

## Supplemental Materials for

Executive Functions and Impulsivity are Genetically Distinct and Independently Predict Psychopathology:  
Results from Two Adult Twin Studies

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## IMPULSIVITY AND EXECUTIVE FUNCTIONS

Table S1

*Descriptive Statistics for Continuous Measures in the LTS and CTS*

Task	N	Mean	SD	Min	Max	Skewness	Kurtosis	Reliability
<b>A. LTS</b>								
EF Age 23								
Antisaccade	748	0.62	0.16	0.20	0.96	-0.13	-0.67	.90 <sup>a</sup>
Stop-signal	735	215 ms	30	116	315	-0.23	0.25	.63 <sup>a</sup>
Stroop	737	156 ms	74	-73	387	0.71	0.71	.96 <sup>b</sup>
Keep track	749	0.72	0.09	0.44	0.96	-0.36	0.11	.66 <sup>a</sup>
Letter memory	749	0.70	0.13	0.38	1.00	0.22	-0.64	.92 <sup>a</sup>
Spatial <i>n</i> -back <sup>c</sup>	749	-0.01	0.91	-2.74	2.70	-0.31	-0.03	.75 <sup>b</sup>
2-back <sup>d</sup>	745	1.08	0.17	0.64	1.45	-0.53	-0.24	.92 <sup>a</sup>
3-back <sup>d</sup>	745	0.97	0.11	0.62	1.40	0.03	0.45	.78 <sup>a</sup>
Number-letter	748	246 ms	157	-241	735	0.91	0.92	.91 <sup>b</sup>
Color-shape	743	221 ms	182	-239	792	1.05	1.19	.90 <sup>b</sup>
Category-switch	747	198 ms	161	-81	735	1.14	1.28	.94 <sup>b</sup>
UPPS-P Age 23								
Positive Urgency	754	1.88	0.54	1.00	4.00	0.56	0.36	.81 <sup>a</sup>
Negative Urgency	754	2.13	0.59	1.00	4.00	0.43	0.01	.81 <sup>a</sup>
Lack of Premeditation	755	1.88	0.48	1.00	3.88	0.36	0.13	.82 <sup>a</sup>
Lack of Perseverance	755	1.72	0.46	1.00	3.50	0.59	0.23	.72 <sup>a</sup>
Sensation Seeking	753	2.87	0.66	1.14	4.00	-0.43	-0.55	.81 <sup>a</sup>
<b>B. CTS</b>								
EF Age 21								
Antisaccade <sup>d</sup>	747	1.07	0.20	0.51	1.57	-0.18	-0.22	.91 <sup>b</sup>
Stop-signal	736	282 ms	65	165	490	1.15	1.35	.78 <sup>b</sup>
Stroop	742	204 ms	89	-14	485	0.72	0.34	.94 <sup>b</sup>
Keep track <sup>d</sup>	759	0.94	0.18	0.38	1.50	0.21	0.39	.65 <sup>a</sup>
Letter memory <sup>d</sup>	761	1.14	0.24	0.56	1.57	0.30	-0.41	.59 <sup>a</sup>
Spatial 2-back <sup>d</sup>	749	1.22	0.15	0.77	1.57	-0.44	1.34	.85 <sup>a</sup>
Number-letter	755	340 ms	185	-89	945	0.86	0.98	.86 <sup>b</sup>
Color-shape	738	314 ms	183	-196	881	0.73	0.81	.85 <sup>b</sup>
Category-switch	748	361 ms	201	-60	1015	1.07	1.42	.83 <sup>b</sup>
UPPS-P Age 27								
Positive Urgency	1687	1.80	0.53	1.00	4.00	0.71	0.61	.81 <sup>a</sup>
Negative Urgency	1689	2.12	0.59	1.00	4.00	0.31	-0.28	.81 <sup>a</sup>
Lack of Premeditation	1689	1.85	0.45	1.00	3.75	0.32	0.20	.79 <sup>a</sup>
Lack of Perseverance	1689	1.74	0.45	1.00	3.67	0.51	-0.01	.68 <sup>a</sup>
Sensation Seeking	1687	2.66	0.69	1.00	4.00	-0.23	-0.64	.81 <sup>a</sup>

*Note.* EF= executive function; LTS= Longitudinal Twin Study; CTS= Community Twin Sample; Min = minimum; Max = maximum.

<sup>a</sup>Internal reliability was calculated using Cronbach's alpha.

<sup>b</sup>Internal reliability was calculated by adjusting split-half or part1-part2 correlations with the Spearman-Brown prophecy formula.

<sup>c</sup>Average of z-scores for the 2- and 3-back tasks.

<sup>d</sup>Accuracy scores were arcsine transformed.

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Table S2

*Psychopathology and Substance Use Disorder Symptom Frequencies in the LTS and CTS*

Measure	Total <i>N</i>	Symptom Count Bin				
		0	1	2	3	4
<b>A. LTS</b>						
MDD	763	574	90	99		
GAD	763	676	52	35		
ADHD	763	612	125	26		
CD	763	490	228	45		
ASPD	763	417	199	147		
Tobacco	762	509	112	141		
Alcohol	762	327	138	164	78	55
Cannabis	762	588	76	98		
Illicit drugs	762	689	73			
<b>B. CTS</b>						
MDD	1743	1278	181	284		
GAD	1743	1518	134	91		
ADHD	1743	1394	287	62		
CD	1743	1091	546	106		
ASPD	1743	888	494	361		
Tobacco	1742	1067	301	374		
Alcohol	1742	719	334	366	166	157
Cannabis	1742	1389	151	202		
Illicit drugs	1742	1537	205			

*Note.* Lifetime symptoms from the Diagnostic Interview Schedule (DIS) or Composite International Diagnostic Interview–Substance Abuse Module (CIDI-SAM), assessed at mean age 23 years for LTS and 27 years for CTS. LTS=Longitudinal Twin Study; CTS=Community Twin Sample; MDD=major depressive disorder; GAD=generalized anxiety disorder; ADHD=attention-deficit/hyperactivity disorder; CD=conduct disorder; ASPD=antisocial personality disorder. For MDD, GAD, ADHD, CD, ASPD, and Tobacco dependence: 0=no symptoms; 1=symptoms but no diagnosis; 2=diagnosis according to DSM–IV criteria, except for diagnosis of ASPD, which did not include the criterion for evidence of CD before age 15. For Alcohol, 0=no symptoms; 1=1 symptom; 2=2-3 symptoms; 3=4-5 symptoms; 4=6 or more symptoms of abuse and dependence. For Cannabis, 0=no symptoms; 1=1 symptoms; 2=2 or more symptoms of abuse and dependence. For Illicit drugs, 0=no symptoms; 1=1 or more symptoms of abuse and dependence for the illicit drug with the highest number of symptoms.

