Supplemental Materials

Sex and Age Effects

Although the EF latent variables were not consistently related to sex or within-wave age of assessment (see Friedman et al., 2016), the ordinal MDDsx variable was somewhat related to both. Specifically, males had lower levels of lifetime depressive symptoms at age 12 (standardized $\beta = -.18$, $p = .026$), and lower levels of past-year depressive symptoms at age 17 (standardized $\beta = -.25$, $p < .001$), but not significantly lower levels at age 23 (standardized $\beta = -.08$, $p = .114$). Within-wave age differences were not associated with MDDsx at age 12 (standardized $\beta = .04$, $p = .665$), but were associated with MDDsx at ages 17 (standardized $\beta = .17$, $p = .002$) and 23 (standardized $\beta = .11$, $p = .030$). CES-D scores were not related to sex (all standardized βs $> -.07$, ps $> .118$) nor within-wave age (all standardized βs $< .07$, ps $> .097$).

Heritability of EFs and Depressive Symptoms at Each Age

ACE models for the EF factors were presented by Friedman et al. (2016). Our results did not differ when examining the age- and sex-regressed residuals and dropping task-specific C components. Table 2 in the main text lists the A, C, and E estimates for each latent variable taken from separate analyses of each age. At age 17, $\chi^2(330) = 389.79$, $p = .013$, CFI=.961, RMSEA=.030, genetic influences explained 96% of the variance in Common EF, $\Delta\chi^2(1) = 32.84$, $p < .001$, 100% of the variance in Updating-Specific, $\Delta\chi^2(1) = 15.74$, $p < .001$, and 78% of the variance in Shifting-Specific, $\Delta\chi^2(1) = 8.78$, $p = .003$. Nonshared environmental influences were significant for Shifting-Specific (22%), $\Delta\chi^2(1) = 6.62$, $p = .010$, but not for Common EF (4%), $\Delta\chi^2(1) = 1.12$, $p = .291$, and shared environmental influences were estimated at zero for all three latent variables. At age 23, $\chi^2(329) = 415.42$, $p < .001$, CFI=.951, RMSEA=.037, genetic influences explained 80% of the variance in Common EF, $\Delta\chi^2(1) = 19.70$, $p < .001$, 99% of the

variance in Updating-Specific, $\Delta\chi^2(1)=21.22$, $p<.001$, and 80% of the variance in Shifting-Specific, $\Delta\chi^2(1)=11.92$, $p<.001$. At this age, nonshared environmental influences became significant for Common EF (16%), $\Delta\chi^2(1)=21.93$, $p<.001$, and remained significant for Shifting-Specific (21%), $\Delta\chi^2(1)=9.69$, $p=.002$. Nonshared environmental influences were not significant for Updating-Specific (1%), $\Delta\chi^2(1)=0.05$, $p=.825$, and shared environmental influences were estimated at zero for the Updating- and Shifting-Specific factors, and at 3% for Common EF, $\Delta\chi^2(1)=0.03$, $p=.856$.

ACE models for the CES-D latent variables are presented in supplemental Table A5. At age 12, genetic influences explained 18% of the variance, $\Delta\chi^2(1)=0.68$, $p=.410$; shared environmental influences explained 29%, $\Delta\chi^2(1)=2.39$, $p=.123$, and nonshared environmental influences explained 53%, $\Delta\chi^2(1)=166.99$, $p<.001$. Although neither the A nor C components were significant with single-df tests, dropping both resulted in a significant decrement in fit, $\Delta\chi^2(2)=47.42$, $p<.001$, Heritability was highest at age 17: Genetic influences explained 61% of the variance, $\Delta\chi^2(1)=22.32$, $p<.001$, and nonshared environmental influences explained the remaining 39%, $\Delta\chi^2(1)=165.70$, $p<.001$. At age 23, genetic influences explained 39% of the variance, $\Delta\chi^2(1)=5.97$, $p=.015$, and nonshared environmental influences explained the remaining 61%, $\Delta\chi^2(1)=438.90$, $p<.001$. Note that these estimates of nonshared environmental influences do not reflect random measurement error, which is removed from the CES-D latent variables, but can reflect systematic method variance in addition to true environmental influences in depressive symptoms.

We do not present ACE models for the MDDsx variables, because the low frequencies of affected individuals for these ordinal measures led to reduced power (Neale, Eaves, & Kendler, 1994) and unreliable estimates, and at age 12, an inestimable model due to missing cells in the

bivariate table. Although the frequencies were sufficient for the phenotypic analyses, they were problematic when the sample was split into twin1 and twin2 for MZ and DZ groups. For this reason, and also because there were few phenotypic associations of EFs with the MDDsx variables, we focused our multivariate genetic analyses on the CES-D latent variables.

