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True Grit and Genetics: Predicting Academic Achievement From Personality

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Grit—perseverance and passion for long-term goals—has been shown to be a significant predictor of academic success, even after controlling for other personality factors. Here, for the first time, we use a U.K.-representative sample and a genetically sensitive design to unpack the etiology of Grit and its prediction of academic achievement in comparison to well-established personality traits. For 4,642 16-year-olds (2,321 twin pairs), we used the Grit-S scale (perseverance of effort and consistency of interest), along with the Big Five personality traits, to predict grades on the General Certificate of Secondary Education (GCSE) exams, which are administered U.K.-wide at the end of compulsory education. Twin analyses of Grit perseverance yielded a heritability estimate of 37% (20% for consistency of interest) and no evidence for shared environmental influence. Personality, primarily conscientiousness, predicts about 6% of the variance in GCSE grades, but Grit adds little to this prediction. Moreover, multivariate twin analyses showed that roughly two-thirds of the GCSE prediction is mediated genetically. Grit perseverance of effort and Big Five conscientiousness are to a large extent the same trait both phenotypically ($r = 0.53$) and genetically (genetic correlation = 0.86). We conclude that the etiology of Grit is highly similar to other personality traits, not only in showing substantial genetic influence but also in showing no influence of shared environmental factors. Personality significantly predicts academic achievement, but Grit adds little phenotypically or genetically to the prediction of academic achievement beyond traditional personality factors, especially conscientiousness.

Keywords: Grit, perseverance, personality, academic achievement, twin study

Academic achievement at the end of compulsory schooling is of major importance to individuals, their families, and society. For example, in the United Kingdom, the results of national standardized examinations (General Certificate of Secondary Education [GCSE]) taken at age 16 are used to make decisions regarding further education and future employment. Understanding the correlates and predictors of differences among children in their academic achievement at the end of compulsory education could have important implications for educational curricula decisions and possible educational interventions.

Extraversion, Agreeableness, Conscientiousness, Openness, and Neuroticism form the broad five dimensions of personality. The Big Five personality factors represent a central approach to the trait theory of personality. They constitute an empirically verified taxonomy of traits, which has been derived empirically as a reasonably comprehensive broad-stroke overview of human personality, with most other finer grained personality measures like effort, willpower, and persistence, encompassed by these five personality facets (Briley, Domiteaux, & Tucker-Drob, 2014; McCabe, Van Yperen, Elliot, & Verbraak, 2013). The Big Five personality factors—especially Conscientiousness, Agreeableness, and Neuroticism (negatively)—predict academic achievement, explaining a significant but modest proportion of variance in achievement (Chamorro-Premuzic & Furnham, 2003; Conard,

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2006; Laidra, Pullmann, & Allik, 2007; Noftle & Robins, 2007; Poropat, 2009). Of all personality factors, Conscientiousness is the most robust predictor of academic achievement across education, with an average correlation of 0.20 (Noftle & Robins, 2007; Poropat, 2009; Richardson, Abraham, & Bond, 2012; Trapmann, Hell, Hirn, & Schuler, 2007; Vedel, 2014; Wagerman & Funder, 2007). In one meta-analysis, Openness also significantly predicted university grades ($r = 0.12$; Poropat, 2009), but another meta-analysis found that only Conscientiousness significantly predicted university grades (Trapmann et al., 2007). There is some evidence that Openness predicts secondary school achievements, such as university entrance exams, but that it is a weaker predictor of success at university (Noftle & Robins, 2007).

Although there is strong evidence for the association between personality factors and achievement, some research suggests that narrower facets of personality, more specific than the Big Five, such as effort and intellectual investment, predict more variance in achievement than the major Big Five personality factors (Briley, Domiteaux, & Tucker-Drob, 2014; Paunonen, Haddock, Forsterling, & Keinonen, 2003; Paunonen & Jackson, 2000). However, such specific traits are usually subsumed within the Big Five factors as lower level traits (Paunonen, Haddock, Forsterling, & Keinonen, 2003). Focusing on these narrower, more specific facets may increase the predictive power as they may explain more variance in the outcomes than the broad Big Five (Briley, Domiteaux, & Tucker-Drob, 2014; Paunonen, Haddock, Forsterling, & Keinonen, 2003; Paunonen & Jackson, 2000).

