

## Research Article

## More Than Just IQ

## School Achievement Is Predicted by Self-Perceived Abilities—But for Genetic Rather Than Environmental Reasons

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**ABSTRACT**—Evidence suggests that children's self-perceptions of their abilities predict their school achievement even after one accounts for their tested cognitive ability (IQ). However, the roles of nature and nurture in the association between school achievement and self-perceived abilities (SPAs), independent of IQ, is unknown. Here we reveal that there are substantial genetic influences on SPAs and that there is genetic covariance between SPAs and achievement independent of IQ. Although it has been assumed that the origins of SPAs are environmental, this first genetic analysis of SPAs yielded a heritability of 51% in a sample of 3,785 pairs of twins, whereas shared environment accounted for only 2% of the variance in SPAs. Moreover, multivariate genetic analyses indicated that SPAs predict school achievement independently of IQ for genetic rather than environmental reasons. It should therefore be possible to identify "SPA genes" that predict school achievement independently of "IQ genes."

Although general cognitive ability as measured by psychometric tests (e.g., *g* or IQ) is the single most important predictor of academic achievement (Deary, Strand, Smith, & Fernandez, 2007; Gottfredson, 2004), it rarely explains more than 50% of the variance in academic performance (Chamorro-Premuzic & Furnham, 2005; Rhode & Thompson, 2007). Clearly, more than IQ is needed to explain achievement, so researchers have turned their attention to alternative constructs, such as self-perceived abilities (SPAs). The past 20 years have shown a growing trend among educational psychologists to endorse the view that in-

dividuals' SPAs—how good people *think* they are—are important predictors of academic achievement independent of actual, tested ability (IQ). Given the evidence for a moderate association between IQ and SPAs (Ackerman & Wolman, 2007; Furnham & Chamorro-Premuzic, 2004) and a substantial association between IQ and achievement (Chamorro-Premuzic & Furnham, 2005), it is important to show that any association between SPAs and achievement is not confounded by IQ. A handful of studies have shown that children's SPAs predict their school performance in analyses controlling for IQ scores (Gose, Wooden, & Muller, 1980; Schicke & Fagan, 1994; Spinath, Spinath, Harlaar, & Plomin, 2006). In addition, meta-analytic evidence suggests that SPAs exert small but consistent effects on subsequent achievement after controlling for previous achievement (Valentine, Dubois, & Cooper, 2004).

Although little is known about the genetic and environmental origins of SPAs, twin and adoption studies consistently yield heritability estimates of around 25% for IQ in early childhood. The heritability of IQ increases across the life span and is estimated at around 40% in middle childhood and 60% in adulthood. In contrast, shared environment—environmental influences that make children growing up in the same family similar to each other—tends to have a large impact on IQ in early childhood, a moderate impact in middle childhood, and negligible influence after adolescence (Davis, Arden, & Plomin, 2008; Plomin, DeFries, McClearn, & McGuffin, 2008). Despite the fact that not a single twin or adoption study has investigated the genetic and environmental etiologies of SPAs, researchers have cited environmental factors as a leading causal explanation for constructs related to SPAs, such as self-efficacy (Bandura, 1995) and self-concept (Shavelson, Hubner, & Stanton, 1976). Moreover, one of the most established theories of SPAs assumes that the development of individual differences in SPAs is shaped primarily by parents' beliefs, expectations, attitudes, and behaviors

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(Eccles (Parsons) et al., 1983; Wigfield & Eccles, 2000). Such environmental influences would seem likely to have shared effects on children growing up in the same family, and thus to contribute to their similarity. However, the influence of parents' beliefs, for example, could also be nonshared if children had different perceptions or interpretations of those beliefs, and thus such aspects of the environment might contribute to sibling dissimilarity. The model of Eccles (Parsons) et al. does not explicitly distinguish between shared and nonshared environmental factors.

But are SPAs really shaped primarily by environmental factors, whether shared or nonshared? What are the genetic and environmental etiologies of the relations among IQ, SPAs, and achievement? In particular, what are the roles of nature and nurture in the association between school achievement and SPAs, independent of IQ?

Questions about the origins of individual differences in SPAs and their relationship with IQ and school achievement are well suited for behavioral genetic methods, such as the twin method. Thus, we used a genetically informative design to investigate the genetic and environmental etiologies of SPAs, IQ, achievement, and their interrelationships in a large sample of twins. Here, we present results based on cross-sectional data (IQ, SPAs, and achievement assessed at age 9, the only age at which we had all three assessments) and also the results from a longitudinal analysis (IQ at 7, SPAs at 9, achievement at 10). The cross-sectional data at age 9 allowed us to explore the etiology of SPAs, to answer the question of whether SPAs are primarily environmental in origin. Multivariate genetic analysis of the cross-sectional data at age 9 allowed us to examine the extent to which the etiology of SPAs overlaps with that of two contemporaneously measured variables—IQ and achievement (i.e., the extent to which genetic or environmental factors associated with SPAs at age 9 also influence IQ and achievement at age 9). Introducing the longitudinal data allowed us to examine whether the etiologies of these relations among IQ, SPAs, and achievement are stable over time (i.e., whether the extent of the etiological overlap among IQ, SPAs, and achievement at age 9 is the same as the extent of the etiological overlap among IQ at age 7, SPAs at age 9, and achievement at age 10). In addition, the longitudinal design addressed the predictive validity of our findings, answering the question of whether SPAs predict subsequent achievement independently of previous IQ for genetic or environmental reasons. We were unable to conduct a full multivariate longitudinal analysis, as we did not have all three measures at all three ages.

