, results of the G $\times$ E moderation models between Aggression and GPA are not presented for either boys or girls. For traits that exhibited significant moderation of GPA, additional model trimming analyses identified the best fitting models as determined by a combination of the lowest AIC and BIC_{adj} values and overall interpretability of the results.

Figures 3-5 provide graphical representations of the best fitting $G \times E$ moderation models for Achievement Striving and Self-Control for girls and Achievement Striving for boys in regards to moderation of the genetic and environmental variance components of GPA. For girls, Achievement Striving and Self-Control exhibited similar effects on GPA such that both personality traits moderated the unique additive genetic and nonshared environmental variance in GPA with the variance of GPA declining at higher levels of Achievement Striving and Self-Control. Additionally, both the genetic and nonshared environmental correlations with GPA increased at higher levels of Achievement Striving and Self-Control (see Table 6). In combination with the overall positive association between Achievement and Control with GPA, these results indicated that as variation in GPA became more restricted at higher levels of Achievement and Control, girls had uniformly higher GPA.

For boys, Achievement Striving moderated the unique shared and nonshared environmental variance in GPA, such that shared environmental variance was greatest at the extremes of Achievement Striving while nonshared environmental variance in GPA declined as Achievement Striving increased. Total variance in GPA was also greatest at the highest and lowest levels of Achievement Striving and minimal at average levels. The additive genetic variance in GPA remained constant across all levels of Achievement Striving such that the heritability of GPA was maximal at average levels of Achievement Striving and lowest at low levels. The shared environmental correlation was greatest at average levels of Achievement Striving. However, this could simply be due to the small proportion of shared environmental variance in GPA at that level of Achievement Striving. The nonshared environmental correlation increased slightly at higher levels of Achievement Striving.

To test for sex differences in the moderation effects, we used the parameter estimates obtained for one sex (e.g., male twins) to fit models to the data for the other sex (e.g., female twins). For Achievement Striving, using male twin parameter estimates to fit the female twin data resulted in a decline in model fit of $\Delta\chi^2(6) = 38.87, p < .001$, while using female twin parameter estimates to fit the male twin data yielded $\Delta\chi^2(6) = 34.03, p < .001$, for an average change in model fit of $\Delta\chi^2(6) = 34.45, p < .001$. For Self-Control, this procedure resulted in a decline in model fit of $\Delta\chi^2(6) = 6.97, p > .10$ when using male twin parameter estimates to fit the female twin data, and $\Delta\chi^2(6) = 29.10, p < .001$ when using female twin parameter estimates to fit the male twin data, for an average change in model fit of $\Delta\chi^2(6) = 18.04, p < .01$. These results indicate that the $G \times E$ moderation effects for both Achievement Striving and Self-Control were significantly different for boys and girls.

Discussion

We sought to examine the association between personality and scholastic achievement, with an emphasis on understanding how personality might help account for the persistent and widening gender gap in academic achievement. Specifically, we examined associations between GPA at age 17 and the personality traits of Achievement, (self) Control, and Aggression due to their empirical and theoretical relevance. We took a very different approach to the question of sex differences academic achievement than have prior studies. Therefore, it is important to consider our study's limitations before discussing its findings and their implications in further detail. First, the sample is representative of the population born in Minnesota in the 1970's and 1980's. It should not be considered representative of the population of the United States as a whole, however, because it is primarily of European-American descent. Moreover, Minnesota has consistently maintained one of the highest high school graduation rates in the United States, and college attendance rates tend to be higher than average there as well (Census, 1995). Second, effects of the kind we explored are often small and difficult to detect (Rowe, 2003). Though we clearly had power to identify several such effects,

there may have been others (including possibly nonlinear effects) present that would have required larger sample sizes to detect.

Finally, though the statistical significance of our findings was clear in this sample, moderation effects such as those we observed may be context-dependent. This means that cohorts reaching maturity in different places and at different times may show different moderation effects or no moderation effects at all. Should this be the case, however, it would not mean that the effects observed here did not exist or were not important to those involved. Rather, it would mean that it is possible to organize the school environment to create different relative results for different groups of students, whether intentionally or unintentionally, generating questions about the specific aspects of those environmental differences that could be explored in future research.