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Table S3

*Zero-Order Correlations for the LTS and CTS*

Measure	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
<b>A. LTS</b>																						
1. Antisaccade																						
2. Stop-signal	<b>.23</b>																					
3. Stroop	<b>.33</b>	<b>.13</b>																				
4. Keep track	<b>.26</b>	<b>.13</b>	<b>.23</b>																			
5. Letter memory	<b>.41</b>	<b>.11</b>	<b>.29</b>	<b>.51</b>																		
6. Spatial <i>n</i> -back	<b>.36</b>	.04	<b>.18</b>	<b>.32</b>	<b>.40</b>																	
7. Number-letter	<b>.27</b>	<b>.09</b>	<b>.18</b>	<b>.11</b>	<b>.09</b>	.04																
8. Color-shape	<b>.19</b>	.02	<b>.16</b>	<b>.14</b>	<b>.12</b>	<b>.10</b>	<b>.43</b>															
9. Category-switch	<b>.35</b>	<b>.14</b>	<b>.29</b>	<b>.22</b>	<b>.20</b>	<b>.14</b>	<b>.51</b>	<b>.42</b>														
10. Pos. Urg.	<b>-.09</b>	-.07	-.06	<b>-.11</b>	<b>-.11</b>	<b>-.17</b>	.01	.02	.03													
11. Neg. Urg.	<b>-.08</b>	-.05	-.01	<b>-.08</b>	-.07	<b>-.12</b>	-.02	-.04	-.02	<b>.61</b>												
12. Lack of Pre.	<b>-.10</b>	.01	-.04	-.01	-.02	-.03	-.02	-.02	.01	<b>.34</b>	<b>.32</b>											
13. Lack of Per.	<b>-.11</b>	-.05	-.06	-.01	-.02	-.01	<b>-.08</b>	-.05	.01	<b>.31</b>	<b>.32</b>	<b>.39</b>										
14. Sen. Seek.	<b>.09</b>	-.03	.02	.00	<b>.09</b>	.04	-.04	-.04	.00	<b>.19</b>	<b>.08</b>	<b>.18</b>	<b>-.10</b>									
15. MDD	-.08	-.03	-.03	-.05	-.06	-.10	-.06	-.05	.01	<b>.15</b>	<b>.24</b>	<b>.10</b>	<b>.16</b>	.03								
16. GAD	-.07	.06	.04	-.01	-.09	-.08	-.03	.06	-.01	<b>.13</b>	<b>.22</b>	-.09	.06	.01	<b>.48</b>							
17. ADHD	<b>-.11</b>	-.02	<b>-.11</b>	<b>-.19</b>	-.09	<b>-.12</b>	-.01	-.07	.00	<b>.27</b>	<b>.31</b>	<b>.22</b>	<b>.18</b>	.07	<b>.28</b>	<b>.24</b>						
18. CD	-.08	-.01	-.06	-.06	-.05	<b>-.11</b>	-.04	-.05	-.03	<b>.21</b>	<b>.36</b>	<b>.17</b>	<b>.18</b>	.09	<b>.37</b>	<b>.33</b>	<b>.46</b>					
19. ASPD	<b>-.18</b>	-.03	<b>-.10</b>	<b>-.16</b>	<b>-.11</b>	<b>-.13</b>	<b>-.10</b>	<b>-.10</b>	<b>-.11</b>	<b>.27</b>	<b>.35</b>	<b>.26</b>	<b>.22</b>	<b>.14</b>	<b>.36</b>	<b>.27</b>	<b>.42</b>	<b>.63</b>				
20. Tobacco	<b>-.15</b>	-.01	<b>-.10</b>	<b>-.19</b>	-.07	<b>-.15</b>	.01	-.08	<b>-.15</b>	<b>.27</b>	<b>.37</b>	<b>.25</b>	<b>.17</b>	<b>.13</b>	<b>.27</b>	<b>.24</b>	<b>.35</b>	<b>.53</b>	<b>.56</b>			
21. Alcohol	<b>-.13</b>	-.01	-.04	-.04	<b>-.10</b>	<b>-.16</b>	-.02	<b>-.08</b>	-.05	<b>.26</b>	<b>.34</b>	<b>.30</b>	<b>.19</b>	<b>.21</b>	<b>.28</b>	<b>.21</b>	<b>.26</b>	<b>.55</b>	<b>.61</b>	<b>.56</b>		
22. Cannabis	<b>-.13</b>	-.06	-.01	-.04	.07	<b>-.12</b>	-.09	-.09	-.06	<b>.25</b>	<b>.33</b>	<b>.21</b>	<b>.23</b>	<b>.11</b>	<b>.31</b>	<b>.22</b>	<b>.26</b>	<b>.47</b>	<b>.56</b>	<b>.49</b>	<b>.55</b>	
23. Illicit	<b>-.15</b>	-.04	-.10	<b>-.12</b>	-.06	-.04	-.06	-.03	-.10	<b>.17</b>	<b>.30</b>	<b>.23</b>	<b>.25</b>	<b>.25</b>	<b>.45</b>	<b>.42</b>	<b>.27</b>	<b>.60</b>	<b>.64</b>	<b>.61</b>	<b>.61</b>	<b>.66</b>
<b>B. CTS</b>																						
1. Antisaccade																						
2. Stop-signal	<b>.29</b>																					
3. Stroop	<b>.18</b>	<b>.16</b>																				
4. Keep track	<b>.20</b>	<b>.17</b>	<b>.25</b>																			
5. Letter memory	<b>.18</b>	<b>.09</b>	<b>.27</b>	<b>.41</b>																		
6. Spatial <i>n</i> -back	<b>.28</b>	<b>.20</b>	<b>.11</b>	<b>.24</b>	<b>.22</b>																	
7. Number-letter	<b>.30</b>	<b>.26</b>	<b>.18</b>	<b>.07</b>	<b>.10</b>	<b>.15</b>																
8. Color-shape	<b>.16</b>	<b>.20</b>	<b>.20</b>	<b>.09</b>	<b>.12</b>	<b>.16</b>	<b>.32</b>															
9. Category-switch	<b>.25</b>	<b>.22</b>	<b>.18</b>	<b>.14</b>	<b>.10</b>	<b>.16</b>	<b>.44</b>	<b>.43</b>														
10. Pos. Urg.	<b>-.08</b>	<b>-.14</b>	-.03	-.04	<b>-.09</b>	<b>-.17</b>	-.02	-.03	-.03													
11. Neg. Urg.	<b>-.13</b>	<b>-.14</b>	.01	-.04	-.06	<b>-.11</b>	-.05	-.03	-.07	<b>.61</b>												
12. Lack of Pre.	-.06	-.06	-.07	.01	<b>-.07</b>	<b>-.10</b>	.02	.04	.06	<b>.35</b>	<b>.33</b>											
13. Lack of Per.	-.04	-.01	.07	.02	-.03	-.04	<b>.09</b>	.06	<b>.08</b>	<b>.33</b>	<b>.31</b>	<b>.36</b>										
14. Sen. Seek.	<b>.11</b>	-.01	.04	.07	.04	.00	<b>.10</b>	.00	.07	<b>.22</b>	.04	<b>.17</b>	<b>-.08</b>									
15. MDD	-.06	-.08	.03	-.01	.01	-.07	.01	-.01	.00	<b>.22</b>	<b>.25</b>	<b>.11</b>	<b>.23</b>	.01								
16. GAD	-.04	-.07	.02	<b>-.12</b>	-.05	<b>-.12</b>	.04	-.01	-.01	<b>.23</b>	<b>.28</b>	<b>.08</b>	<b>.21</b>	-.08	<b>.55</b>							