## METHOD

### Participants

Subjects were followed over three data-collection periods: IQ was tested at ages 7 and 9, SPAs were assessed at age 9, and achievement was assessed at ages 9 and 10. All subjects were drawn from records of twin births in the United Kingdom as part of the Twins Early Development Study (TEDS); TEDS parents

have been shown to be representative of parents of young children in the United Kingdom in terms of education, ethnicity, and employment status (Oliver & Plomin, 2007). Children with severe neurological or genetic conditions were excluded from the sample.

The cross-sectionally assessed sample consisted of 2,287 pairs of twins: 1,217 pairs of monozygotic (MZ) twins and 1,070 pairs of dizygotic (DZ) same-sex twins. Subjects were included in our longitudinal analyses if they had data from at least two of the three waves of assessment. The longitudinally assessed sample consisted of 3,785 pairs of twins: 1,966 pairs of MZ twins and 1,819 pairs of DZ same-sex twins. Participants had a mean age of 7.12 years ( $SD = 0.24$ ) at the 7-year assessment, 9.01 years ( $SD = 0.28$ ) at the 9-year assessment, and 10.11 years ( $SD = 0.29$ ) at the 10-year assessment. Informed parental consent was obtained at all waves of assessment. Given the complexities of including DZ opposite-sex twins in multivariate genetic model-fitting analyses (Neale, Røysamb, & Jacobson, 2006), our analyses were based on MZ and same-sex DZ twins only.

### Measures and Procedure

#### IQ

IQ at age 7 was assessed by telephone using a battery of four cognitive-ability measures: two verbal tests and two nonverbal tests. The verbal tests were the Vocabulary and Similarities subtests from the Wechsler Intelligence Scale for Children—3rd edition, UK (WISC-III-UK; Wechsler, 1992). The nonverbal tests were the Picture Completion subtest from the WISC-III-UK and the Conceptual Grouping task from the McCarthy Scales of Children's Abilities (McCarthy, 1972). Prior to the test sessions, test stimuli were mailed to each family in a sealed envelope, with separate instructions stating that the envelope should not be opened until the time of testing. Each child was tested directly (i.e., without involvement of a parent) and individually, and the same tester was used for the two members of a given twin pair. All testers were blind to zygosity. (For further details on the administration of the tests and the validity of the telephone testing, see Kovas, Haworth, Dale, & Plomin, 2007).

IQ at age 9 was assessed under parental supervision. Test booklets were mailed to the families in conjunction with an instruction booklet to guide parents. Each booklet included two verbal tests, the Vocabulary and General Knowledge tests, which were adapted from the Information subtest of the multiple-choice version of the WISC-III-UK (Kaplan, Fein, Kramer, Delis, & Morris, 1999). Each booklet also contained two nonverbal tests, the Puzzle test and the Shapes test, which were adapted from the Cognitive Abilities Test 3 (Smith, Fernandes, & Strand, 2001). Internal consistencies (Cronbach's alpha) were .63 for the Vocabulary test, .63 for the General Knowledge test, .91 for the Puzzle test, and .85 for the Shapes test. (For further details on the IQ measures used in TEDS, see Davis et al., 2008.)

### SPAs

Children's SPAs with respect to English, mathematics, and science were assessed at age 9 using the 9-item Perceived Abilities in School Scale (PASS; Spinath et al., 2006). The PASS items were formulated to correspond to activities listed in the United Kingdom National Curriculum for English, Mathematics and Science. Responses were made on a 5-point Likert scale, with 1 indicating that the respondents believed they were "not at all good" at the activity in question, and 5 indicating that they believed they were "very good" at that activity. Factor analysis of the PASS clearly revealed three factors that corresponded to SPAs in English, mathematics, and science (for details, see Spinath et al., 2006). All internal consistencies fell in the moderate range ( $\alpha = .62$  for SPAs in English,  $.82$  for SPAs in mathematics, and  $.65$  for SPAs in science).

### School Achievement

When the participants were ages 9 and 10, their school achievement in English, mathematics, and science was assessed using teachers' ratings based on United Kingdom National Curriculum criteria, which are uniform assessment guidelines followed by all teachers within the United Kingdom school system (Department for Education and Employment, 2000). The Qualifications and Curriculum Authority provides teachers with National Curriculum materials and grading keys for three academic categories each within mathematics (using and applying mathematics; numbers; shapes, space, and measures), English (speaking and listening, reading, writing), and science (scientific inquiry, life processes and living things, physical processes). The grading key stipulates five levels of achievement for each academic subject area, each level encompassing a broad range of skills. Final scores lie on a 5-point scale ranging from 1 (*far below average*) to 5 (*far above average*). Achievement ratings were obtained by mailed questionnaires, which were sent to the teachers directly. The National Curriculum assessments have been shown to be valid measures of academic achievement (Kovas et al., 2007).