Results Involving Observed Personality and GPA and Basic Quantitative Genetic Models

Consistent with previous studies, girls achieved higher GPA of a medium effect size (Cohen's $d = .47$). Girls also scored slightly higher on Control while boys scored slightly higher on Achievement and much higher on Aggression. For both boys and girls, Achievement and Control were positively correlated and Aggression negatively correlated with GPA. The associations were of moderate effect size. The correlation between Achievement and GPA was significantly greater for girls as evidenced by the significant Sex $\times$ Achievement interaction. In a regression model that included the three personality variables, each personality trait remained significant, indicating that each trait accounted for unique variance in GPA. Mediation analyses revealed that sex differences in Aggression could account for approximately one-half the sex difference in GPA. Sex differences in Control and Achievement accounted for only small portions of the sex difference in GPA.

Univariate and bivariate behavioral genetic analyses demonstrated that GPA was highly heritable, even more so than personality. This is of interest as it has long been recognized that personality is under partial genetic influence (Bouchard & Loehlin, 2001), but GPA is commonly conceptualized as being more environmentally determined. Our current results challenge such a conceptualization, as environmental factors (whether shared or nonshared) accounted for a relatively modest portion of the variance in GPA, notably less than for personality. Although these results may be inconsistent with conventional beliefs regarding academic achievement, they are consistent with other twin studies that have actually attempted to estimate the relative genetic and environmental contributions to GPA (Johnson et al., 2005, 2006, 2007; Spinath, Spinath, & Plomin, 2004; Walker, Petrill, Spinath, & Plomin, 2004). The accumulating empirical evidence, then, suggests an alternative conceptualization of academic achievement that incorporates the role of genetic influence and links with individual differences in variables such as personality and intelligence. Such a conceptualization may well provide a more integrative framework by which to investigate causal processes. Here, bivariate behavior genetic analyses demonstrated that genetic variance accounted for most of the covariance between each personality trait and GPA.

Results of G $\times$ E Moderation Models

Quantitative G $\times$ E moderation models detected significant moderation effects for Achievement and Control in girls and Achievement in boys. The moderation effects of Achievement and Control on GPA in girls were very similar, with the total, additive genetic, and nonshared environmental variance in GPA declining at higher levels of Achievement and Control. The genetic and nonshared environmental correlations both increased at higher levels of Achievement and Control, indicating the operation of a selection process driven by both forms of influence at higher levels of the personality traits. The moderation effect of Achievement on GPA in boys was very different, as the shared environmental variance in GPA was relatively large at the extremes of Achievement and minimal at average levels of

Achievement, while nonshared environmental variance in GPA decreased with increasing levels of Achievement. Additive genetic variance in GPA remained constant across different levels of Achievement. There were no moderating effects of Control on GPA in boys, and the genetic correlations involving both traits were lower for boys than girls. The selection process that appeared to operate rather effectively to yield uniformly higher GPA in women was relatively absent in boys.

In all cases of significant moderation effects, personality moderated the unique variance in GPA rather than variance shared between GPA and Achievement or Control. This indicates that the moderation effects associated with Achievement and Control functioned as contextual factors that activated or suppressed processes underlying GPA rather than influencing processes common to GPA and personality. It may not be intuitive to conceptualize an individual difference variable such as a personality trait as an environmental context; however, such an approach can be useful in interpreting the results of the present study.

In the present case, at least for girls, an individual's levels of Achievement and Control seemed to create contexts facilitating performance of tasks associated with the attainment of higher GPA such as setting goals, positive affective engagement, and the cognitive and behavioral control necessary to persist and prioritize completing incremental tasks to accomplish these goals. Though conceived of as independent aspects of personality, it is clear that Achievement and Control would contribute to a single such context in similar ways, so that the consistency of the modeling results makes intuitive sense. High levels of Achievement and Control likely created this context by mitigating processes that contributed to very low GPA, restricting both the genetic and nonshared environmental variance in GPA. The fact that the genetic and nonshared environmental correlations increased as the variance in GPA became more restricted suggests that the causal processes underlying GPA became more entwined with Achievement and Control when levels of these traits were higher. In contrast, girls who exhibited low levels of Achievement and Control exhibited greater variance in GPA and weaker genetic and nonshared environmental correlations. This suggests that at low levels of Achievement and Control, the compensatory effects associated with these traits were not present to mitigate pathogenic processes that contribute to lower GPA. As a consequence, GPA outcomes became more variable and less influenced by Achievement and Control, while likely being more highly determined by other factors such as intellectual ability.