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17. ADHD	<b>-.13</b>	<b>-.11</b>	.00	-.10	-.09	<b>-.13</b>	.05	-.07	.06	<b>.30</b>	<b>.30</b>	<b>.32</b>	<b>.25</b>	<b>.09</b>	<b>.30</b>	<b>.35</b>							
18. CD	<b>-.12</b>	<b>-.13</b>	-.03	-.08	<b>-.11</b>	<b>-.11</b>	-.02	-.07	.00	<b>.23</b>	<b>.30</b>	<b>.17</b>	<b>.17</b>	<b>.15</b>	<b>.27</b>	<b>.31</b>	<b>.45</b>						
19. ASPD	<b>-.12</b>	<b>-.11</b>	-.01	<b>-.11</b>	-.08	<b>-.14</b>	-.04	-.02	-.04	<b>.31</b>	<b>.31</b>	<b>.20</b>	<b>.18</b>	<b>.17</b>	<b>.31</b>	<b>.31</b>	<b>.42</b>	<b>.60</b>					
20. Tobacco	<b>-.09</b>	<b>-.14</b>	.04	-.09	<b>-.11</b>	<b>-.18</b>	-.03	-.06	-.04	<b>.24</b>	<b>.28</b>	<b>.19</b>	<b>.10</b>	<b>.08</b>	<b>.25</b>	<b>.27</b>	<b>.36</b>	<b>.47</b>	<b>.50</b>				
21. Alcohol	-.04	-.02	.02	-.07	-.04	<b>-.09</b>	.01	.06	.04	<b>.24</b>	<b>.27</b>	<b>.22</b>	<b>.14</b>	<b>.13</b>	<b>.29</b>	<b>.20</b>	<b>.23</b>	<b>.40</b>	<b>.53</b>	<b>.49</b>			
22. Cannabis	.01	-.08	.08	-.02	-.06	-.02	.05	<b>.12</b>	.04	<b>.18</b>	<b>.22</b>	<b>.13</b>	<b>.12</b>	<b>.11</b>	<b>.26</b>	<b>.35</b>	<b>.28</b>	<b>.51</b>	<b>.55</b>	<b>.55</b>	<b>.52</b>		
23. Illicit	-.07	-.08	.08	-.09	.05	-.04	.03	.06	-.02	<b>.15</b>	<b>.20</b>	<b>.18</b>	<b>.09</b>	<b>.17</b>	<b>.36</b>	<b>.35</b>	<b>.33</b>	<b>.58</b>	<b>.67</b>	<b>.56</b>	<b>.58</b>	<b>.72</b>	

*Note.* Partial correlations, controlling for sex, based on all data (total  $N=765$  in LTS and total  $N=1784$ ; EF  $N=761$  in CTS), adjusted for missing observations. All correlations estimated with the means and variance adjusted weighted least squares (WLSMV) estimator. Correlations involving ordinal psychopathology symptom variables are polychoric and polyserial correlations estimated with threshold models. Directionality of the reaction time measures was reversed so that for all executive function tasks, higher scores indicate better performance. LTS= Longitudinal Twin Study; CTS= Community Twin Sample; Pos. Urg. = positive urgency; Neg. Urg. = negative urgency; Lack of Pre. = lack of premeditation; Lack of Per. = lack of perseverance; Sen. Seek. = sensation seeking; MDD = major depressive disorder; GAD = generalized anxiety disorder; ADHD = attention-deficit/hyperactivity disorder; CD = conduct disorder; ASPD = antisocial personality disorder. Boldface type indicates  $p < .05$ , adjusted for non-independence of twin pairs.