## RESULTS

The measures of IQ, SPAs, and achievement were corrected for sex and age by means of regression (McGue & Bouchard, 1984), and standardized residual scores were created. These standardized scores were used in a latent-factor model of IQ, SPAs, and achievement.

### Phenotypic Analyses

Figure 1 presents the phenotypic correlations among the latent factors, as calculated by the structural-equation-modeling program Mx (Neale, Boker, Xie, & Maes, 2003). The phenotypic correlations were modest to moderate and similar for the cross-sectional (Fig. 1a) and longitudinal (Fig. 1b) data. Loadings of the specific measures on the latent factors were moderate to

high, which suggests that the latent factors adequately captured the variance that was common among the measures.

### Genetic Analyses

#### *The Twin Method*

Genetic analyses were based on standard assumptions of the twin method (Plomin et al., 2008). The twin method capitalizes on the fact that similarities between MZ and DZ twins raised together can be attributed to genetic effects or common environmental effects. Genetic relatedness is 1.0 for MZ twins, who are genetic clones, and  $.5$  for DZ twins, who on average share 50% of their segregating genes (just as any siblings do). As MZ and DZ twins both share 100% of their family-wide environment, shared environmental relatedness is 1.0. In contrast, differences between MZ and DZ twins can be attributed to nonshared environmental factors, which have a 0 correlation. On the basis of these facts, it was possible to partition the variance in IQ, SPAs, and achievement into genetic variance (called heritability,  $A$ ), shared environmental variance ( $C$ ), and nonshared environmental variance ( $E$ ).

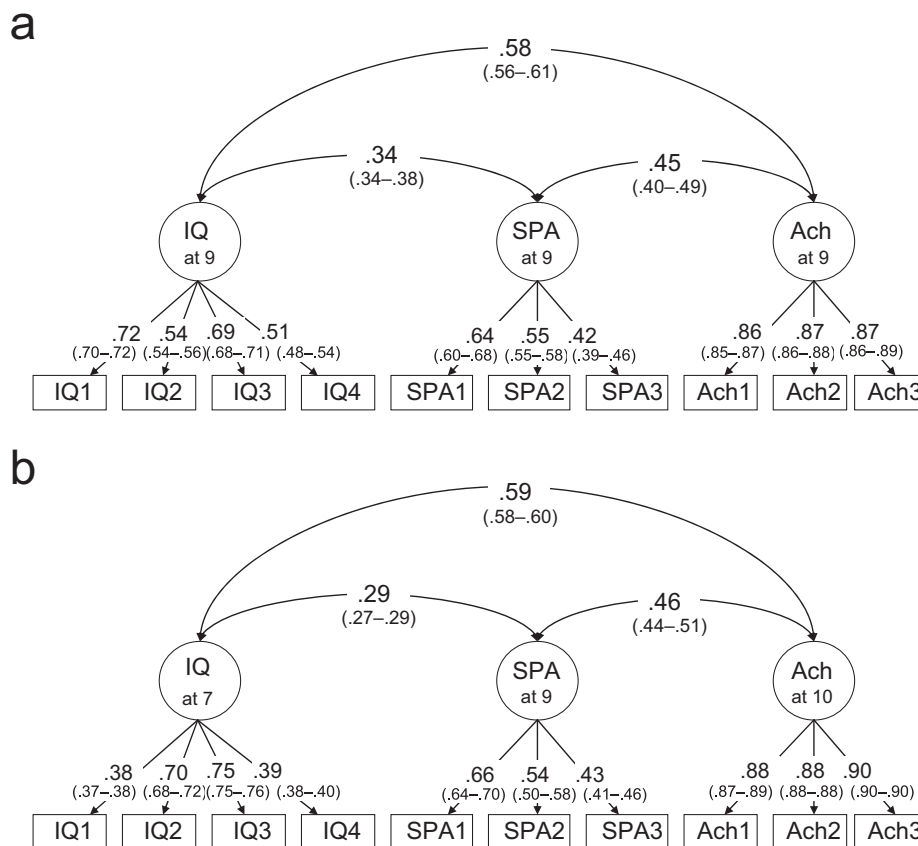
#### *Intraclass and Cross-Twin Cross-Trait Correlations*

To obtain an impression of the genetic and environmental contributions to IQ, SPAs, and achievement, we used SPSS Version 15.0 (SPSS, Inc., 2006) to calculate intraclass correlations (ICCs) for the specific measures of IQ, SPAs, and achievement (see Table 1). For both the cross-sectional and the longitudinal data, all MZ ICCs were greater than the DZ ICCs. This pattern of results suggests additive genetic influences on IQ, SPAs, and achievement. For IQ and achievement, all MZ ICCs were less than twice the DZ ICCs, which suggests that shared environmental influences also contribute to the variance in IQ and achievement. In addition, ICCs were lower for SPA measures than for measures of IQ or achievement, which suggests that SPAs are influenced by nonshared environment to a greater extent than IQ and achievement are.

Cross-twin cross-trait correlations (CTCTs), which indicate the correlation of scores of Twin 1 on Trait 1 with scores of Twin 2 (i.e., the co-twin) on Trait 2, were also calculated for the measures of IQ, SPAs, and achievement (results are available on request from the first author). Many MZ CTCTs were higher than DZ CTCTs, and many CTCTs were nonsignificant, which suggests that genetic as well as nonshared environmental factors are primarily responsible for the covariance among IQ, SPAs, and achievement.