Grit might be one of these narrower facets of personality that predict school achievement. *Grit*—perseverance and passion for long-term goals, as defined by Duckworth, Peterson, Matthews, & Kelly (2007)—has emerged in recent years as a significant predictor of life success and school achievement (Duckworth et al., 2007). Although Grit is closely related to Conscientiousness (phenotypic correlations around .70), some evidence suggests that Conscientiousness is multifaceted (Eskreis-Winkler, Shulman, Beal, & Duckworth, 2014), so whereas Grit is not identical to Conscientiousness it might be very similar to facets of Conscientiousness, such as industriousness and perseverance. Studies suggest that a more fine-grained measure of Conscientiousness like Grit might increase the predictive usefulness of this personality facet (Duckworth et al., 2007; Eisenberg, Duckworth, Spinrad, & Valiente, 2014; MacCann, Duckworth, & Roberts, 2009). Indeed, Grit (comprising perseverance of effort and consistency of interests) has been found to predict life success such as job retention, graduation from high school and scholastic achievement across the life span because it refers to extreme stamina and effort (Eskreis-Winkler, Shulman, Beal, & Duckworth, 2014). Grit remains a significant predictor of life outcomes when controlling for Big Five personality factors, although it explains only minor incremental variance (Duckworth, 2013; Duckworth & Eskreis-Winkler, 2013; Duckworth et al., 2007; Eskreis-Winkler et al., 2014; Von Culin, Tsukayama, & Duckworth, 2014).

A critical limitation of most research studying Grit has been the use of highly selected populations such as undergraduate students, spelling competition finalists, cadets, and teachers; research on less restricted samples might yield higher correlations. Moreover, despite the evidence for Grit's significant prediction of educational achievement, more attention to the effect size and distinctiveness of this prediction is warranted prior to considering intervention. Some researchers have suggested that Grit might be more malleable than socioeconomic status, intelligence, and other predictors of academic achievement (Duckworth & Gross, 2014). It is often assumed that its origins lie with family values and thus would be more amenable to training (Duckworth & Gross, 2014) as compared with cognitive factors or socioeconomic status, which are considered to be very difficult to amend (Moffitt et al., 2011). However, these assumptions may be premature for three reasons. First, all personality traits show similar heritability. Second, previous research suggests that it is nonshared environment (environmental influences that do not contribute to similarities between siblings growing up in the same family and attending the same school) and not shared environment that is important for personality traits (Turkheimer, Pettersson, & Horn, 2013). Third, we are not aware of studies that have shown the effects of training Grit. Despite the lack of empirical evidence training Grit has been set as a priority by the U.S. Department of Education (see http://edf.stanford.edu/readings/download-promotings-grit-tenacity-and-perseverance-report) and the U.K. Department for Education (see https://www.gov.uk/government/news/england-to-become-a-global-leader-of-teaching-character). The effectiveness of training programs should be rigorously researched before they are rolled out widely.

Little is known about why children differ in Grit or about the etiology of its correlates with educational achievement. Although there has as yet been no genetically sensitive study investigating the etiology of Grit or its links with school achievement, twin studies investigating the associations between Big Five traits and educational achievement have found that these associations are largely explained by genetic factors rather than environmental factors (Krapohl et al., 2014; Luciano, Wainwright, Wright, & Martin, 2006).

Given the potential impact of Grit on educational policy in the United Kingdom and the United States, it is vital to understand this trait more fully. Here, for the first time, we investigate the genetic and environmental origins of individual differences in Grit within a large representative U.K. sample of 16-year-olds. We also consider the power of Grit to predict academic achievement beyond the Big Five personality traits and the extent to which this prediction is mediated by genetic and environmental factors.

Method

Participants

The present study used the Twins Early Development Study (TEDS) sample, which is a large longitudinal study that recruited over 16,000 twin pairs born in England and Wales between 1994 and 1996 (Haworth, Davis, & Plomin, 2013). Although there has been some attrition, more than 10,000 twin pairs remain actively involved in the study. Rich data have been collected over many years on cognitive and learning abilities, personality, and behavior. It is important to note that in relation to the highly selected nature of samples used in previous research, the present sample is representative of the U.K. population (Haworth, Davis, & Plomin, 2013; Kovas, Haworth, Dale, & Plomin, 2007).

The present study included 4,642 TEDS participants (2,321 twin pairs) from whom Grit, Big Five personality factors and GCSE scores were available. The sample size for each measure is shown

in the results. Children who had major medical or psychiatric problems were excluded from the analyses. Zygosity was assessed using a parent questionnaire of physical similarity, which is 95% accurate when compared with DNA testing (Price et al., 2000). DNA testing was conducted when zygosity was not clear from the physical similarity criteria. Both same-sex twin pairs and opposite-sex twin pairs were included in the study, with the overall sample including 883 monozygotic (MZ) pairs, 761 same-sex dizygotic (DZ) twin pairs and 677 opposite-sex DZ twin pairs.

Measures

Grit was assessed at age 16 using the Grit-S questionnaire with online administration (Duckworth & Quinn, 2009). The Grit-S includes eight items and is scored on two scales, perseverance of effort (four items) and consistency of interest (four items). Twins were asked, "To what extent do the following statements describe you?" Participants were asked to rate the statements on a 5-point scale ranging from from 1 (*very much like me*) to 5 (*not like me at all*). For example, a perseverance item was "Setbacks don't discourage me" and a consistency of interest item was "I have difficulty maintaining my focus on projects that take more than a few months to complete (reversed)." Both subscales have been shown to have reasonable reliability; in the present study, Cronbach alphas for consistency of interest and perseverance of effort were .73 and .63.