Table S4  
*Twin Correlations and ACE Estimates for LTS and CTS*

Measure	Twin Correlations <sup>a</sup>		Variance Components (%)			$\chi^2$ (df)	Model Fit		
	MZ	DZ	A	C	E		<i>p</i>	RMSEA	CFI
<b>A. LTS UPPS-P Age 23</b>									
Positive Urgency	.34*	.07	32*	0	68*	6.87 (6)	.334	.027	.962
Negative Urgency	.46*	.03	40*	0	60*	10.78 (6)	.095	.064	.888
Lack of Premeditation	.34*	-.06	27*	0	73*	12.80 (6)	.046	.076	.696
Lack of Perseverance	.47*	.07	44*	0	56*	27.70 (6)	.000	.136	.533
Sensation Seeking	.44*	.31*	29	16	55*	2.96 (6)	.814	.000	1.00
<b>B. CTS UPPS-P Age 27</b>									
Positive Urgency	.36*	.18*	30*	4	66*	13.82 (6)	.032	.053	.867
Negative Urgency	.43*	.18*	41*	0	59*	8.54 (6)	.201	.030	.971
Lack of Premeditation	.35*	.10*	32*	0	68*	5.35 (6)	.500	.000	1.00
Lack of Perseverance	.30*	.17*	21	7	72*	5.05 (6)	.538	.000	1.00
Sensation Seeking	.48*	.17*	45*	0	55*	11.87 (6)	.065	.046	.940
<b>C. LTS EF Age 23</b>									
Antisaccade	.57*	.36*	45*	13	42*	1.61 (6)	.952	.000	1.00
Stop-signal	.27*	.22*	12	15	73*	3.78 (6)	.707	.000	1.00
Stroop	.52*	.08	49*	0	51*	8.77 (6)	.187	.049	.955
Keep track	.60*	.15	58*	0	43*	6.38 (6)	.382	.018	.996
Letter memory	.69*	.34*	69*	0	31*	0.80 (6)	.992	.000	1.00
Spatial 2-back	.54*	.16*	52*	0	48*	9.27 (6)	.159	.053	.954
Number-letter	.51*	.17*	53*	0	47*	11.29 (6)	.080	.068	.917
Color-shape	.32*	.21*	30	4	66*	4.60 (6)	.597	.000	1.00
Category-switch	.49*	.21*	47*	0	53*	5.41 (6)	.493	.000	1.00
<b>D. CTS EF Age 21</b>									
Antisaccade	.48*	.22*	48*	0	52*	9.06 (6)	.170	.051	.941
Stop-signal	.36*	.17*	34	0	66*	5.78 (6)	.449	.000	1.00
Stroop	.53*	.26*	46*	5	49*	3.57 (6)	.735	.000	1.00
Keep track	.53*	.14	48*	0	52*	8.30 (6)	.217	.044	.962
Letter memory	.53*	.10	50*	0	50*	9.60 (6)	.142	.055	.941
Spatial 2-back	.41*	.08	38*	0	62*	12.67 (6)	.049	.075	.797
Number-letter	.33*	.15*	32	0	68*	1.24 (6)	.975	.000	1.00
Color-shape	.34*	.21*	28	6	66*	4.65 (6)	.589	.000	1.00
Category-switch	.38*	.10	36*	0	64*	8.75 (6)	.188	.048	.900
<b>E. LTS Psychopathology</b>									
MDD	.36*	.29*	14	22	64*	11.43 (9)	.248	.037	.879
GAD	.22	.36*	0	28	72*	5.54 (9)	.785	.000	1.00
ADHD	.60*	-.12	53*	0	47*	22.48 (9)	.008	.087	.816
CD	.60*	.42*	35	25	40*	6.59 (9)	.680	.000	1.00
ASPD	.50*	.23*	50*	0	50*	5.28 (9)	.809	.000	1.00
Alcohol	.60*	.35*	52*	9	40*	16.76 (15)	.334	.024	.987
Tobacco	.67*	.44*	46	21	33*	14.61 (9)	.102	.056	.958
Cannabis	.51*	.33*	37	14	49*	5.51 (9)	.788	.000	1.00
Illicit drugs	.59*	.53*	12	47	42*	1.41 (6)	.965	.000	1.00
<b>F. CTS Psychopathology</b>									
MDD	.30*	.28*	3	27	70*	7.99 (13)	.844	.000	1.00
GAD	.41*	.20	41	0	59*	10.46 (13)	.656	.000	1.00
ADHD	.52*	.15	48*	0	52*	12.60 (13)	.479	.000	1.00
CD	.56*	.39*	35*	21	44*	8.60 (13)	.803	.000	1.00
ASPD	.50*	.27*	46*	4	50*	7.58 (13)	.870	.000	1.00

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Alcohol	.47*	.23*	47*	0	53*	12.83 (19)	.847	.000	1.00
Tobacco	.79*	.33*	78*	0	22*	7.44 (13)	.878	.000	1.00
Cannabis	.51*	.29*	44	8	49*	9.95 (13)	.698	.000	1.00
Illicit drugs	.68*	.42*	52*	16	32*	12.42 (10)	.258	.023	.973

*Note.* All continuous variables residualized on sex prior to modeling, and ordinal psychopathology variables residualized on sex within the model. Variance components sum to 100%, within rounding error. Ordinal psychopathology variables modeled with weighted least squares mean and variances adjusted (WLSMV) using the delta parameterization. LTS=Longitudinal Twin Study; CTS=Community Twin Sample; MDD=major depressive disorder; GAD=generalized anxiety disorder; ADHD=attention-deficit/hyperactivity disorder; CD=conduct disorder; ASPD=antisocial personality disorder. MZ=monozygotic; DZ=dizygotic; A=additive genetic variance; C=shared environmental variance; E=nonshared environmental variance; RMSEA=root-mean-square error of approximation.

CFI=confirmatory fit index.  $\chi^2/df < 2$ , RMSEA<.06, and CFI >.95 indicate good fit.

<sup>a</sup>Correlations are maximum likelihood estimates (from Mplus) based on all data, adjusted for missing observations. For UPPS-P scales for which the DZ correlations were less than half the MZ correlations, we also examined ADE models. In the LTS, the ADE models showed acceptable fit (RMSEA<.038 and CFI>.927) for all but lack of perseverance,  $\Delta\chi^2(6)=21.57$ ,  $p=.001$ , CFI=.665, RMSEA=.115. For this scale, the poor fit seemed to be due to standard mean and variance equalities imposed across twins and zygosity, which can happen by chance when randomizing twins to twin1 and twin2. Dominance (D) was significant for negative urgency, lack of premeditation, and lack of perseverance, all  $\Delta\chi^2(1)>4.80$ ,  $p<.029$ , but not positive urgency,  $\Delta\chi^2(1)=2.03$ ,  $p=.155$ . However, in each of these models, the A variance was estimated at zero, leaving all the genetic variance as dominant, which is biologically implausible. Moreover, when we examined ADE models for the UPPS-P scales that showed DZ correlations that were less than half the MZ correlations in the CTS, D was not significant for any model, all  $\Delta\chi^2(1)<1.81$ ,  $p>.179$ , nor did the same ACE models fit poorly. Thus, we retained the ACE models for the purposes of examining the relations of the A and E components with EFs in the LTS. We note that the genetic estimates provided here should be interpreted as broad-sense heritability (the overall effect of genes) rather than narrow-sense heritability (specific to additive genetic influences).