This process did not appear to work nearly as effectively in boys, especially for Achievement. For boys, extremely high or low levels of Achievement seemed to activate shared environmental sources of variance on GPA not present at average levels of Achievement. The extreme high or low levels of Achievement increased the variability in GPA, suggesting that current academic contexts may be best suited for boys with average levels of Achievement. Alternatively, it is possible that distinguishing between shared environmental and additive genetic variance became increasingly difficult at extreme levels of the moderator. Therefore, these results may simply indicate that variance in GPA is due more to familial factors at extreme levels of Achievement especially high levels.

Using These Results to Understand Sex Differences in GPA

How can these results help to better understand the sex difference in GPA? For girls, the moderation of GPA on Achievement and Control functioned to create a context congruent with attaining uniformly higher GPA by reducing the variance of GPA at higher levels of Achievement and Control. For some reason, Achievement and Control did not have this beneficial effect on GPA in boys. That is, for boys, higher levels Achievement and Control were apparently unable to shape a context that was especially congruent with attaining higher GPA. In fact, extreme levels of Achievement actually resulted in greater variance in GPA, suggesting that for men both very low and very high levels of Achievement were not associated

with stable and predictable GPA levels. Overall, this suggests that, even when they were achievement oriented, boys were less able to make effective use of the academic environment in which grades were awarded. In combination with the present results involving Control, one way to interpret this is that, even when they wanted to achieve well, boys often were not able to muster the discipline necessary to complete high quality work assignments. This is very consistent with results of the previous literature, especially those of Duckworth and Seligman (2006) who showed that sex differences in self-discipline largely explained sex differences in scholastic achievement in a younger group of students. In addition to corroborating these results, however, our present findings provide insight into the nature of the processes involved in the association.

In contrast to Achievement and Control, Aggression had a main and mediating effect rather than a moderating effect on GPA. This means that Aggression had a constant effect of decreasing GPA for both boys and girls, but did not affect the overall variance in GPA. As a result, the large sex difference in Aggression accounted for a significant portion of the sex difference in GPA. That is, because boys exhibited higher levels of Aggression (and its correlated traits such as delinquency and disruptive behavior), there was a uniform decrement in GPA relative to girls. The remaining sex difference in GPA was likely due to the preponderance of neuropsychological deficits in boys such as reading disorders, learning disabilities, lower verbal IQ, and attention problems (Moffitt et al., 2001). Control operated in a similar manner for boys in that it was associated uniformly with higher GPA, but did not act to further provide a protective factor by restricting the variance in GPA. The fact that Control accounted for only a small portion of the sex difference in GPA was due to the modest sex difference on Control.

In sum, our results provide a systematic analysis of the relationship between personality and GPA. They show that various traits contribute to GPA and that sex differences on these traits account for notable portions of the sex difference in GPA. At an etiological level our results also contribute to our understanding of the sex difference in GPA in that certain traits help to shape a broader context that produces more uniform and high levels of GPA and that these processes are at work in girls but not in boys. This suggests that the educational environment these students experienced was better suited to girls as somehow girls were better able to take advantage of certain personality traits to shape a context associated with maximal academic benefit. As their educational environment was very typical of those in the United States currently, this was probably indicative of a more general situation. Future research should extend the current findings by examining the interplay between cognitive abilities and personality in the determination of GPA. Additionally, it would be useful to take the present analysis a step further by examining what process variables are at work that allow for the moderation effects to operate for girls but not boys.

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Figure 1.

GPA = grade point average. Standard bivariate behavior genetic model also known as a Cholesky decomposition. A refers to additive genetic effects, C to shared environmental effects, and E to nonshared influences. Factors $A_1C_1E_1$ include genetic and environmental influences that overlap between Achievement and GPA, while $A_2C_2E_2$ are genetic and environmental influences unique to GPA. The parameters for each effect are constant.

Figure 2.

