

Supporting Information

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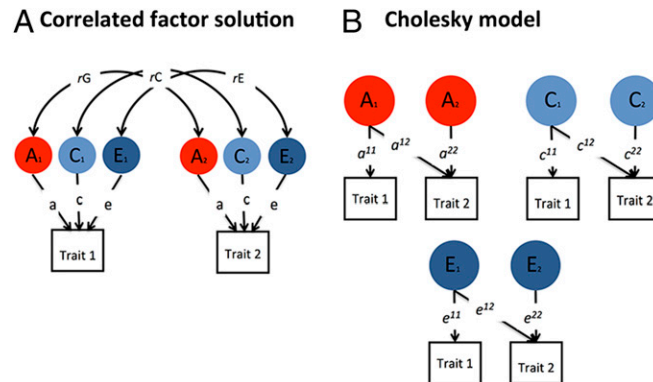


Fig. S1. Bivariate model of additive genetic (A), shared environmental (C), and nonshared environmental (E) contributions to the correlations between traits. Two algebraically equivalent representations of the bivariate model are shown: (A) correlated factor solution of genetic correlation (r_G), shared environmental correlation (r_C), and nonshared environmental correlation (r_E) and (B) Cholesky decomposition.

Table S1. Descriptive statistics

	<i>N</i>	Whole sample	Male	Female	MZm	DZm	MZf	DZf	DZos	Sex	Zygoty	Sex × zygoty	R^2
GCSE core subjects mean grade	12,103	8.91 (1.23)	8.86 (1.23)	8.96 (1.21)	8.83 (1.23)	8.90 (1.21)	8.95 (1.16)	8.95 (1.24)	8.93 (1.24)	20.26*	1.91	0.13	<0.01

GCSE core subjects mean grade have a maximum of 11 and a minimum of 4, representing grades A* to G. n = sample size after exclusions (individuals). ANOVA performed (one randomly selected twin per pair) to test main and interaction effects of sex and zygoty: results = F statistic. R^2 = proportion of variance explained by sex, zygoty, and their interaction. DZ, dizygotic; f, female; m, male; MZ, monozygotic; os, opposite sex. * $P < 0.01$.

Table S2. Twin correlations for all nine predictors and GCSE and cross-correlations for all nine predictors with GCSE

	Twin correlations within trait		Cross-correlations with GCSE	
	MZ	DZ	MZ	DZ
GCSE	0.85 (0.83–0.87) $n = 2115$	0.54 (0.51–0.56) $n = 3794$		
Intelligence	0.60 (0.55–0.66) $n = 760$	0.32 (0.27–0.38) $n = 1182$	0.53 (0.47–0.59) $n = 752$	0.29 (0.23–0.33) $n = 1209$
Self-efficacy	0.62 (0.54–0.64) $n = 830$	0.40 (0.37–0.47) $n = 1326$	0.40 (0.33–0.45) $n = 807$	0.21 (0.16–0.26) $n = 1316$
School environment	0.45 (0.39–0.51) $n = 826$	0.29 (0.24–0.34) $n = 1322$	0.32 (0.25–0.38) $n = 804$	0.16 (0.10–0.21) $n = 1314$
Home environment	0.54 (0.50–0.62) $n = 786$	0.33 (0.28–0.39) $n = 1233$	0.19 (0.11–0.25) $n = 766$	0.12 (0.07–0.17) $n = 1244$
Personality	0.64 (0.42–0.55) $n = 764$	0.21 (0.15–0.26) $n = 1188$	0.25 (0.18–0.32) $n = 752$	0.07 (0.01–0.16) $n = 1203$
Well-being	0.54 (0.48–0.62) $n = 704$	0.35 (0.29–0.40) $n = 1106$	0.25 (0.18–0.34) $n = 679$	0.14 (0.08–0.19) $n = 1091$
Parent-reported behavior problems	0.87 (0.87–0.91) $n = 1661$	0.63 (0.60–0.65) $n = 1963$	0.28 (0.23–0.33) $n = 1460$	0.16 (0.12–0.19) $n = 2568$
Child-reported behavior problems	0.48 (0.44–0.53) $n = 1639$	0.22 (0.18–0.25) $n = 1923$	0.19 (0.15–0.25) $n = 1448$	0.10 (0.06–0.14) $n = 2547$
Health	0.61 (0.57–0.65) $n = 1237$	0.36 (0.33–0.40) $n = 2286$	0.10 (0.04–0.16) $n = 1103$	0.06 (0.01–0.10) $n = 1992$

DZ, dizygotic; MZ, monozygotic.