References

Friedman, N. P., Miyake, A., Altamirano, L. J., Corley, R. P., Young, S. E., Rhea, S. A., & Hewitt, J. K. (2016). Stability and change in executive function abilities from late adolescence to early adulthood: A longitudinal twin study. *Developmental Psychology*, *52*(2), 326–340. http://doi.org/10.1037/dev0000075

Neale, M. C., Eaves, L. J., & Kendler, K. S. (1994). The power of the classical twin study to resolve variation in threshold traits. *Behavior Genetics*, *24*(3), 239–258. http://doi.org/10.1007/BF01067191

Table S1

Descriptive Statistics for Continuous Measures

Measure	*N*	Mean	SD	Min	Max	Skewness	Kurtosis	Reliability
Age 17 EF								
Antisaccade[a]	779	1.04	0.20	0.47	1.57	–0.12	–0.26	.89[b]
Stop-signal	741	282 ms	63	151	489	1.13	1.51	.75[b]
Stroop	759	214 ms	90	0	488	0.59	0.19	.91[b]
Keep track[a]	774	0.94	0.18	0.38	1.49	0.31	0.56	.65[c]
Letter memory[a]	785	1.09	0.25	0.38	1.57	0.29	–0.20	.62[c]
Spatial 2-back[a]	777	1.17	0.17	0.65	1.57	–0.93	1.65	.90[c]
Number–letter	776	331 ms	183	–14	923	1.04	1.12	.86[b]
Color–shape	768	331 ms	189	–196	916	0.76	0.75	.85[b]
Category-switch	766	333 ms	181	–34	899	0.98	0.92	.83[b]
Age 23 EF								
Antisaccade	748	0.62	0.16	0.20	0.96	–0.13	–0.67	.90[c]
Stop-signal	735	215 ms	30	116	315	–0.23	0.25	.63[c]
Stroop	737	156 ms	74	–73	387	0.71	0.71	.96[b]
Keep track	749	0.72	0.09	0.44	0.96	–0.36	0.11	.66[c]
Letter memory	749	0.70	0.13	0.38	1.00	0.22	–0.64	.92[c]
Spatial *n*-back[d]	749	–0.01	0.91	–2.74	2.70	–0.31	–0.03	.75[b]
2-back[a]	745	1.08	0.17	0.64	1.45	–0.53	–0.24	.92[c]
3-back[a]	745	0.97	0.11	0.62	1.40	0.03	0.45	.78[c]
Number–letter	748	246 ms	157	–241	735	0.91	0.92	.91[b]
Color–shape	743	221 ms	182	–239	792	1.05	1.19	.90[b]
Category-switch	747	198 ms	161	–81	735	1.14	1.28	.94[b]
CES-D[e]								
Age 12	747	9.73	7.79	0.00	48.00	0.18	0.61	.82[c]
Age 17	795	9.45	7.50	0.00	47.00	0.08	0.33	.87[c]
Age 23	752	11.06	8.94	0.00	46.00	0.08	–0.11	.90[c]

Note. EF = executive function; CES-D = Center for Epidemiological Studies–Depression scale; SD = standard deviation; Min = minimum; Max = maximum.

[a]Accuracy scores were arcsine transformed.

[b]Internal reliability was calculated by adjusting split-half or part1–part2 correlations with the Spearman–Brown prophecy formula.

[c]Internal reliability was calculated using Cronbach's alpha.

[d]Average of *z*-scores for the 2- and 3-back tasks.

[e]Analyses conducted on latent variables constructed from three parcels, square-root transformed to improve normality. Means, SD, range, and reliability provided for raw total scores; skewness and kurtosis provided for transformed total scores.