\* $p<.05$ , determined with chi-square difference tests for the ACE models and with z-values for the correlations.

Table S5

*Standardized Regression Coefficients and Correlations for Psychopathology and Substance Use Disorder Symptoms*

Independent Variables	Psychopathology or Substance Use Disorder								
	MDD	GAD	ADHD	CD	ASPD	ALC	TOB	CAN	ILL
<b>A. LTS Regression Coefficients from</b>									
Common EF	-.05	.00	-.12*	-.07	-.17*	-.09	-.16*	-.06	-.19*
Updating-specific	-.08	-.09	-.11	-.05	-.09	-.10	-.09	.02	-.01
Shifting-specific	.00	.01	.03	.00	-.04	-.01	.01	-.08	.05
Positive Urgency	-.03	.01	.06	-.06	-.01	-.03	-.03	.03	-.16
Negative Urgency	.21*	.24*	.19*	.34*	.25*	.25*	.30*	.24*	.28*
Lack of Premeditation	-.01	-.20*	.10	.03	.11*	.16*	.11*	.05	.05
Lack of Perseverance	.11*	.07	.06	.08	.10*	.07	.04	.12*	.19*
Sensation Seeking	.04	.04	.05	.08	.13*	.19*	.11*	.08	.29*
<b>B. LTS Correlations with</b>									
Common EF	-.07	.00	-.16*	-.09	-.21*	-.12*	-.19*	-.10	-.20*
Updating-specific	-.09	-.13	-.14	-.07	-.11	-.12	-.12	.00	.01
Shifting-specific	-.01	.01	.03	-.01	-.05	-.02	.00	-.08	.01
Positive Urgency	.15*	.13*	.27*	.21*	.27*	.26*	.27*	.25*	.17*
Negative Urgency	.24*	.22*	.31*	.36*	.35*	.34*	.37*	.33*	.30*
Lack of Premeditation	.10*	-.09	.22*	.17*	.26*	.30*	.25*	.21*	.23*
Lack of Perseverance	.16*	.06	.18*	.18*	.22*	.19*	.17*	.23*	.25*
Sensation Seeking	.03	.01	.07	.09	.14*	.21*	.13*	.11*	.25*
<b>C. CTS Regression Coefficients from</b>									
Common EF	-.06	-.03	-.13	-.17*	-.14*	.00	-.13*	.02	-.06
Updating-specific	.04	-.14	-.07	-.07	-.08	-.08	-.11	-.07	-.01
Shifting-specific	.04	.07	.12	.07	.04	.07	.04	.11	.07
Positive Urgency	.06	.08	.06	-.04	.09*	.06	.04	.01	-.04
Negative Urgency	.16*	.22*	.14*	.24*	.17*	.18*	.20*	.19*	.17*
Lack of Premeditation	-.05	-.07	.15*	.00	.03	.09*	.08*	.01	.08
Lack of Perseverance	.17*	.12*	.10*	.10*	.09*	.02	-.01	.04	.02
Sensation Seeking	.02	-.08	.07	.18*	.16*	.09*	.07	.11*	.18*
<b>D. CTS Correlations with</b>									
Common EF	-.10	-.09	-.20*	-.20*	-.19*	-.06	-.19*	-.01	-.08
Updating-specific	.04	-.14	-.07	-.06	-.08	-.08	-.10	-.06	.00
Shifting-specific	.08	.10	.19*	.11	.10	.11*	.07	.14	.11
Positive Urgency	.22*	.23*	.30*	.23*	.31*	.24*	.24*	.18*	.15*
Negative Urgency	.25*	.28*	.30*	.30*	.31*	.27*	.28*	.22*	.20*
Lack of Premeditation	.11*	.08*	.32*	.17*	.20*	.22*	.19*	.13*	.18*
Lack of Perseverance	.23*	.21*	.25*	.17*	.18*	.14*	.10*	.12*	.09*