#### *Model-Fitting Analyses*

We conducted twin model-fitting analyses, using Mx, to estimate the relative contributions of genes and environments to the latent variables of IQ, SPAs, and achievement and their interrelationships. The  $n$ s were larger for the longitudinal analyses than for the cross-sectional analyses because models were fitted



**Fig. 1.** Latent factor models showing correlations among general cognitive ability (IQ), self-perceived abilities (SPAs), and achievement (Ach), and factor loadings on the three latent factors. The two panels show results from (a) cross-sectional and (b) longitudinal analyses. Latent factors (IQ, SPA, Ach) are represented as circles; observed variables (specific measures of IQ, SPAs, and Ach) are represented as rectangles. Arrows from the three latent factors to the measures represent the factor loadings on the specific measures. The double-headed arrows represent the phenotypic correlations among IQ, SPA, and Ach. Numbers in parentheses are 95% confidence intervals. In the cross-sectional analyses, measures of IQ (age 9) were the Puzzle test (IQ1), the Vocabulary test (IQ2), the Shapes test (IQ3), and the General Knowledge test (IQ4). In the longitudinal analyses, measures of IQ (age 7) were the Conceptual Grouping test (IQ1), the Similarities test (IQ2), the Vocabulary test (IQ3), and the Picture Completion test (IQ4). SPA1 = SPAs in English; SPA2 = SPAs in mathematics; SPA3 = SPAs in science; Ach1 = achievement in English; Ach2 = achievement in mathematics; Ach3 = achievement in science.

to raw data, which allowed the inclusion of participants with incomplete data. The program Mx used full-information maximum-likelihood estimation to handle incomplete data.

We used three indices to evaluate model fit. First, we used the likelihood-ratio chi-square test of goodness of fit, which compares the likelihood statistic ( $-2LL$ ) of the data for each observation of the genetic model with that of the saturated model. The saturated model estimates the maximum number of parameters (variances, covariances, and mean vectors). The difference in  $-2LL$  between the saturated and the genetic model ( $\Delta-2LL$ ) is distributed as chi-square with the number of degrees of freedom equivalent to the difference in degrees of freedom between the models ( $\Delta df$ ). A nonsignificant chi-square value indicates that the model is a good fit. Our second fit index was Akaike's information criterion (AIC; Akaike, 1987). If the ge-

netic model has a lower AIC than the saturated model, it is a better fit. The third fit index was the root-mean-square error of approximation ( $RMSEA$ ), which adjusts for degrees of freedom and is relatively independent of sample size.  $RMSEA$  values less than or equal to .06 indicate a good fit to the data (Hu & Bentler, 1999).

*Are SPAs Really Primarily Shaped by Environmental Factors?*

To answer this question, we used common-pathway models, which also allowed us to estimate the genetic and environmental etiologies of IQ and achievement (see Fig. 2). In these models, three latent factors (IQ, SPAs, and Achievement) mediate the effects of three sets of common genetic ( $A$ ), shared environmental ( $C$ ), and nonshared environmental ( $E$ ) factors on the specific measures of IQ, SPAs, and achievement. In addition, 10

**TABLE 1**  
*Intraclass Correlations for the Measures of IQ, Self-Perceived Abilities, and Achievement*

Measure	Cross-sectional analysis				Longitudinal analysis			
	Monozygotic twins		Dizygotic twins		Monozygotic twins		Dizygotic twins	
	<i>ICC</i>	<i>n</i>	<i>ICC</i>	<i>n</i>	<i>ICC</i>	<i>n</i>	<i>ICC</i>	<i>n</i>
<b>IQ</b>								
Puzzle	.64 (.60–.67)	1,150	.49 (.44–.53)	1,000	—	—	—	—
Vocabulary (age 9)	.59 (.55–.62)	1,195	.47 (.42–.52)	1,044	—	—	—	—
Shapes	.61 (.58–.65)	1,184	.49 (.44–.54)	1,033	—	—	—	—
General Knowledge	.61 (.57–.64)	1,181	.53 (.49–.58)	1,029	—	—	—	—
Conceptual Grouping	—	—	—	—	.34 (.30–.38)	1,800	.28 (.24–.33)	1,639
Similarities	—	—	—	—	.52 (.49–.55)	1,788	.40 (.36–.44)	1,627
Vocabulary (age 7)	—	—	—	—	.62 (.59–.65)	1,792	.49 (.46–.53)	1,631
Picture Completion	—	—	—	—	.51 (.47–.54)	1,802	.44 (.40–.48)	1,635
<b>Self-perceived abilities</b>								
English	.37 (.32–.42)	1,163	.16 (.10–.22)	994	.38 (.33–.43)	1,182	.13 (.07–.19)	1,021
Mathematics	.39 (.34–.43)	1,170	.10 (.04–.16)	1,014	.39 (.34–.44)	1,181	.12 (.06–.18)	1,019
Science	.34 (.29–.39)	1,163	.23 (.17–.29)	1,008	.30 (.25–.35)	1,178	.21 (.15–.27)	1,021
<b>Achievement</b>								
English	.80 (.77–.82)	781	.46 (.40–.52)	709	.81 (.78–.83)	936	.55 (.50–.60)	822
Mathematics	.76 (.73–.79)	779	.45 (.40–.51)	707	.76 (.74–.79)	931	.48 (.43–.53)	815
Science	.78 (.75–.80)	771	.47 (.41–.53)	693	.76 (.73–.79)	923	.57 (.52–.61)	801