Table S2

Ns in Each Bin For Diagnostic Interview Schedule (DIS) Depression Scores

MDDsx Measure	Total	0: No Criteria Met	1: 1+ Criteria, No DX	2: DX
Age 12 (lifetime)	750	718	21	11
Age 17 (past year)	797	715	54	28
Age 23 (past year)	763	592	113	58

Note. MDDsx = major depressive disorder (children's version used when participants were under 18), coded as 0 for no diagnostic criteria met, 1 for at least one criterion met but no diagnosis, and 2 for diagnosis (DX)

Table S3

Zero-Order Correlations

Task	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1. Antisaccade 17	—																							
2. Stop-signal 17	**–.29**	—																						
3. Stroop 17	**–.20**	**.14**	—																					
4. Keep track 17	**.19**	**–.24**	**–.21**	—																				
5. Letter memory 17	**.27**	**–.16**	**–.24**	**.46**	—																			
6. Spatial 2-back 17	**.24**	**–.25**	**–.13**	**.27**	**.26**	—																		
7. Number–letter 17	**–.17**	**.26**	**.23**	**–.13**	**–.19**	**–.15**	—																	
8. Color–shape 17	**–.19**	**.22**	**.27**	**–.14**	**–.14**	**–.12**	**.41**	—																
9. Category-switch 17	**–.20**	**.29**	**.26**	**–.17**	**–.16**	**–.20**	**.49**	**.44**	—															
1. Antisaccade 23	**.50**	**–.27**	**–.20**	**.18**	**.22**	**.22**	**–.29**	**–.24**	**–.33**	—														
11. Stop-signal 23	**–.15**	**.21**	**.16**	–.05	**–.08**	–.02	**.11**	**.17**	**.11**	**–.21**	—													
12. Stroop 23	**–.22**	**.23**	**.44**	**–.19**	**–.22**	**–.15**	**.16**	**.09**	**.23**	**–.33**	**.13**	—												
13. Keep track 23	**.19**	**–.21**	**–.20**	**.55**	**.45**	**.26**	**–.14**	**–.09**	**–.20**	**.26**	**–.12**	**–.23**	—											
14. Letter memory 23	**.29**	**–.18**	**–.25**	**.46**	**.54**	**.28**	**–.12**	**–.14**	**–.18**	**.40**	**–.11**	**–.29**	**.51**	—										
15. Spatial *n*-back 23	**.28**	**–.19**	**–.15**	**.34**	**.30**	**.33**	**–.10**	**–.13**	**–.14**	**.36**	–.04	**–.18**	**.33**	**.40**	—									
16. Number–letter 23	**–.14**	**.15**	**.19**	**–.08**	–.06	–.07	**.51**	**.38**	**.48**	**–.27**	**.09**	**.18**	**–.11**	**–.10**	–.04	—								
17. Color–shape 23	**–.14**	**.14**	**.22**	**–.16**	**–.14**	–.07	**.32**	**.43**	**.38**	**–.20**	.02	**.16**	**–.15**	**–.12**	**–.10**	**.43**	—							
18. Category-switch 23	**–.22**	**.27**	**.26**	**–.19**	**–.13**	**–.16**	**.46**	**.35**	**.53**	**–.35**	**.14**	**.30**	**–.23**	**–.20**	**–.15**	**.50**	**.42**	—						
19. CES-D 12	–.07	**.08**	**.10**	**–.16**	**–.15**	–.07	.03	.05	–.05	–.04	.05	.07	**–.20**	**–.16**	**–.09**	–.03	.04	.01	—					
20. CES-D 17	**–.10**	**.18**	**.09**	**–.14**	**–.14**	**–.13**	**.09**	**.12**	**.10**	**–.15**	**.10**	**.10**	**–.22**	**–.18**	**–.12**	.03	.03	**.12**	**.34**	—				
21. CES-D 23	–.04	**.11**	.04	**–.08**	–.04	**–.09**	.04	.03	.01	**–.08**	.01	.06	**–.12**	**–.14**	**–.11**	.05	.02	**.07**	**.19**	**.40**	—			
22. DIS MDDsx 12	**–.20**	–.07	**.19**	–.04	.04	–.08	.13	.11	.14	–.15	–.02	.13	–.07	–.07	–.17	.00	.07	.11	**.34**	**.17**	.12	—		
23. DIS MDDsx 17	–.05	–.02	.13	–.08	–.04	**–.18**	.01	–.01	.03	–.12	–.06	.06	**–.16**	–.07	–.11	.00	.04	.00	**.21**	**.44**	**.24**	.18	—	
24. DIS MDDsx 23	.00	**.12**	.00	–.11	.00	**–.12**	.00	.02	–.03	–.08	.04	.03	–.08	–.07	**–.13**	.06	.04	–.03	**.16**	**.33**	**.37**	**.25**	**.48**	—

Note. Partial correlations, controlling for sex and age of assessment, based on all data (*N*=877), adjusted for missing observations. Correlations are maximum likelihood estimates, except for correlations involving the ordinal MDD scores, which are polychoric and point-polyserial correlations estimated with threshold models using means and variance adjusted weighted least squares (WLSMV). Directionality of the reaction time measures was reversed so that for all EF tasks, higher scores indicate better performance. CES-D = Center for Epidemiological Studies-Depression scale; CES-D 12 = CES-D age 12; CES-D 17 = CES-D age 17; CES-D 23 = CES-D age 23; DIS MDDsx = Diagnostic Interview Schedule major depressive disorder (children's version used when participants were under 18), coded as 0 for no criteria met, 1 for at least one criterion met but no diagnosis, and 2 for diagnosis. Boldface type indicates $p<.05$, adjusted for non-independence of twin pairs.