Personality was measured using the abbreviated questionnaire of the five-factor model—Five-Factor Model Rating Form (FFMRF), which was administered online (Mullins-Sweatt, Jamerson, Samuel, Olson, & Widiger, 2006). The FFMRF consists of 30 items, with six items for each of the five personality traits. Twins were asked to rate themselves on a 5-point scale on which 1 = *extremely low*, 2 = *low*, 3 = *nether high nor low*, 4 = *high*, and 5 = *extremely high*. For example, the Conscientiousness item of self-discipline was rated from dogged/devoted to hedonistic/negligent; the Neuroticism item of depressiveness was rated from pessimistic/glum to optimistic. The FFMRF has been reported to be reliable (Samuel, Mullins-Sweatt, & Widiger, 2013); in our sample, Cronbach alphas were .78 for Conscientiousness, .68 for Neuroticism, .70 for Extraversion, .63 for Openness, and .68 for Agreeableness.

Educational achievement was assessed by the GCSE, a U.K.-wide national exam administered at the end of compulsory schooling, usually at age 16. Students typically start GCSE courses at the age of 14 and can choose from a variety of courses such as history, music, physical education, and modern foreign languages, although English, mathematics, and science are compulsory. The exams are graded from A* to G, with a U grade given for failed exams. Grades were coded from 11 (A*) to 4 (G) to create equivalent numerical comparisons. No information about failed courses was available. Most pupils receive five or more grades between A* and C, which is the requirement for further education in the United Kingdom. GCSE grades were obtained from parents or the twins themselves via questionnaires sent in by mail or conducted over the telephone. For 7,367 twins, the grades were verified using the National Pupil Database (NPD; https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/251184/SFR40_2013_FINALv2.pdf), and yielded a correlation with parent- and twin-reported grades of 0.99 for mathematics, 0.98 for English and >0.95 for all the sciences.

We created a mean composite measure of core academic subjects: English (English language or English literature grade), mathematics and sciences (single- or double weighted science; or when taken separately, physics, chemistry, and biology grade). The mean of these core GCSE exam grades was used as a general index of academic achievement at the end of compulsory education.

Analyses

Phenotypic analyses. We compared means and variance for boys and girls and for MZ and DZ twins. Mean differences for age and sex and their interaction were tested using univariate analysis of variance (ANOVA).

Correlation was used to estimate associations between the two Grit-S subscales (perseverance of effort and consistency of interest), the Big Five personality scales, and GCSE grades. Principal component analyses were used to assess the factor structure of Grit-S scale.

Multiple regression assessed the extent to which Grit-S perseverance of effort and consistency of interest predict GCSE grades. Hierarchical multiple regression tested the incremental prediction of GCSE grades from the two Grit subscales when Big Five personality factors were entered as the first step in the regression model. Because the present sample was a twin sample, we maintained independence of data by randomly selecting one twin per pair for all phenotypic analyses.

Twin analyses. The twin method was used to estimate the relative contribution of additive genetic (A), shared environmental (C) and nonshared environmental (E) components of variance. The twin method compares the resemblance for MZ twins, who share 100% of their genes, to DZ twins who share on average 50% of their segregating genes (Plomin, DeFries, Knopik, & Neiderhiser, 2013). If MZ correlations are larger than DZ correlations, genetic influence can be inferred. Shared environmental influences are assumed to be the same for both MZ and DZ twins growing up in the same household. Nonshared environmental influences are unique to individuals, and do not contribute to similarities between twins; importantly this component of variance also includes the measurement of error. A can be calculated approximately by doubling the difference between MZ and DZ correlations, C can be calculated by deducting the heritability estimate from the MZ correlations, and E can be calculated by deducting the MZ correlation from unity (Rijsdijk & Sham, 2002). These ACE parameters can be calculated more accurately and with confidence intervals using structural equation models with maximum likelihood estimation. The data were analyzed using the structural equation modeling program OpenMx (Boker et al., 2011).

Bivariate genetic analysis extends univariate ACE analysis to the covariance between two traits. The ACE parameters can be estimated for the covariance between traits by comparing the cross-twin cross-trait correlations (Twin 1 score on Trait A with Twin 2 score on Trait B) for MZ and DZ twin pairs. The extent to which these MZ correlations exceed DZ correlations indexes genetic mediation of the phenotypic correlation between the two traits. The contributions of C and E to the phenotypic correlation can also be estimated.