Table S3. Model fitting estimates (and 95% CIs) for additive genetic (A), shared environment (C), and nonshared environment (E) components of variance for GCSE and nine predictors

	Variance components (95% CIs)		
	A	C	E
GCSE	0.62 (0.58–0.67)	0.26 (0.21–0.30)	0.12 (0.11–0.13)
Intelligence	0.58 (0.46–0.63)	0.04 (0.01–0.13)	0.39 (0.35–0.43)
Self-efficacy	0.40 (0.30–0.52)	0.21 (0.12–0.30)	0.38 (0.34–0.42)
School environment	0.45 (0.33–0.53)	0.11 (0.05–0.20)	0.44 (0.40–0.49)
Home environment	0.46 (0.33–0.55)	0.09 (0.03–0.20)	0.44 (0.40–0.49)
Personality	0.46 (0.36–0.51)	0.00 (0.00–0.08)	0.53 (0.49–0.58)
Well-being	0.35 (0.22–0.49)	0.17 (0.06–0.28)	0.47 (0.43–0.52)
Parent-reported behavior problems	0.53 (0.49–0.57)	0.36 (0.32–0.40)	0.11 (0.10–0.12)
Child-reported behavior problems	0.48 (0.42–0.51)	0.00 (0.00–0.04)	0.52 (0.49–0.56)
Health	0.48 (0.39–0.57)	0.13 (0.11–0.20)	0.39 (0.36–0.42)

Table S4. Phenotypic correlation matrix between GCSE and nine predictors (with 95% CIs)

	GCSE	Intelligence	Self-efficacy	School environment	Home environment	Personality	Well-being	Parent-reported behavior problems	Child-reported behavior problems	Health
GCSE	1.00									
Intelligence	0.58 (0.56–0.60)	1.00								
Self-efficacy	0.49 (0.46–0.51)	0.35 (0.33–0.38)	1.00							
School environment	0.34 (0.32–0.37)	0.24 (0.21–0.27)	0.46 (0.43–0.48)	1.00						
Home environment	0.17 (0.14–0.20)	0.13 (0.10–0.16)	0.30 (0.28–0.33)	0.52 (0.50–0.55)	1.00					
Personality	0.28 (0.25–0.31)	0.18 (0.15–0.21)	0.42 (0.39–0.45)	0.39 (0.37–0.42)	0.38 (0.36–0.41)	1.00				
Well-being	0.26 (0.23–0.28)	0.17 (0.14–0.20)	0.41 (0.38–0.44)	0.54 (0.52–0.56)	0.61 (0.59–0.63)	0.51 (0.49–0.54)	1.00			
Parent-reported behavior problems	0.33 (0.31–0.35)	0.26 (0.22–0.29)	0.26 (0.22–0.29)	0.29 (0.26–0.33)	0.31 (0.27–0.35)	0.22 (0.18–0.26)	0.38 (0.35–0.41)	1.00		
Child-reported behavior problems	0.25 (0.23–0.27)	0.18 (0.15–0.21)	0.36 (0.33–0.38)	0.39 (0.37–0.42)	0.42 (0.39–0.45)	0.30 (0.27–0.33)	0.54 (0.52–0.56)	0.38 (0.36–0.40)	1.00	
Health	0.08 (0.05–0.12)	0.07 (0.03–0.11)	0.14 (0.10–0.18)	0.23 (0.20–0.27)	0.26 (0.23–0.30)	0.08 (0.04–0.12)	0.32 (0.28–0.35)	0.17 (0.15–0.20)	0.42 (0.40–0.44)	1.00

Table S5. Bivariate model-fitting estimates (and CIs)