Ac = Achievement Striving; GPA = grade point average. Model of moderation of genetic and environmental influences on GPA as a function of different levels of Achievement Striving. A refers to additive genetic effects, C to shared environmental effects, and E to nonshared influences. Factors $A_1C_1E_1$ include genetic and environmental influences that overlap between Achievement Striving and GPA, while $A_2C_2E_2$ are genetic and environmental influences unique to GPA. Achievement Striving can moderate either the common variance with GPA or the unique variance of GPA. The β 's indicate the direction (+ or -) and magnitude of any moderation effects on the paths from the ACE effects to GPA while Ac indicates the level of Achievement Striving.

GPA Moderated by Achievement Striving in Female Twins

Figure 3.

Variance in Grade Point Average as a function of Achievement Striving for female twins. A refers to additive genetic variance, C to shared environmental variance, and E to nonshared environmental variance.

GPA Moderated by Self-Control in Female Twins

Figure 4.

Variance in Grade Point Average as a function of Self-Control for female twins. A refers to additive genetic variance, C to shared environmental variance, and E to nonshared environmental variance.

GPA Moderated by Achievement Striving in Male Twins

Figure 5.

Variance in Grade Point Average as a function of Achievement Striving for male twins. A refers to additive genetic variance, C to shared environmental variance, and E to nonshared environmental variance.

Table 1

Descriptive statistics and mean-level sex differences in GPA and personality traits.

Variable	Girls <i>M (SD)</i>	Boys <i>M (SD)</i>	Effect Size
GPA	3.19 (.67)	2.85 (.78)	.47*
Achievement	48.1 (8.3)	50.0 (8.1)	-.23*
Control	48.1 (7.8)	46.8 (7.1)	.17*
Aggression	34.4 (8.9)	41.8 (9.2)	-.82*

Note. GPA = grade point average. Effect sizes are Cohen's *d* calculated as $(M_1 - M_2)/SD_{pooled}$.

* $p < .01$.

Table 2

Correlations among GPA and personality variables.

Variable	1	2	3	4
1. GPA	--	.21	.24	-.22
2. Achievement	.38	--	.31	-.11
3. Control	.33	.39	--	-.30
4. Aggression	-.22	-.22	-.36	--

Note. GPA = grade point average. Correlations for female twins are below the diagonal; correlations for male twins are above the diagonal. Significance levels have been adjusted for the non-independence of the twin observations. All correlations are significant at $p < .01$.

Table 3

Regression and mediation analyses for GPA regressed on sex and personality traits.

Step	Predictors	β	p	R	R^2
Step 1	Sex	.23	< .001	.23	.053
Step 2a	Sex	.24	< .001	.36	.128
	Achievement	.22	< .001		
	Sex $\times$ Achievement	.08	< .05		
Step 2b	Sex	.19	< .001	.35	.121
	Control	.26	< .001		
	Sex $\times$ Control	.02	<i>ns</i>		
Step 2c	Sex	.12	< .001	.30	.090
	Aggression	-.25	< .001		
	Sex $\times$ Aggression	-.02	<i>ns</i>		
Step 3	Sex	.17	< .001	.42	.174
	Achievement	.16	< .001		
	Control	.16	< .001		
	Aggression	.14	< .001		
	Sex $\times$ Achievement	.06	< .05		

Note. For Sex, 0 = male, 1 = female. All significance levels were adjusted for the non-independence of the twin observations. *ns* = nonsignificant at $p < .05$.

Twin correlations, standardized ACE variance components, and genetic and nonshared environmental correlations between GPA and personality traits.

Table 4

Variable	Twin Correlations		Standardized Variance Components					% Covariance due to A	
	MZ	DZ	A	C	E	r_G	r_E		
GPA									
Girls	.74	.45	.56	.17	.26				
Boys	.72	.38	.69	.04	.27				
Achievement									
Striving									
Girls	.46	.03	.42	.00	.58	.69	.15	88	
Boys	.40	.23	.42	.00	.58	.41	.19	94	
Self-Control									
Girls	.44	.06	.41	.00	.59	.60	.14	87	
Boys	.30	.18	.32	.00	.68	.39	.12	77	
Aggression									
Girls	.51	.25	.44	.05	.51	-.38	-.02	86	
Boys	.52	.10	.51	.00	.49	-.29	-.18	72	

Note. GPA = grade point average; MZ = monozygotic; DZ = dizygotic; A = additive genetic variance; C = shared environmental variance; E = nonshared environmental variance; r_G = genetic correlation; r_E = nonshared environmental correlation.