**Note.** Numbers in parentheses are 95% confidence intervals. The cross-sectional analysis included measures of IQ, self-perceived abilities, and achievement obtained at age 9. The longitudinal analysis included IQ at age 7, self-perceived abilities at age 9, and achievement at age 10. All intraclass correlation coefficients (ICCs) were significant at the .001 level. The number of twin pairs (*n*) is higher for the longitudinal than for the cross-sectional analyses because IQ scores were available for more children at age 7 than at age 9, and because achievement data were available for more children at age 10 than at age 9. All pairs in which at least 1 twin had missing data were excluded from the calculations reported in this table.

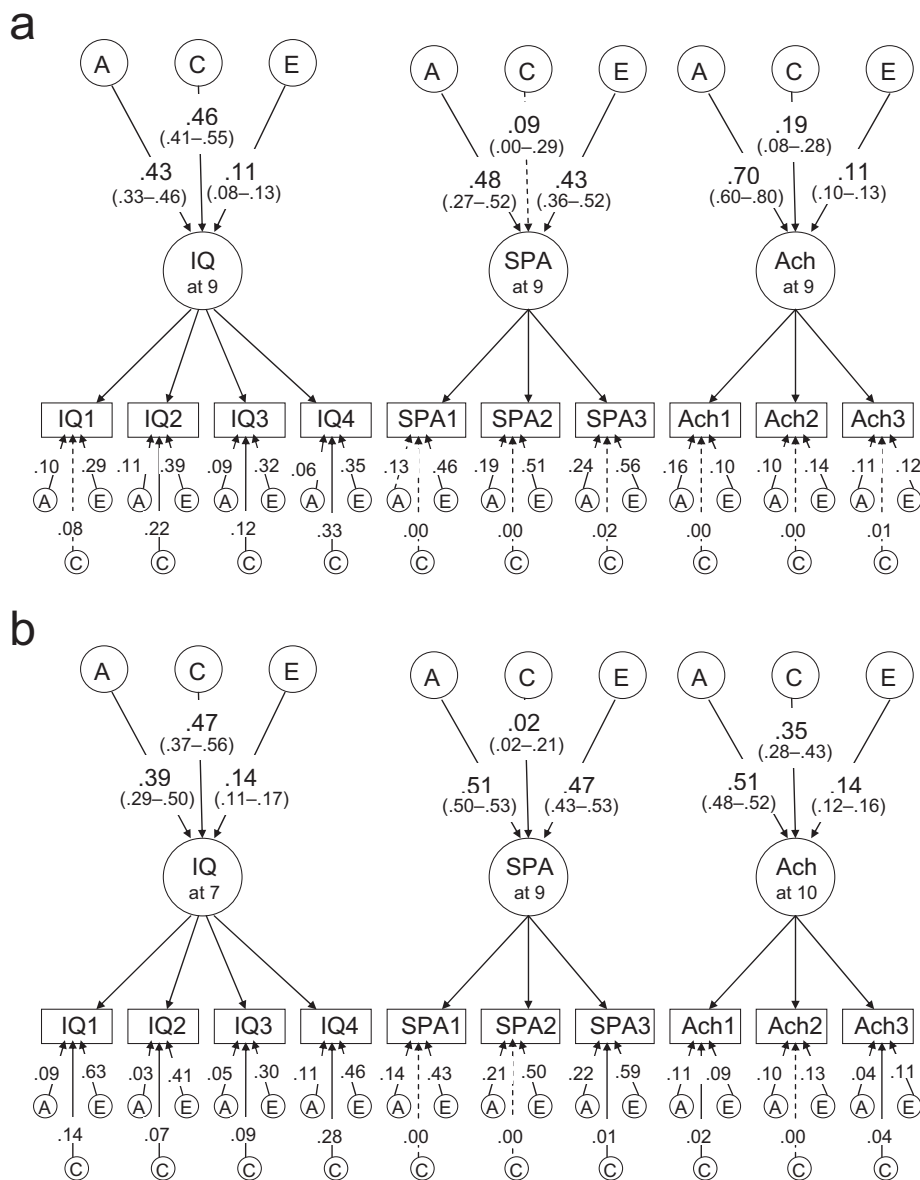
sets of specific *A*, *C*, and *E* factors are assumed to influence residual variance of the 10 specific measures of IQ, SPAs, and achievement that is not accounted for by the latent variables. The *AIC* and *RMSEA* criteria indicated that the cross-sectional model fitted the data well: *AIC* (saturated model) = 23,968.90, *AIC* (common-pathway model) = 16,509.33; *RMSEA* = .00. These tests also indicated that the longitudinal model fitted the data well: *AIC* (saturated model) = 37,416.73, *AIC* (common-pathway model) = 24,952.10; *RMSEA* = .00. The chi-square test statistics were significant in both cases,  $\chi^2(17445) = 42,349.562$ ,  $p < .001$ , and  $\chi^2(22865) = 58,194.63$ ,  $p < .001$ , respectively, but this statistic has often been referred to as being too conservative, particularly in large samples, for which even small differences between models can be significant (Bentler & Bonett, 1980).