	Proportion of phenotypic correlation explained by A, C, and E (95% CIs)		
	A	C	E
Intelligence-GCSE	0.75 (0.63–0.86)	0.15 (0.06–0.26)	0.10 (0.07–0.13)
Self-efficacy-GCSE	0.64 (0.51–0.77)	0.21 (0.09–0.33)	0.15 (0.11–0.18)
School environment-GCSE	0.59 (0.37–0.80)	0.31 (0.12–0.50)	0.10 (0.04–0.16)
Home environment-GCSE	0.08 (-0.35–0.50)	0.81 (0.44–1.18)	0.10 (-0.01–0.26)
Personality-GCSE	0.92 (0.66–1.17)	(-0.05) (-0.27–0.17)	0.14 (0.06–0.21)
Well-being-GCSE	0.53 (0.22–0.85)	0.34 (0.06–0.61)	0.13 (0.04–0.21)
Parent-reported behavior problems-GCSE	0.81 (0.70–0.93)	0.11(-4.25E-03–0.22)	0.07 (0.06–0.10)
Child-reported behavior problems-GCSE	0.89 (0.70–1.08)	(-0.01) (-0.18–0.15)	0.12 (0.12–0.12)
Health-GCSE	0.71 (0.55–1.43)	0.28 (-0.37–0.85)	0.01 (-0.17–0.19)

Bivariate estimates (and 95% CIs) for additive genetic (A), shared environmental (C), and nonshared environmental (E) contributions to the correlations between GCSE and nine predictors.

Table S6. Bivariate model-fitting results of the extent to which the heritability of GCSE can be explained by the nine predictors (95% CIs)

	Heritability of GCSE	
	Shared	Independent
Intelligence	0.31 (0.22–0.37)	0.31 (0.25–0.41)
Self-efficacy	0.23 (0.15–0.33)	0.39 (0.15–0.32)
School environment	0.12 (0.05–0.25)	0.50 (0.37–0.59)
Home environment	0.00 (6E-18–0.02)	0.63 (6E-01–0.02)
Personality	0.13 (7E-02–0.22)	0.50 (4E-01–0.58)
Well-being	0.05 (0.01–0.12)	0.58 (0.50–0.65)
Parent-reported behavior problems	0.13 (0.13–0.16)	0.50 (0.44–0.54)
Child-reported behavior problems	1E-01 (6E-02–0.15)	5E-01 (6E-02–0.15)
Health	0.01 (5E-05–0.03)	0.62 (6E-01–0.67)

The graph displays the decomposition of heritability of GCSE into shared variance accounted for by genetic influences on the respective domain and independent variance, which is residual (i.e., unaccounted by the respective domain). As an example, for intelligence, the genetic loading of 0.31 on GCSE, estimated for the squared path a^{27} (Fig. 4), indicates that genetic influences on intelligence accounted for ~50% of the heritability of GCSE.

Table S7. Phenotypic multivariate Cholesky and genetic multivariate Cholesky model-fitting estimates (and 95% CIs) for all nine predictors

Predictors of GCSE	Phenotypic variance of GCSE		Heritability of GCSE	
	Shared	Independent	Shared	Independent
Intelligence	0.34 (0.30–0.38)	0.66 (0.63–0.70)	0.31 (0.25–0.41)	0.31 (0.22–0.37)
Eight noncognitive predictors	0.28	0.72 (0.69–0.76)	0.30	0.31 (3E-16–0.38)
Eight noncognitive predictors and intelligence	0.45	0.55 (0.52–0.58)	0.45	0.15 (6E-16–0.24)

Decomposition of the phenotypic variance and of heritability of GCSE into shared variance accounted for by phenotypic or genetic influences on the respective predictors and independent variance, which is residual (i.e., unaccounted by the respective predictors). As an example, the eight noncognitive predictors alone account for 28% (0.28/1.0) of the phenotypic variance in GCSE and 49% (0.30/0.61) of the heritability of GCSE, leaving 72% (0.72/1.0) phenotypic and 51% (0.31/0.61) residual GCSE heritability. For the models with multiple predictors (i.e., eight noncognitive predictors and intelligence), the shared variance represents the sum of the GCSE variance/heritability explained by all predictors together. Hence, CIs cannot be computed for these summed estimates, but only for the independent GCSE variance/heritability or single predictors (i.e., intelligence).