Table 1
Descriptive Statistics: Means (Standard Deviations in Parentheses) for Grit Consistency of Interest, Grit Perseverance of Effort, and Big Five Personality Factors

Personality trait	*n*	Whole sample	Male	Female	MZm	DZm	MZf	DZf	DZos	Sex	Zygosity	Sex × Zygosity	R^2
Grit Consistency of Interest	4,849	2.85 (.80)	2.75 (.81)	2.95 (.81)	2.75 (.81)	2.70 (.81)	3.01 (.82)	2.93 (.82)	2.84 (.79)	31.08**	2.19	1.48	.02
Grit Perseverance	4,850	3.73 (.62)	3.71 (.62)	3.73 (.62)	3.78 (.59)	3.71 (.61)	3.76 (.63)	3.70 (.61)	3.68 (.63)	.23	7.64*	.72	<.01
Extraversion	4,782	3.65 (.63)	3.62 (.63)	3.68 (.62)	3.67 (.62)	3.62 (.62)	3.66 (.63)	3.68 (.60)	3.65 (.64)	3.12	.33	1.32	<.01
Openness	4,779	3.65 (.63)	3.56 (.61)	3.59 (.58)	3.58 (.63)	3.54 (.61)	3.57 (.58)	3.59 (.59)	3.58 (.58)	.70	.10	1.20	<.01
Agreeableness	4,771	3.67 (.58)	3.54 (.57)	3.75 (.59)	3.56 (.58)	3.50 (.58)	3.76 (.58)	3.73 (.60)	3.66 (.59)	59.48**	1.15	.02	.03
Conscientiousness	4,768	3.72 (.62)	3.64 (.62)	3.78 (.62)	3.76 (.63)	3.67 (.61)	3.82 (.60)	3.74 (.65)	3.67 (.62)	22.63**	5.14*	.68	.01
Neuroticism	4,786	2.58 (.68)	2.47 (.64)	2.65 (.67)	2.41 (.58)	2.49 (.67)	2.64 (.72)	2.70 (.63)	2.56 (.66)	44.14**	2.95	5.96*	.02

Note. For the results in the last four columns: *F* statistics; R^2 = proportion of the variance explained by the combined effects of sex, zygosity, and their interaction. *n* = sample size after exclusions (individuals); MZm = monozygotic male; DZm = dizygotic male; MZf = monozygotic female; DZf = dizygotic female; DZos = dizygotic opposite sex.
* $p < .05$. ** $p < .01$.

Bivariate genetic analysis yields an additional set of statistics, including the genetic correlation (r_G), which indicates the extent to which the same genes influence two traits regardless of their heritabilities. In other words, the heritability of two traits could be low, but the genetic correlation between the traits could be high. The genetic correlation indexes the extent to which genetic influences on one trait also impact the other trait (Plomin, DeFries, Knopik, & Neiderhiser, 2013). Roughly speaking, the genetic correlation indicates the chance that a genetic variant associated with one trait is also associated with the other trait. The genetic correlation implies causality in the sense that it indexes the extent to which the same genes affect both traits; although the current method does not provide information on the possible underlying mechanisms (Ligthart & Boomsma, 2012). Similarly, bivariate analysis estimates the shared environmental correlation (r_C) and the nonshared environmental correlation (r_E). A shared environmental correlation of 1.0 indicates that the shared environmental influences that make twins similar for one trait also make twins similar on the other trait. Similarly, for nonshared environment, a correlation of zero indicates that completely different nonshared environmental influences affect two traits (Plomin, DeFries, Knopik, & Neiderhiser, 2013).

Results

Phenotypic Analyses

Table 1 presents mean scores and standard deviations for five groups: MZ males, MZ females, DZ males, DZ females, and DZ opposite-sex twin pairs. ANOVA results conducted after randomly selecting one twin per pair, show that sex, zygosity and their interaction explain only around 1% of the variance on average.

Factor analysis was used to assess the factors structure of the Grit-S scale. Table 2 illustrates the factor loadings using oblique factor rotations, which suggests that the two-factor model fits the Grit data best. The factor structure was virtually identical when we tested this in the other half of the data (we randomly assigned members of each twin pair to two subsamples). The two Grit subscales, consistency of interest and perseverance of effort, in the present representative sample of 16-year-olds in the United Kingdom correlate less than previously reported ($r = 0.29$, $p < .001$). For these reasons, subsequent analyses were conducted for the two subscales separately rather than combining them as is often done.

Table 3 presents correlations among all measures. Conscientiousness and Grit perseverance correlated most highly with GCSE scores ($r = 0.24$ and 0.17, respectively). Grit perseverance was

Table 2
Factor Loadings for Grit-S Scale Using Direct Oblim Rotation

Grit scale item	Direct Oblim rotation with Kaiser normalization pattern matrix: Consistency of Interest	Perseverance of Effort
New ideas and projects sometimes distract me from previous ones (reversed)	.73	−.09
Setbacks don't discourage me	−.04	.63
I have been obsessed with a certain idea or project for a short time but later lost interest (reversed)	.78	−.06
I am a hard worker	.06	.74
I often set a goal but later choose to pursue a different one (reversed)	.75	.01
I have difficulty maintaining my focus on projects that take more than a few months to complete	.68	.25
I finish whatever I begin	.28	.64
I am diligent	−.15	.71