The cross-sectional data revealed heritability estimates of .43, .48, and .70 for the latent variables of IQ, SPAs, and achievement, respectively (Fig. 2a). As in previous research (Kovas et al., 2007; Plomin et al., 2008), IQ and achievement showed modest to moderate *C* influences (.46 and .19 respectively), and modest *E* influences (.11 and .11 respectively). SPAs showed the opposite pattern, with negligible *C* influences (.09) and moderate *E* influences (.43). The high estimate for non-shared environmental influences on SPAs is not due to measurement error: In the common-pathway model, effects of *E* on the latent factors do not include the error term. Although almost

all genetic and shared environmental influences on the 10 measures acted through the three latent factors, there were some specific effects, in particular for SPAs in science (specific *A* = .24), the Vocabulary test (specific *C* = .22), and the General Knowledge test (specific *C* = .33). Moderate specific effects of nonshared environment were found (*E* estimates ranged from .10 to .56), although the common-pathway model subsumes measurement error at the level of these measure-specific *E* factors. The longitudinal data yielded similar results (see Fig. 2b).

#### *What Are the Etiologies of the Relations Among IQ, SPAs, and Achievement?*

We answered this question by calculating genetic ( $r_A$ ), shared environmental ( $r_C$ ), and nonshared environmental ( $r_E$ ) correlations. The genetic correlations indicate the extent to which the same genes affect IQ, SPAs, and achievement independently of their heritabilities and phenotypic correlations (Plomin & DeFries, 1979). Estimates were derived from a Cholesky decomposition analysis (see Fig. 3), which is mathematically equivalent to the common-pathways model (Loehlin, 1996). Table 2 summarizes the cross-sectional and longitudinal results shown in Figure 3. There was evidence for substantial genetic overlap among IQ, SPAs, and achievement, both when the variables were assessed contemporaneously at age 9 and when they were assessed longitudinally.



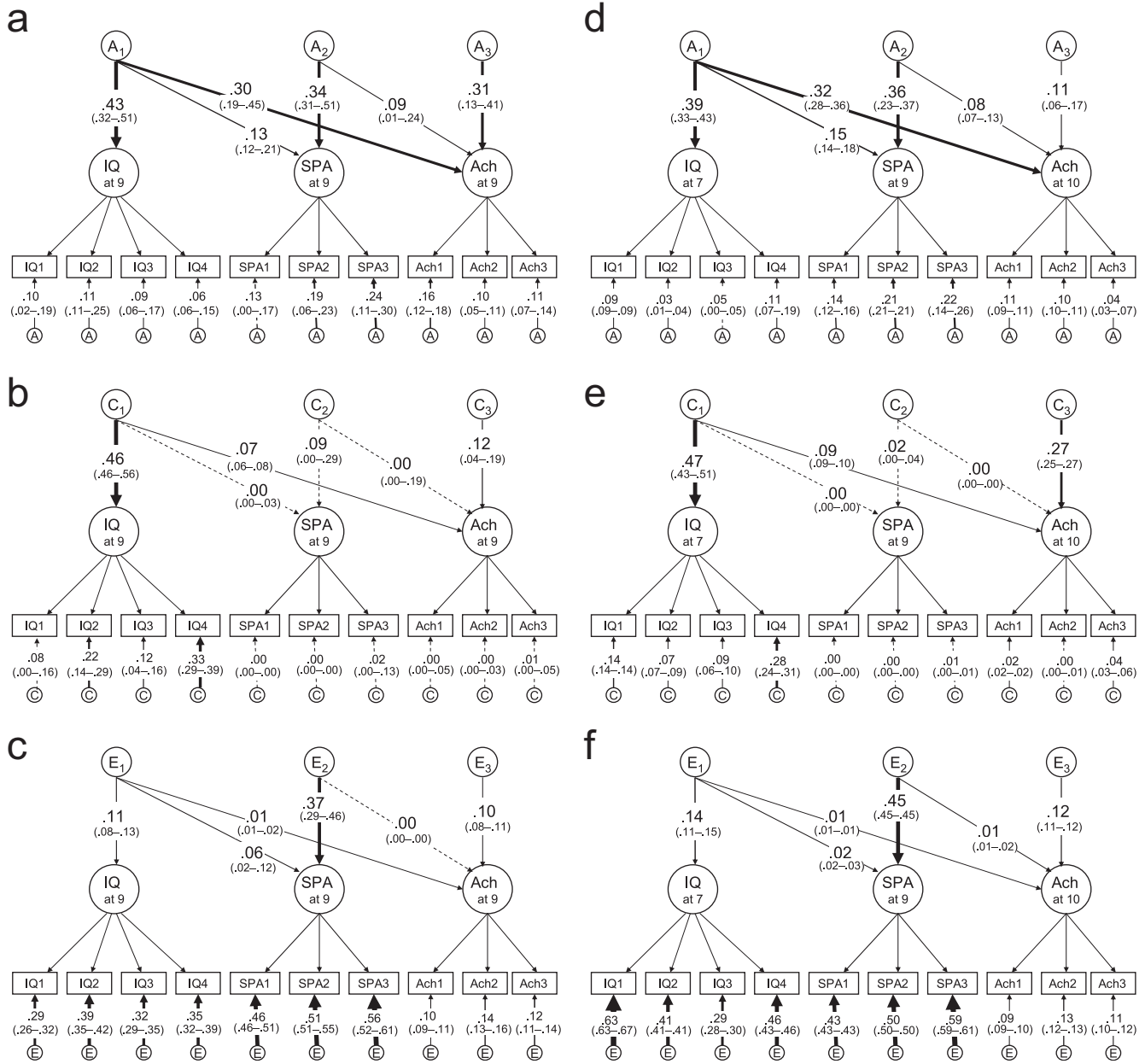
**Fig. 2.** Results of common-pathway model analyses of genetic (A), shared environmental (C), and non-shared environmental (E) influences on the latent factors of IQ, self-perceived abilities (SPAs), and achievement (Ach). The two panels show results from (a) cross-sectional and (b) longitudinal analyses. The upper section of each diagram shows path estimates representing common A, C, and E influences on each latent factor (95% confidence intervals are given in parentheses). The bottom section of each diagram shows path estimates representing specific A, C, and E influences on the 10 specific measures of IQ, SPA, and Ach (see Fig. 1 for an explanation of the abbreviations); these estimates indicate the residual variance in the specific measures (95% confidence intervals are given in Fig. 3). All path estimates are standardized and squared to refer to the percentage of variance explained.