Table S9. Shared environmental (*r*_C) correlation matrices between the GCSE composite and the nine predictor composites (with 95% CIs)

	Shared environment correlations (<i>r</i> _C)									
	GCSE	Intelligence	Self-efficacy	School environment	Home environment	Personality	Well-being	Parent-reported behavior problems	Child-reported behavior problems	Health
GCSE	1.00									
Intelligence	0.65 (0.40–0.87)	1.00								
Self-efficacy	0.47 (0.28–0.65)	(–0.09) (–0.48–0.27)	1.00							
School environment	0.62 (0.32–0.98)	0.28 (–0.27–0.80)	0.55 (0.19–0.89)	1.00						
Home environment	0.66 (0.34–0.92)	0.49 (–0.04–0.86)	0.66 (0.31–0.90)	0.85 (0.39–1.00)	1.00					
Personality	(–0.03) (0.94–0.86)	0.09 (–0.97–0.91)	0.48 (–0.76–0.99)	0.48 (–0.81–0.99)	0.67 (–0.58–1.00)	1.00				
Well-being	0.46 (0.18–0.72)	0.13 (–0.31–0.63)	0.40 (0.05–0.67)	0.81 (0.39–0.98)	0.75 (0.40–0.95)	0.49 (–0.56–1.00)	1.00			
Parent-reported behavior problems	0.16 (0.04–0.27)	0.25 (–0.05–0.54)	0.09 (–0.13–0.28)	0.41 (0.12–0.76)	0.57 (0.28–0.82)	0.61 (–0.19–1.00)	0.79 (0.56–0.96)	1.00		
Child-reported behavior problems	0.19 (–0.18–0.54)	0.12 (–0.45–0.68)	0.52 (0.01–0.81)	0.63 (–0.04–0.95)	0.83 (0.42–0.98)	0.81 (–0.26–1.00)	0.80 (0.41–0.98)	0.80 (0.52–0.99)	1.00	
Health	0.17 (–0.09–0.45)	0.32 (–0.26–0.81)	0.45 (0.01–0.86)	0.43 (–0.28–0.91)	0.74 (0.13–0.98)	0.65 (–0.57–1.00)	0.33 (–0.16–0.76)	0.38 (0.20–0.62)	0.77 (0.25–0.98)	1.00

Derived from the standardized multivariate Cholesky (correlated factors solution).

Table S10. Nonshared environmental (rE) correlation matrices between the GCSE composite and the nine predictor composites (with 95% CIs)

	Nonshared environmental correlations (rE)									
	GCSE	Intelligence	Self-efficacy	School environment	Home environment	Personality	Well-being	Parent-reported behavior problems	Child-reported behavior problems	Health
GCSE	1.00									
Intelligence	0.24 (0.17–0.31)	1.00								
Self-efficacy	0.31 (0.24–0.37)	0.21 (0.15–0.28)	1.00							
School environment	0.13 (0.07–0.20)	0.09 (0.03–0.16)	0.31 (0.25–0.36)	1.00						
Home environment	0.05 (–0.02–0.13)	0.10 (0.03–0.17)	0.23 (0.17–0.30)	0.45 (0.40–0.50)	1.00					
Personality	0.14 (0.06–0.21)	0.08 (0.20–0.15)	0.33 (0.27–0.39)	0.24 (0.18–0.30)	0.23 (0.16–0.29)	1.00				
Well-being	0.10 (0.03–0.17)	0.12 (0.05–0.18)	0.36 (0.30–0.42)	0.39 (0.33–0.44)	0.43 (0.37–0.48)	0.41 (0.35–0.46)	1.00			
Parent-reported behavior problems	0.20 (0.15–0.25)	0.12 (0.04–0.20)	0.20 (0.12–0.28)	0.09 (0.02–0.17)	0.13 (0.05–0.22)	0.09 (0.01–0.17)	0.19 (0.11–0.26)	1.00		
Child-reported behavior problems	0.12 (0.06–0.17)	0.13 (0.06–0.20)	0.16 (0.09–0.22)	0.15 (0.09–0.22)	0.26 (0.19–0.32)	0.15 (0.06–0.24)	0.35 (0.30–0.41)	0.27 (0.22–0.31)	1.00	
Health	0.00 (–0.06–0.06)	(–0.04) (–0.13–0.05)	0.02 (–0.08–0.11)	0.14 (0.05–0.23)	0.15 (0.06–0.24)	(–0.02) (–0.11–0.07)	0.25 (0.17–0.33)	0.07 (0.02–0.12)	0.27 (0.22–0.31)	1.00

Derived from the standardized multivariate Cholesky (correlated factors solution).