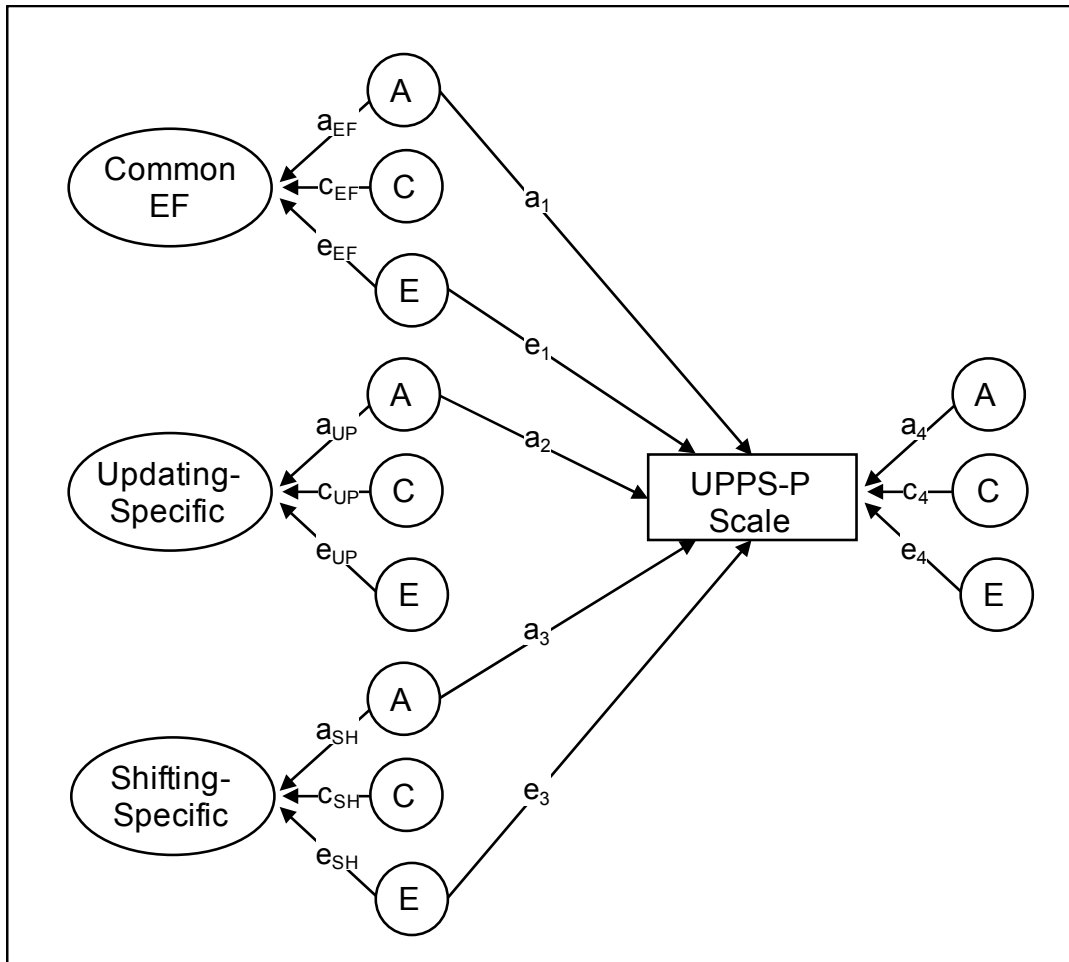
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Sensation Seeking	.01	-.08	.09*	.15*	.17*	.13*	.08*	.11*	.17*
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*Note.* Standardized regression coefficients, controlling for sex, from a structural equation model in the Longitudinal Twin Study (LTS; total  $N=765$ ),  $\chi^2(104)=133.57$ ,  $p=.027$ , CFI=.991, RMSEA=.019, and Community Twin Sample (CTS; total  $N=1784$ ,  $N=761$  with EF data),  $\chi^2(106)=167.51$ ,  $p<.001$ , CFI=.991, RMSEA=.018. Correlations from a statistically equivalent confirmatory factor analysis (i.e., relations without controlling for correlated predictors) are also presented for comparison. Executive function (EF) variables were latent variables modeled as shown in Figure S2, and UPPS-P scales were manifest variables. All indicators were regressed on sex. All independent variables were allowed to correlate, except for the orthogonal EF latent factors. The residual variances for the dependent psychopathology and substance use disorder variables were also allowed to correlate. Model estimated with the means and variance adjusted weighted least squares (WLSMV) estimator to account for the ordinal psychopathology and substance use disorder symptom data. MDD=major depressive disorder; GAD=generalized anxiety disorder; ADHD=attention-deficit/hyperactivity disorder; CD=conduct disorder; ASPD=antisocial personality disorder; ALC=alcohol abuse and dependence symptoms; TOB=tobacco abuse and dependence symptoms; CAN=cannabis abuse and dependence symptoms; ILL=illicit drugs abuse and dependence symptoms.

\* $p<.05$ , adjusted for non-independence of twin pairs.



*Figure S1.* Schematic of ACE Cholesky decomposition of the correlation between 3 orthogonal EF factors and one UPPS-P scale. The rectangle represents the manifest UPPS-P variable, and ellipses represent the latent EF variables (EF task indicators and their residual A and E variances not shown for simplicity). Each EF's variance is decomposed into genetic (A), shared environmental (C), and nonshared environmental (E) variances; variance explained is obtained by squaring the paths from these variables (e.g.,  $a_{EF}$ ,  $c_{EF}$ , and  $e_{EF}$  for Common EF). The EF ACE variance components that are not zero or close to zero are allowed to also predict variance in the UPPS-P scale (paths  $a_1$ - $e_3$ ), and the remaining variance in the UPPS-P scale is decomposed into genetic and environmental sources (paths  $a_4$ - $e_4$ ).