*What Are the Roles of Nature and Nurture in the Association Between School Achievement and SPAs Independent of IQ?*

We answered this question using the Cholesky decomposition model presented in Figure 3. The Cholesky decomposition partitioned genetic influences on IQ, SPAs, and achievement into variance that could be attributed to (a) a general genetic factor ( $A_1$ ) that influences IQ at age 7, SPAs at age 9, and achievement at age 10; (b) a genetic factor that influences

SPAs at age 9 and achievement at age 10 but that is independent of IQ at age 7 ( $A_2$ ); and (c) a genetic factor specific to achievement at age 10 and independent of IQ at age 7 and SPAs at age 9 ( $A_3$ ). The variance due to shared ( $C_1, C_2, C_3$ ) and nonshared ( $E_1, E_2, E_3$ ) environmental effects was partitioned in the same manner.

For the cross-sectional data at age 9, the Cholesky analyses revealed that the same genetic factors ( $A_1$ ) that explained 43% of



**Fig. 3.** Results from the Cholesky decomposition of genetic (*A*), shared environmental (*C*), and nonshared environmental (*E*) covariance among IQ, self-perceived abilities (SPAs), and achievement (Ach). Results from (a–c) cross-sectional and (d–f) longitudinal analyses are shown. Also shown are estimates of the residual variance in the specific measures (from Fig. 2). All path estimates are standardized and squared to refer to the percentage of variance explained. The thickness of each arrow indicates the strength of the corresponding path. Insignificant paths are represented as dashed lines. Numbers in parentheses are 95% confidence intervals. See Figure 1 for an explanation of the abbreviations of the specific measures.

the variance in IQ also accounted for 13% of the variance in SPAs and 30% of the variance in achievement (see Fig. 3a). Genetic factors associated with SPAs (*A*<sub>2</sub>) accounted for a significant proportion (9%) of the variance in achievement independent of IQ. In contrast, shared and nonshared environmental influences were largely measure-specific (see Figs. 3b

and 3c). Environmental factors associated with SPAs (*C*<sub>2</sub> and *E*<sub>2</sub>) did not account for a significant proportion of the variance in achievement independent of IQ.

Results from the analysis of the longitudinal data (Figs. 3d, 3e, and 3f) were highly similar. Most notably, the path from *A*<sub>2</sub> to achievement remained significant (.08).

**TABLE 2**  
*Genetic, Shared Environmental, and Nonshared Environmental Correlations*

Correlation	IQ at 9–SPAs at 9	IQ at 9–Ach at 9	SPAs at 9–Ach at 9	IQ at 7–SPAs at 9	IQ at 7–Ach at 10	SPAs at 9–Ach at 10
Genetic ( $r_A$ )	.53 (.29–.79)	.66 (.55–.77)	.65 (.47–.89)	.53 (.53–.55)	.59 (.48–.63)	.76 (.64–.96)
Shared environmental ( $r_C$ )	.09 (.00–.30)	.62 (.58–.83)	.06 (.00–.77)	.00 (.00–.30)	.49 (.45–.51)	.00 (.00–.85)
Nonshared environmental ( $r_E$ )	.38 (.34–.52)	.29 (.17–.29)	.30 (.21–.40)	.19 (.04–.19)	.29 (.29–.38)	.30 (.30–.33)

**Note.** Numbers in parentheses are 95% confidence intervals (CIs); CIs that include 0 indicate nonsignificant correlations. The cross-sectional analyses included 1,217 pairs of monozygotic twins and 1,070 pairs of dizygotic twins; the longitudinal analyses included 1,966 pairs of monozygotic twins and 1,819 pairs of dizygotic twins. Ach = achievement; SPA = self-perceived ability.