Table 3
Phenotypic Correlations Between Two Grit Subscales, Big Five Personality Factors, and GCSE Scores (95% Confidence Intervals in Parentheses)

Factor or subscale	C	N	E	O	A	CoI	P	GCSE
Conscientiousness (C)	—							
Neuroticism (N)	−.18 (−.20, −.15)	—						
Extraversion (E)	.20 (.17, .23)	−.38 (−.41, −.35)	—					
Openness (O)	.06 (.03, .09)	−.06 (−.09, −.03)	.22 (.19, .25)	—				
Agreeableness (A)	.29 (.26, .29)	−.19 (−.21, −.16)	.15 (.12, .18)	.20 (.17, .23)	—			
Consistency of Interest (CoI)	.28 (.25, .30)	−.19 (−.21, −.16)	.07 (.04, .10)	−.10 (−.13, −.07)	.10 (.09, .13)	—		
Perseverance (P)	.53 (.50, .55)	−.31 (−.36, −.28)	.27 (.24, .30)	.08 (.05, .08)	.18 (.15, .20)	.29 (.26, .31)	—	
GCSE score	.24 (.21, .27)	.02 (−.01, .05)	.04 (.01, .07)	.09 (.05, .12)	.03 (.01, .07)	.06 (.03, .09)	.17 (.13, .20)	1.00

Note. GCSE = General Certificate of Secondary Education exams.

substantially correlated with Big Five Conscientiousness (r = 0.53). Grit consistency of interest correlated only 0.06 with GCSE scores.

Table 4 summarizes results for multiple regression analyses that take into account the intercorrelations among the personality measures in their prediction of GCSE scores. Together, the two Grit-S subscales explained 2% of the variance in GCSE grades. Grit perseverance of effort significantly predicted GCSE independent of Grit consistency of interest but not vice versa.

Table 4 also includes results for the hierarchical multiple regression used to estimate the prediction of GCSE scores from Grit-S perseverance of effort and consistency of interest when Big Five personality factors (Extraversion, Openness, Agreeableness, Conscientiousness, Neuroticism) were entered into the regression model in the first step. Big Five personality factors explained 5.5% of the variance in GCSE grades. Adding the Grit-S subscales to the regression model increased the variance explained by only 0.5%.

Twin Analyses

Univariate genetic analyses. Table 5 shows the twin correlations for the Big Five and Grit personality factors and their cross-trait cross-twin correlations with GCSE grades.

Table 6 shows the ACE estimates for the two Grit subscales and the Big Five traits, which follow from the MZ and DZ twin correlations presented in Table 5. The Grit subscales yielded results similar to the Big Five traits: moderate heritability, negligible shared environmental influence, and substantial nonshared environmental influences. All personality measures at age 16 were significantly heritable, with heritability estimates explaining approximately one third of the variance (20% to 38%), whereas shared environmental influences were negligible and not significant and two thirds of the variance was explained by nonshared environmental influences (62% to 76%).

Bivariate genetic analyses. Figure 1 illustrates the results of bivariate analyses between the personality measures and GCSE grades, which follow from the MZ and DZ cross-trait cross-twin correlations shown in Table 4. Bivariate heritability can be calculated by the product of the square root of the heritability of variable 1, the square root of the heritability of variable 2 and the genetic correlation between the two variables. The proportion of variance explained by C and E is calculated the same way, using C and E (and rC and rE, respectively). In Figure 1, for example, the top bar shows that the phenotypic correlation between Grit perseverance and GCSE scores was 0.17; the bivariate heritability is 0.15. Thus, 88% of the phenotypic correlation (0.15/0.17) was mediated by genetic factors. The highest phenotypic correlation was between Big Five conscientiousness and GCSE grades (0.24); 67% of this correlation was mediated genetically (bivariate heritability of 0.16). The phenotypic correlations between other Big Five personality factors and exam performance were very small, but are presented in Figure 1 for completeness.

Table 7 presents the genetic correlations and shared and nonshared environmental correlations between the personality measures and GCSE grades. The highest genetic correlations between personality and GCSE grades emerged for Big Five Conscientiousness (0.36) and Grit perseverance (0.33). The genetic correlation of 0.86 between Big Five Conscientiousness and Grit perseverance indicates that to a large extent the same genes influence these two

Table 4
Regression Analyses Investigating the Predictors of GCSE Achievement From Personality Measures

Personality trait	F	R^2	β
Multiple regression	$F(2, 1975) = 23.28^{**}$	.02	
Consistency of Interest			−.01
Perseverance of Effort			.15**
Hierarchical regression			
Step 1	$F(5, 1912) = 22.15^{**}$	.055	
Neuroticism			.08*
Extraversion			.01
Openness			.07*
Agreeableness			−.05*
Conscientiousness			.23**
Step 2	$F(7, 1912) = 17.34^{**}$	.06	
	F change (2,1905) = 5.09**	R^2 change = .005	
Neuroticism			.09**
Extraversion			.01
Openness			.07*
Agreeableness			−.05*
Conscientiousness			.19**
Consistency of Interest			−.02
Perseverance of Effort			.09**

Note. For the hierarchical multiple regression, variables were entered in the regression model in the following order: (Step 1) Big Five personality scales; (Step 2) Big Five personality scales and Grit. β = standardized beta value; R^2 = variance explained. GCSE = General Certificate of Secondary Education exams.
* $p < .05$. ** $p < .01$.

personality factors. Although some of the shared environmental correlations are very high, little weight can be placed on these estimates, because there is so little shared environmental variance (see Table 5).