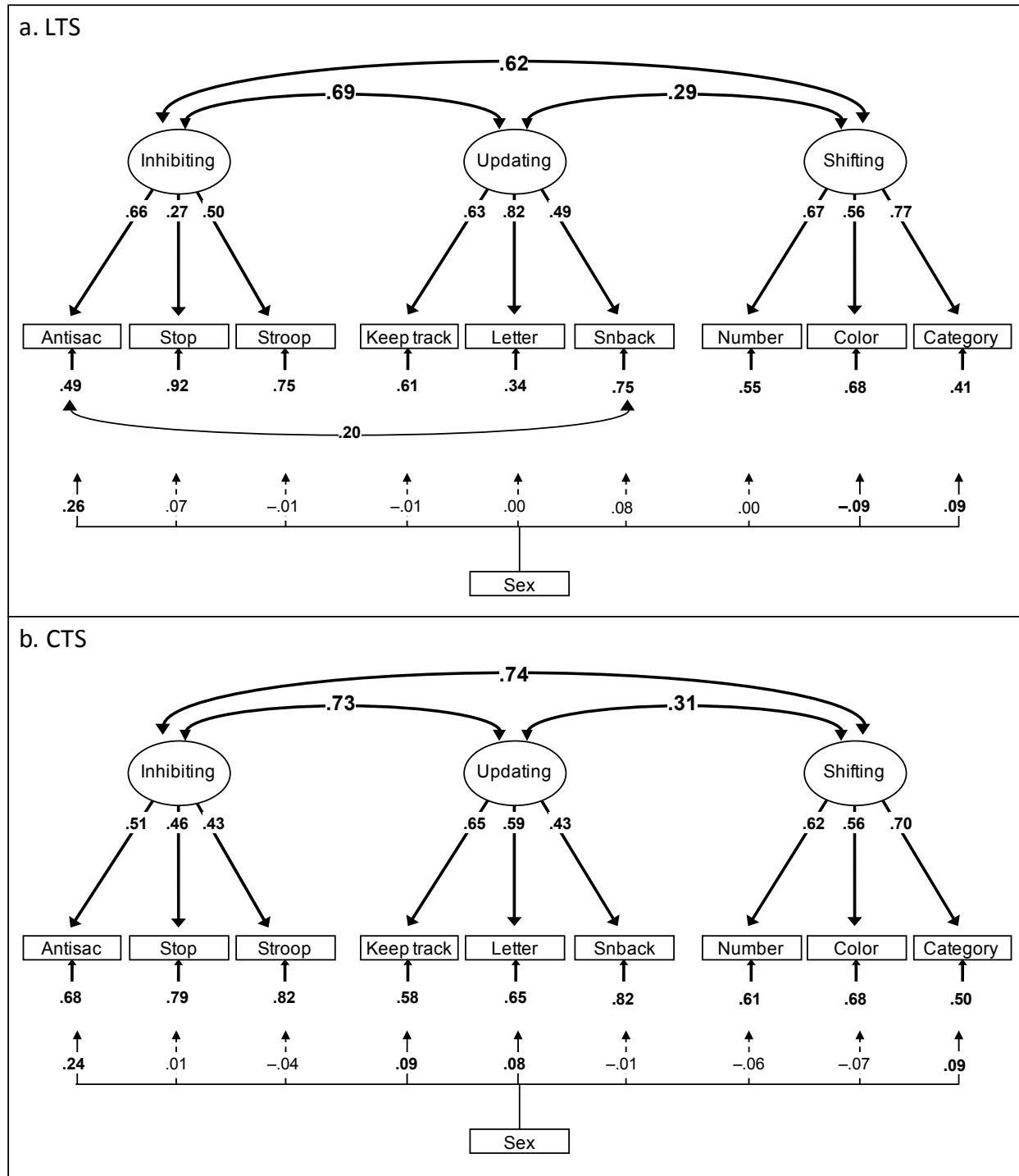
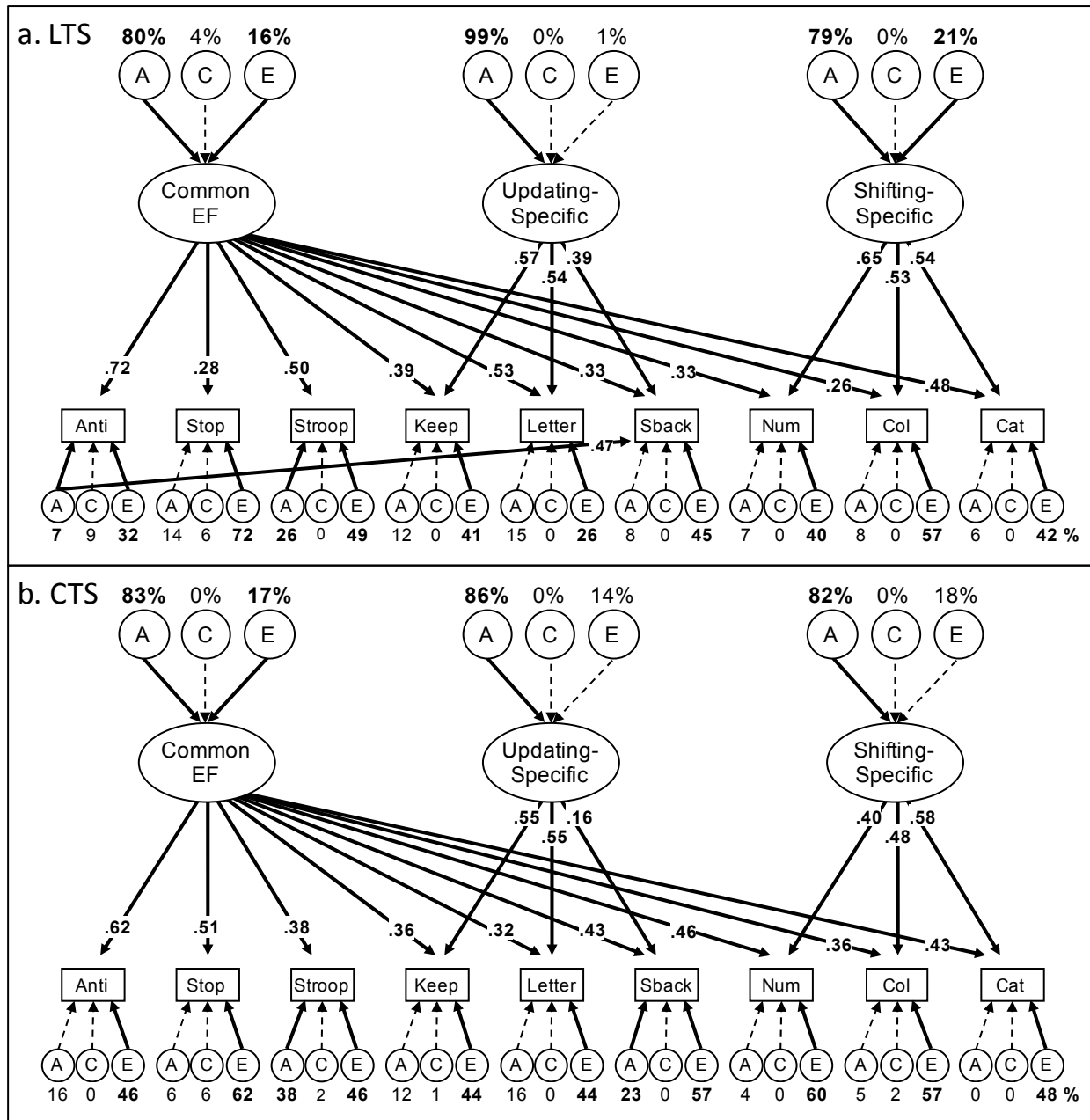


Figure S2. Longitudinal Twin Study (LTS, panel a) and Community Twin Sample (CTS, panel b) correlated factors unity/diversity executive function (EF) model ( $N=749$  for LTS and  $N=761$  for CTS), with sex covaried (LTS fit:  $\chi^2(23)=48.04$ ,  $p=.002$ , CFI=.978, RMSEA=.038. CTS fit:  $\chi^2(24)=81.56$ ,  $p<.001$ , CFI=.933, RMSEA=.056). Numbers on arrows are standardized factor loadings, those under the smaller arrows are residual variances, and the one on the curved double-headed arrow is a residual correlation. Numbers on arrows from sex variable are standardized paths from a categorical sex variable (males higher) predicting the indicators. Antisac=antisaccade, Stop=stop-signal, Letter=letter memory, Snback=spatial  $n$ -back, Number=number-letter, Color=color-shape, Category=category-switch. Boldface

type and solid lines indicate  $p < .05$ , corrected for nonindependence of twin pairs; dashed lines indicate  $p > .05$ .