## DISCUSSION

We conclude that, contrary to extant theories, SPAs are substantially influenced by genetic factors, and they are influenced by genetic factors at least as much as IQ is. We found evidence that the phenotypic associations among IQ, SPAs, and achievement reported in previous studies (Chamorro-Premuzic & Furnham, 2005; Furnham & Chamorro-Premuzic, 2004; Spinath et al., 2006) can be attributed primarily to genetic factors. Moreover, there was evidence for substantial genetic overlap among IQ, SPAs, and achievement (overlap greater than 50%). That is, results indicated that a common set of genes affected all three constructs, not only when they were assessed contemporaneously (at age 9), but also when each construct was assessed at a different age (IQ at age 7, SPAs at age 9, and achievement at age 10). These results provide evidence for temporally stable genetic influences on the three constructs. It is important to note that genetic factors associated with SPAs accounted for a significant, albeit small, proportion of the variance in achievement independent of IQ, but there was little evidence for an environmental link between SPAs and achievement independent of IQ. Again, this was the case not only when the variables were measured contemporaneously, but also when each variable was assessed at a different age, which suggests that the prediction of future achievement by previous SPAs is largely mediated genetically, and not at all mediated by shared environment.

Although the findings of substantial heritability for SPAs and genetic covariance between SPAs and achievement independent of IQ are interesting, the environmental findings are equally important. A first point that we hope no longer needs highlighting is that heritability does not imply immutability. Finding genetic influence on SPAs does not imply that SPAs are impervious to environmental change. Moreover, although about half the variance in SPAs is due to genetic factors, the rest is due to environmental factors. In contrast to twin analyses, the model-fitting analysis focused on SPAs assessed as a latent variable indexed by the commonality among three SPA measures and thus excluded most error of measurement from its estimates of environmental influence. The important finding about environmental influences is that the salient environmental factors in-

fluencing SPAs are nonshared experiences that do not contribute to similarity among children growing up in the same family.

### Strengths and Limitations of This Study

One strength of this study is its large, representative sample of twins, which provided powerful estimates of genetic and environmental sources of variance and covariance. Another strength is its combined use of cross-sectional and longitudinal analyses, which enabled us to examine the temporal stability of the etiology of the relations among IQ, SPAs, and achievement and to add predictive validity to our findings. A third strength is our multimethod design, which used teachers' ratings, self-ratings, and objective test scores. General limitations of the twin method (Plomin et al., 2008) applied, although the validity of the twin method has been documented (Boomsma, Busjahn, & Peltonen, 2002; Martin, Boomsma, & Machin, 1997). One limitation specific to our study is the measures used to assess IQ, SPAs, and achievement; in particular, the loadings of some of the measures on the IQ and SPA factors were only moderate.

### Directions for Future Research

One direction for future research is to use genetically sensitive designs to identify other factors, beyond SPAs and IQ, that explain genetic variance in achievement. Although nearly 80% of the genetic variance in achievement can be explained by SPAs and IQ (Fig. 3d), 20% of the genetic variance remains to be explained, perhaps by other aspects of personality, attitudes, and motivation.

Another direction for research is to investigate possible reciprocal influences. We found that higher SPAs are linked to higher subsequent achievement independent of IQ; nonetheless, even independently of IQ, higher achievement may also lead to higher subsequent SPAs. Such reciprocal influences have been reported in previous research (e.g., Marsh, Byrne, & Yeung, 1999). Future research should therefore not only control for previous IQ, but also take into account the role that previous achievement may play in the etiology of the relations among IQ, SPAs, and achievement. It would also be interesting to investigate whether there are direct phenotypic effects of SPAs on achievement that, in addition to or instead of genetic effects, may account for our findings. It is clear that the origins of these

reciprocal relations merit further investigation in a full multivariate, longitudinal design in which all measures are obtained at all ages.

Finally, genetic research on SPAs (or on any other complex trait) will benefit from understanding the mechanisms by which genetic variation leads to phenotypic variation. The complex pathways between genes and behavior include all levels of analysis (e.g., the brain), but we are especially interested in top-down analyses that begin with behavior. We suggest that personality may contribute to genetic influence on SPAs independent of IQ (Marsh, Trautwein, Lüdtke, Köller, & Baumert, 2006).

### Implications

One implication of our findings concerns molecular genetics research, much of which is aimed at identifying the many “genes” of small effect that are responsible for genetic influence on complex traits and common disorders. Although it is still difficult to reliably identify these genes, the pace of discovery in molecular genetics is fast (Plomin & Davis, 2009), and we hope that the present behavioral genetic findings will eventually translate into molecular genetic findings. Future studies should be able to identify “SPA genes” (i.e., DNA polymorphisms that account for the heritability of SPAs). Further, if such genes were to be found, we would expect there to be a greater than 50% chance that they would also be associated with IQ. However, our results also indicate that it may eventually be possible to identify SPA genes that predict school achievement independently of “IQ genes.”

**Acknowledgments**—This study was supported by the United Kingdom Medical Research Council (G050079) and by the U.S. National Institute of Child Health and Human Development (HD44454 and HD46167). We are grateful to the Twins Early Development Study families for their participation and support for more than a decade.

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(RECEIVED 3/17/08; REVISION ACCEPTED 11/9/08)