Discussion

Using a large representative sample of the U.K. population, we found that personality factors explain around 6% of the variance in academic achievement at the end of compulsory education at age 16. However, at this stage of education Grit adds only 0.5% to the prediction of GCSE variance after accounting for the association between achievement and Big Five personality factors. We believe that these results should warrant concern with the educational policy directives in the United States and the United Kingdom (Shechtman, DeBarger, Dornsife, Rosier, & Yarnall, 2013).

Twin analyses, conducted for the first time in the present study, showed that Grit (perseverance of effort and consistency of interest), just as other personality factors (Turkheimer, Pettersson, & Horn, 2013), is moderately heritable, with genetic factors explain-

Table 5
Twin Correlations for Personality Factors and Cross Trait Cross-Twin Correlations With GCSE Results and Personality Factors (95% Confidence Intervals in Parentheses)

Personality trait	MZ correlation	DZ correlation	MZ cross-trait cross-twin correlation	DZ cross-trait cross-twin correlation
Perseverance of Effort	.35 (n = 776) (.30, .42)	.17 (n = 1,211) (.12, .23)	.18 (n = 757) (.11, .24)	−.01 (n = 1,210) (−.06, .05)
Consistency of Interests	.24 (n = 781) (.18, .31)	.15 (n = 1,219) (.09, .20)	.04 (n = 760) (-.03, .11)	−.01 (n = 1,216) (−.06, .05)
Conscientiousness	.34 (n = 755) (.28, .40)	.07 (n = 1,167) (.008, .12)	.19 (n = 747) (.12, .25)	.03 (n = 1,194) (−.03, .08)
Neuroticism	.29 (n = 759) (.23, .36)	.15 (n = 1,183) (.10, .22)	.003 (n = 751) (-.08, .06)	.03 (n = 1,200) (−.02, .09)
Extraversion	.39 (n = 751) (.32, .44)	.14 (n = 1,173) (.08, .19)	.11 (n = 743) (.03, .18)	.03 (n = 1,198) (−.02, .09)
Openness	.35 (n = 757) (.29, .41)	.08 (n = 1,176) (.03, .14)	.08 (n = 748) (.01, .15)	.02 (n = 1,199) (−.03, .08)
Agreeableness	.24 (n = 750) (.18, .31)	.11 (n = 1,167) (.05, .16)	.03 (n = 744) (-.04, .10)	−.02 (n = 1,190) (−.07, .04)

Note. To increase power in the present analyses, the full sample was used, combining males and females and including opposite-sex pairs. GCSE = General Certificate of Secondary Education exams; MZ = monozygotic; DZ = dizygotic.

Table 6
Model Fitting Results for Univariate Analyses for Additive Genetic (A), Shared Environmental (C), and Nonshared Environmental (E) Components of Variance for Personality Factors (95% Confidence Intervals in Parentheses)

Personality factor	Variance components (95% CI)		
	A	C	E
Perseverance of Effort	.37 (.24, .42)	.00 (0, .10)	.63 (.58, .69)
Consistency of Interests	.20 (.03, .31)	.05 (0, .17)	.75 (.69, .82)
Conscientiousness	.30 (.24, .36)	0 (0, .04)	.70 (.64, .76)
Neuroticism	.27 (.10, .35)	.02 (0, .15)	.71 (.65, .77)
Extraversion	.38 (.30, .43)	.00 (0, .05)	.62 (.57, .68)
Openness	.31 (.24, .37)	0 (0, .04)	.69 (.63, .75)
Agreeableness	.24 (.11, .30)	.00 (0, .10)	.76 (.70, .82)

ing about a third of the variance. Shared environmental factors, which are factors that contribute to similarities between members of a twin pair growing up in the same family and attending the same schools, explained no significant variance in these scales. The majority of the variance in all personality factors was explained by nonshared environmental factors, which are the factors that do not contribute to similarities between twin pairs growing up in the same family and attending the same schools. It should be emphasized, however, that behavioral genetic results such as these describe components of variance in a particular population at a particular time. Specifically, heritability does not imply immutability. The most limiting finding, for any possible intervention, is that shared environmental influence is negligible. This means that current differences between families and schools explain little variance in the development of Grit. However, even this finding does not limit the possible effect of a novel intervention that is not currently part of the environmental variation.