Table S4

Phenotypic Correlations of Depression Measures with EF Latent Variables From a Correlated Factors EF Model

	Inhibiting		Updating		Shifting	
Depression Measure	Age 17	Age 23	Age 17	Age 23	Age 17	Age 23
CES-D Latent[a]						
Age 12	−.23* [.07]	−.12* [.06]	−.25* [.05]	−.28* [.06]	−.03 [.06]	−.01 [.06]
Age 17	−.31* [.06]	−.25* [.06]	−.22* [.05]	−.27* [.05]	−.16* [.05]	−.10* [.05]
Age 23	−.14* [.07]	−.12* [.05]	−.11* [.05]	−.20* [.05]	−.04 [.05]	−.08 [.04]
DIS MDDsx[b]						
Age 12 Lifetime	−.29* [.13]	−.18 [.13]	−.04 [.09]	−.15 [.10]	−.19* [.09]	−.09 [.10]
Age 17 Past Year	−.11 [.09]	−.11 [.09]	−.16* [.08]	−.17* [.08]	−.02 [.07]	−.02 [.08]
Age 23 Past Year	−.08 [.08]	−.10 [.07]	−.13 [.08]	−.14* [.06]	.01 [.06]	−.03 [.06]

Note. The EF model consisted of three correlated factors, with three tasks loading on each factor and each task loading on only one factor. Correlations within- and across-wave were freely estimated. CES-D and DIS modeled separately. In the CES-D model, all indicators were age-of-assessment- and sex-regressed residuals. In the DIS model, the EF tasks were age- and sex-regressed residuals, and the ordinal depression measures were regressed on age and sex within the model, except that age 12 DIS was not regressed on age because it was not related to age. Thus, numbers are partial correlations. Standard errors in brackets. CES-D=Center for Epidemiological Studies–Depresssion scale; DIS MDDsx=Diagnostic Interview Schedule major depressive disorder (children's version used when participants were under 18), coded as 0 for no criteria met, 1 for at least one criterion met but no diagnosis, and 2 for diagnosis; EF=executive function. CES-D model fit: $\chi^2(269)=383.34$, $p<.001$, CFI=.982, RMSEA=.022; DIS model fit: $\chi^2(206)=268.12$, $p=.002$, CFI=.976, RMSEA=.019.

*$p<.05$, determined with chi-square difference tests.

[a]Latent variables at each time point, each predicting 3 parcels.

[b]Ordinal variables analyzed with a threshold model.

Table S5

Twin Correlations and ACE Estimates for Depression Symptom Measures

	Twin Correlations[a]		Variance Components			ACE Model Fit				
Depression Measure	MZ	DZ	A	C	E	χ^2	df	*p*	CFI	RMSEA
CES-D Latent										
Age 12	.47*	.38*	.18 [.22]	.29 [.18]	.53* [.07]	52.08	43	.162	.988	.034
Age 17	.65*	.16*	.61* [.06]	.00 [.00]	.39* [.06]	39.27	43	.634	1.00	.000
Age 23	.41*	.13	.39* [.06]	.00 [.00]	.61* [.06]	32.27	43	.884	1.00	.000

Note. Each age of CES-D modeled separately as a latent variable predicting 3 parcels, which were age-of-assessment- and sex-regressed residuals. Each parcel had specific E variance. Standard errors in brackets. CES-D=Center for Epidemiological Studies–Depresssion scale; MZ=monozygotic; DZ=dizygotic; A=additive genetic variance; C=shared environmental variance; E=nonshared environmental variance; CFI=confirmatory fit index; RMSEA=root-mean-square error of approximation. χ^2/df < 2, CFI > .95, and RMSEA < .06 indicate good fit.
*p<.05, determined with chi-square difference tests for ACE variances and z-tests for twin correlations.
[a]Twin correlations for the CES-D latent variable are taken from a model in which the factor loadings, intercepts, residual variances, and factor variances were constrained to be equal for twin 1 and twin 2 and across zygosity.