Table 5

Fit statistics from models of variance components allowing for gene-environment interaction and correlation.

Moderator	Model	Fit Statistics			Model Comparisons		
		-2LL	df	AIC	BIC _{adj}	LRT	p
Achievement							
Girls	Full G × E	6045.9	2318	1409.9	-768.0	--	--
	No G × E	6079.2	2324	1431.2	-761.1	33.4	6 < .001
	Moderation of unique A and E variance	6052.2	2322	1408.2	-771.6	6.3	4 ns
Boys	Full G × E	5600.7	2037	1526.7	-347.9	--	--
	No G × E	5627.8	2043	1541.8	-343.6	27.1	6 < .001
	Moderation of unique C and E variance	5602.8	2041	1520.8	-353.0	2.1	4 ns
Control							
Girls	Full G × E	6070.0	2312	1446.0	-742.4	--	--
	No G × E	6102.9	2318	1466.9	-735.8	32.9	6 < .001
	Moderation of unique A and E variance	6072.1	2316	1440.1	-747.9	2.10	4 ns
Boys	Full G × E	5534.2	2041	1452.2	-389.3	--	--
	No G × E	5541.6	2047	1447.6	-394.8	7.4	6 ns
Aggression							
Girls	Full G × E	6127.4	2322	1483.4	-735.6	--	--
	No G × E	6140.9	2328	1484.9	-738.6	13.5	6 < .05
Boys	Full G × E	5749.9	2037	1675.9	-273.3	--	--
	No G × E	5756.5	2043	1670.5	-279.2	6.6	6 ns

Note. -2LL = -2*loglikelihood; df = degrees of freedom; AIC = Akaike Information Criterion; BIC_{adj} = sample-size adjusted Bayesian Information Criterion; LRT = likelihood ratio test; $G \times E$ = gene-environment interplay model with gene-environment interactions and correlations; A = additive genetic variance; C = shared environmental variance; E = nonshared environmental variance; *ns* = nonsignificant at $p < .05$.

Table 6
Estimates of variance components and proportions of variance in GPA moderated by personality traits.

Variance Components	Achievement - Girls						Moderator Variable - Sex						Control - Girls						Achievement - Boys					
	Achievement - Girls			Moderator Variable - Sex			Control - Girls			Achievement - Boys			Control - Girls			Achievement - Boys			Control - Girls			Achievement - Boys		
	-2 SD	0 SD	2 SD	-2 SD	0 SD	2 SD	-2 SD	0 SD	2 SD	-2 SD	0 SD	2 SD	-2 SD	0 SD	2 SD	-2 SD	0 SD	2 SD	-2 SD	0 SD	2 SD	-2 SD	0 SD	2 SD
Additive genetic	.95	.59	.35	.66	.49	.35	.66	.49	.35	.86	.86	.86	.86	.86	.86	.86	.86	.86	.86	.86	.86	.86	.86	.86
Shared environment	.12	.12	.12	.24	.24	.24	.24	.24	.24	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60
Nonshared environment	.37	.26	.17	.47	.26	.11	.46	.29	.17	.46	.29	.17	.46	.29	.17	.46	.29	.17	.46	.29	.17	.46	.29	.17
Proportions of Variance																								
Additive genetic	.66	.61	.55	.48	.49	.50	.45	.69	.56															
Shared environment	.08	.12	.19	.18	.24	.34	.31	.07	.33															
Nonshared environment	.26	.27	.27	.34	.26	.16	.24	.23	.11															
Correlations with Moderator																								
Genetic	.45	.57	.74	.57	.66	.78	.23	.23	.23															
Shared environment	-1.00	-1.00	-1.00	1.00	1.00	1.00	.39	.99	.43															
Nonshared environment	.16	.19	.24	.09	.12	.18	.16	.20	.27															

Note. GPA = grade point average; SD = standard deviation. The very large (+1.00) and small (-1.00) shared environmental correlations are due to small portions shared environmental variance making it difficult to estimate the shared environmental covariance between GPA and the moderator.