The focus of this study was the relationship between personality and academic achievement. Big Five personality traits have been well studied and research has consistently shown that these traits explain a small but significant proportion of the variance in educational achievement (Chamorro-Premuzic & Furnham, 2003; Krapohl et al., 2014; Laidra et al., 2007; Luciano et al., 2006; Noftle & Robins, 2007; Poropat, 2009). It has been argued that narrower aspects of personality could explain a larger proportion of the variance in academic achievement than the well-studied Big Five factors, such as curiosity, self-control, or motivation (Briley et al., 2014). Grit could be one of these narrower facets, but the effect size of Grit as measured by the Grit-S in the present study was very small, especially when the association among the Big Five was accounted for. Thus, the association between achievement and personality is largely explained by the Big Five and Grit adds little to this relationship. We also found that Grit consistency of interest does not significantly predict school achievement. One possibility is that consistency of interest has both positive and negative effects on scholastic achievement. Although it is good to keep focused and interested in the task at hand, it is also sometimes more adaptive to focus on new ideas and projects without distraction from previous interest. The core finding is that Grit, especially the perseverance of effort subscale, is substantially correlated with Conscientiousness, both phenotypically (0.53) and genetically (0.86). The extent to which an individual can have different scores on these two traits stems largely from nonshared environment; this may result from some measure-specific measurement error or aspects of the environment that affect only one trait.

The present findings show that Grit adds little to the prediction of academic achievement when other personality factors are controlled. This does not exclude the possibility that other cognitive or noncognitive predictors are important correlates of academic success. For example, self-efficacy has consistently been shown to be associated with school achievement (Chamorro-Premuzic, Harlaar, Greven, & Plomin, 2010; Greven, Harlaar, Kovas, Chamorro-Premuzic, & Plomin, 2009; Luciano et al., 2006; Richardson et al., 2012; Zimmerman, Bandura, & Martinez-Pons, 1992). Specifically, we have recently shown that at the end of compulsory education self-efficacy correlates substantially (0.49) with GCSE grades, although this correlation is largely mediated by genetic factors (Krapohl et al., 2014). Curiosity, specifically intellectual engagement, has also been shown to be a significant predictor of school achievement—a hungry mind could be the driving force for effort and perseverance (von Stumm, Hell, & Chamorro-Premuzic, 2011). Another noncognitive factor that has consistently been

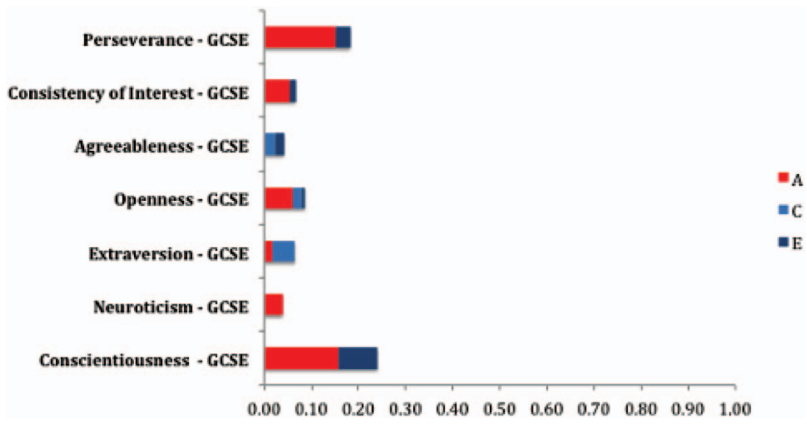

Figure 1. Bivariate estimates for additive genetic (A), shared environmental (C), and nonshared environmental (E) contributions to the correlations between personality measures and General Certificate of Secondary Education (GCSE) exam grades. The total length of the bar indicates the phenotypic correlations.

Table 7
Genetic (rG), Shared Environmental (rC) and Nonshared Environmental (rE) Correlations Between Grit, Big Five, and GCSE Exam Grades (95% Confidence Intervals in Parentheses)