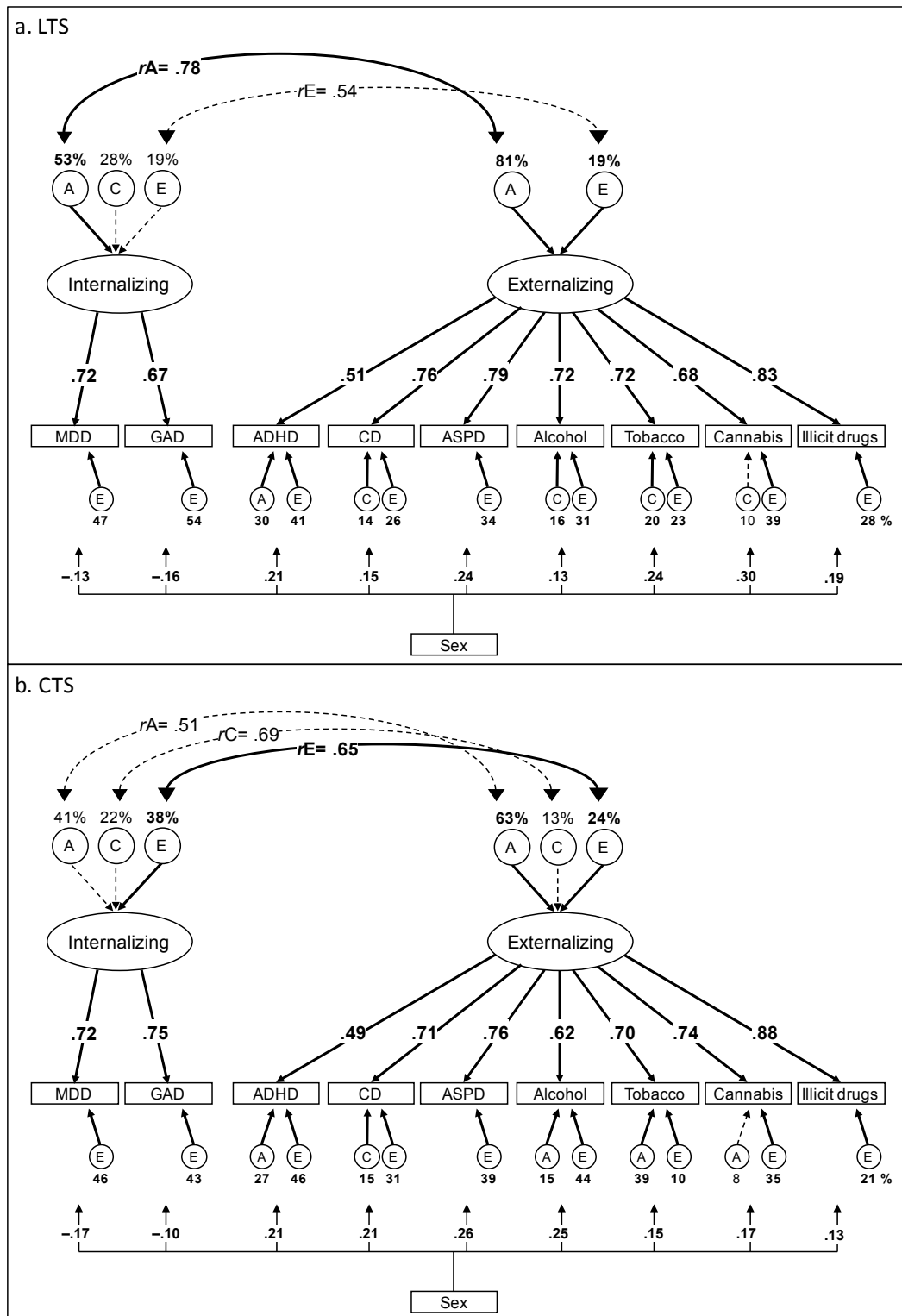


*Figure S3.* Longitudinal Twin Study (LTS, panel a) and Community Twin Sample (CTS, panel b) bifactor ACE genetic model of the EF data (LTS  $N=205$  monozygotic and 181 dizygotic pairs,  $\chi^2(320)=419.80$ ,  $p < .001$ , CFI=.945, RMSEA=.040. CTS,  $N=199$  monozygotic and 193 dizygotic pairs,  $\chi^2(322)=380.74$ ,  $p=.013$ , CFI=.952, RMSEA=.031). Sex was regressed out of all EF tasks prior to modeling. Numbers on arrows are standardized factor loadings, those above the top ACEs are the percentages of the Common EF, Updating-Specific, and Shifting-Specific factors' variances due to genetic and environmental influences, and those below the lower ACEs are estimates for the remaining nonexecutive variances in individual tasks. Boldface type and solid lines indicate statistical significance ( $p < .05$ ) and dashed lines indicate non-significance ( $p > .05$ ), determined with chi-square difference tests for the ACE variances.

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A=additive genetic variance; C=shared environmental variance; E=nonshared environmental variance;  
Anti=antisaccade, Stop=stop-signal, Keep=keep track; Letter=letter memory, Sback=spatial  $n$ -back,  
Num=number-letter, Col=color-shape, Cat=category-switch.



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in individual measures. To aid model convergence, some A and C variances were fixed to zero based on twin correlations. Boldface type and solid lines indicate statistical significance ( $p < .05$ ) and dashed lines indicate non-significance ( $p > .05$ ), determined with chi-square difference tests for the ACE variances. A=additive genetic variance; C=shared environmental variance; E=nonshared environmental variance; MDD=major depressive disorder; GAD=generalized anxiety disorder; ADHD=attention-deficit/hyperactivity disorder; CD=conduct disorder; ASPD=antisocial personality disorder.