	C	N	E	O	A	CoI	P	GCSE
				rG				
Conscientiousness (C)	—							
Neuroticism (N)	−.38 (−.69, −.36)	—						
Extraversion (E)	.44 (.28, .58)	−.61 (−.90, −.41)	—					
Openness (O)	.13 (−.04, .30)	−.07 (−.42, .17)	.09 (.03, .24)	—				
Agreeableness (A)	.47 (.23, .68)	−.27 (−.71, .13)	.16 (−.17, .39)	.21 (−.07, .48)	—			
Consistency of Interest (CoI)	.63 (.40, .87)	−.46 (−.76, −.46)	.41 (.16, .0.68)	−.19 (−.48, −.10)	.75 (.65, .96)	—		
Perserevance (P)	.86 (.76, 1.00)	−.37 (−.63, −.31)	.47 (.30, .68)	.06 (−.16, .17)	.46 (.19, .46)	.80 (.58, .96)	—	
GCSE core	.36 (.22, .52)	.10 (−.10, .32)	.04 (−.11, .18)	.14 (−.01, .29)	−.02 (−.25, .20)	.15 (.11–.37)	.33 (.17, .50)	—
				rC				
Conscientiousness (C)	—							
Neuroticism (N)	−.48 (−1.00, 1.00)	—						
Extraversion (E)	.68 (−.11, 1.00)	−.51 (−1.00, 1.00)	1.00					
Openness (O)	−.48 (−1.00, 1.00)	.59 (−1.00, 1.00)	.14 (−1.00, 1.00)	1.00				
Agreeableness (A)	.99 (−.05, 1.00)	−.49 (−1.00, 1.00)	.75 (−.74, 1.00)	−.40 (−1.00–1.00)	1.00			
Consistency of Interest (CoI)	−.97 (−1.00, 1.00)	.26 (−1.00, 1.00)	−.56 (−1.00, .88)	.42 (−1.00, 1.00)	−.95 (−.96, .16)	1.00		
Perserevance (P)	.48 (.31, .48)	−.81 (−1.00, 1.00)	.05 (−1.00, 1.00)	−.95 (−1.00, 1.00)	.42 (−1.00, 1.00)	−.34 (−1.00, 1.00)	1.00	
GCSE core	.15 (−.98, 1.00)	−.14 (−.14, 1.00)	.81 (−1.00, 1.00)	.66 (−1.00, 1.00)	.25 (−.47, .25)	−.06 (−.54, .62)	−.45 (−1.00, 1.00)	1.00
				rE				
Conscientiousness (C)	—							
Neuroticism (N)	−.10 (−.15, −.04)	—						
Extraversion (E)	.08 (.02, .14)	−.27 (−.33, −.21)	—					
Openness (O)	.03 (−.03, .09)	−.06 (−.12, −.06)	.30 (.24, .35)	—				
Agreeableness (A)	.23 (.17, .28)	−.15 (−.20, −.08)	.13 (.07, .19)	.21 (.15, .27)	—			
Consistency of Interest (CoI)	.18 (.12, .18)	−.12 (−.18, −.06)	−.04 (−.09, .02)	−.09 (−.15, −.03)	−.01 (−.05, .05)	—		
Perserevance (P)	.37 (.32, .42)	−.27 (−.26, −.21)	.17 (.11, .23)	.10 (.04, .16)	.07 (.06, .12)	.12 (.06, .18)	—	
GCSE score	.25 (.18, .32)	−.02 (−.09, .05)	−.08 (−.15, −.01)	.02 (−.05, .02)	.05 (−.02, .12)	.04 (−.04, .10)	.15 (.08, .23)	—

Note. GCSE = General Certificate of Secondary Education exams.

associated with academic achievement and life success is self-control—the capacity to regulate behavior and focus in the presence of temptation (Duckworth & Gross, 2014; Duckworth, Quinn, & Tsukayama, 2012; Duckworth, Tsukayama, & Kirby, 2013; Moffitt et al., 2011; Tangney, Baumeister, & Boone, 2004). Self-control has been shown to correlate highly with life success, even after controlling for other factors, such as intelligence and socioeconomic status, which might make it a good target for intervention (Moffitt et al., 2011). However, to our knowledge, no studies have specifically focused on the efficacy of training self-control. More research is needed to find how intervention programs could enhance self-control, or indeed any other noncognitive factors, during childhood, and whether this intervention could have a lasting effect.

Limitations of our study begin with the usual limitations of a twin study, such as the equal environment assumption or the assumption of random mating, as described in detail elsewhere (Plomin et al., 2013; Rijsdijk & Sham, 2002). It should also be noted that our results may be limited to age 16 and that Grit could play a larger role in academic success in university or postgraduate studies (Briley et al., 2014; Duckworth & Quinn, 2009). Indeed, research has shown that Grit increases with age and becomes increasingly important when individuals understand what their lifelong goals as well as their interests are (Duckworth & Eskreis-Winkler, 2013).

The results of the present study could also be affected by gene–environment interplay. As children grow older, they increasingly select, modify, and tailor their environments in part because of their genetic propensities, including genetically driven aspects of their personality, a concept known as *gene−environment correlation* (Plomin et al., 2013; Krapohl et al., 2014). In education, genetic factors not only influence children's aptitude and scholastic achievement, but also influence their appetite for learning.

The findings of the present study do not mean that teaching children to be grittier cannot be done or indeed that it is not beneficial. Throughout adult life, children will face challenges, thus perseverance in long-term goals might help them to develop habits of hard work and the continuous pursuit of their goals, despite the many obstacles they face. Our findings suggest, however, that although personality significantly predicts academic achievement, Grit adds little phenotypically or genetically to the prediction of academic achievement beyond well-established personality factors, especially Conscientiousness. Therefore, trying to increase Grit or perseverance could have long-term benefits for children but more research is warranted into intervention and training programs before concluding that such training increases educational achievement and life outcomes.

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