Evidence for a unitary structure of spatial cognition beyond general intelligence

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Supplementary Methods

Measures of general cognitive ability (g) over development

General cognitive ability (*g* ; intelligence) was assessed in TEDS at ages 7, 9, 10, 12, 14, and 16. For the present analyses we created a longitudinal composite measure of *g* as a mean of these six assessments. At age 7, 'g' was calculated as a mean of conceptual grouping[1], a WISC similarities test[2], a WISC vocabulary test[2], and a WISC picture completion test[2] all collected over telephone testing. At age 9, 'g' was calculated as a mean of a shapes test[3], a WISC vocabulary test[4], a WISC general knowledge task[4], and a puzzle test[3] ; all tests were administered in booklets sent to the twins by post. At age 10, 'g' was calculated as a mean of the Ravens Standard Progressive Matrices[5], a WISC vocabulary[4], WISC picture completion[2], and a WISC general knowledge test[4]; at age 10 and subsequent assessments, all 'g' data were obtained by internet testing. At age 12, 'g' was calculated as a mean of the Ravens Progressive Matrices[5], a WISC picture completion[2], a WISC vocabulary[4], and a WISC general knowledge test[4]. At age 14, 'g' was calculated as a mean of the Raven's Progressive Matrices[5] and a WISC vocabulary[4]. At age 16, 'g' was calculated as a mean of Mill Hill Vocabulary test[6] and Raven's Progressive Matrices[5].

References

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Tables

Table S1. (a) Descriptive statistics for each spatial test and *g*, randomly selecting one twin out of each pair. **(b)** Descriptive statistics for the other half of the sample.

(a)

	N	mean	sd	min	max	range	skew	kurtosis
Navigation directions (cardinal points	1330	0.000	1.000	-3.220	2.440	5.660	-0.170	-0.300
Navigation landmarks	1278	0.000	1.000	-4.260	1.980	6.240	-1.140	1.610
Map reading	1244	0.000	1.000	-4.180	1.620	5.800	-1.020	1.040
Route memorizing	1217	0.000	1.000	-4.260	1.510	5.770	-1.350	1.920
Large-scale perspective taking	1285	0.000	1.000	-3.350	1.470	4.830	-0.960	0.400
Large-scale scanning	1229	0.000	1.000	-4.160	1.590	5.750	-1.430	2.120
KC cross-section	927	0.000	1.000	-2.200	2.310	4.510	-0.180	-0.760
KC 2d drawing	920	0.000	1.000	-3.480	1.540	5.020	-0.710	-0.020
KC pattern assembly	896	0.000	1.000	-2.260	2.620	4.870	-0.370	-0.520
KC Elithorne maze	804	0.000	1.000	-3.210	1.990	5.200	-1.160	1.290
KC mechanical reasoning	914	0.000	1.000	-3.060	2.940	6.000	-0.180	-0.050
KC paper folding	888	0.000	1.000	-2.290	2.090	4.390	-0.120	-1.000
KC 3d drawing	833	0.000	1.000	-2.030	2.340	4.370	0.030	-1.000
KC shapes rotation	850	0.000	1.000	-2.330	1.870	4.200	-0.340	-0.850
KC small-scale perspective taking	859	0.000	1.000	-1.640	2.980	4.620	0.610	-0.190
KC mazes	850	0.000	1.000	-3.070	2.650	5.720	-0.140	-0.120
General cognitive ability (g)	1234	0.000	1.000	-2.830	3.040	5.870	0.320	0.010

Note: all measures were standardized and residualized for age and sex within the randomly selected half of the sample by means of linear regression

(b) Descriptive statistics for the other half of the sample

	N	mean	sd	min	max	range	skew	kurtosis
Navigation directions (cardinal points	1349	0.000	1.000	-3.250	2.790	6.050	-0.110	-0.330
Navigation landmarks	1312	0.000	1.000	-4.330	2.070	6.400	-0.900	0.870
Map reading	1268	0.000	1.000	-4.300	1.620	5.930	-1.000	1.160
Route memorizing	1234	0.000	1.000	-4.500	1.550	6.050	-1.250	1.710
Large-scale perspective taking	1316	0.000	1.000	-3.450	1.450	4.900	-0.850	0.170
Large-scale scanning	1260	0.000	1.000	-3.960	1.610	5.570	-1.250	1.510
KC cross-section	939	0.000	1.000	-2.250	2.330	4.580	-0.260	-0.710
KC 2d drawing	932	0.000	1.000	-3.230	1.610	4.850	-0.790	0.180
KC pattern assembly	911	0.000	1.000	-2.420	2.130	4.550	-0.440	-0.580
KC Elithorne maze	815	0.000	1.000	-3.850	1.940	5.790	-1.060	1.280
KC mechanical reasoning	921	0.000	1.000	-3.080	2.590	5.680	-0.100	-0.230
KC paper folding	893	0.000	1.000	-2.380	1.900	4.280	-0.270	-0.960
KC 3d drawing	868	0.000	1.000	-2.130	2.240	4.380	-0.090	-1.010
KC shapes rotation	857	0.000	1.000	-2.450	1.920	4.370	-0.420	-0.760
KC small-scale perspective taking	880	0.000	1.000	-1.680	3.180	4.850	0.590	-0.450
KC mazes	862	0.000	1.000	-3.170	2.550	5.720	-0.220	-0.180
General cognitive ability (g)	1242	0.000	1.000	-2.770	2.950	5.720	0.150	-0.150

Note: all measures were standardized and residualized for age and sex within the randomly selected half of the sample by means of linear regression

Table S2. Sex limitation model fitting sub-model comparisons (significant differences are marked in bold). FullHetACE=full genetic heterogeneity model, rG=Free; HetACE= quantitative heterogeneity model; cFullHetACE=full environmental heterogeneity model, rC=Free; HomACE= homogeneity model (no sex differences at all); ep=estimated parameters; minus2LL= minus 2 log-likelihood; df= degrees of freedom; AIC= Akaike information criterion; diffLL= change in log-likelihood; diffdf= change in degrees of freedom (significant differences are marked in bold).

Navigation ability							
Qualitative genetic differences:							
	ep	-2LL	df	AIC	diffLL	diffdf	p
Model: FullHetACE	9	5863.64	2121	1621.64	-	-	-
Model: HetACE	8	5863.64	2122	1619.64	0	1	0.96
Qualitative environmental differences:							
	ep	-2LL	df	AIC	diffLL	diffdf	p
Model: cFullHetACE	9	5870.66	2121	1628.66	-	-	-
Model: HetACE	8	5863.64	2122	1619.64	-7.01	1	1
Quantitative differences:							
	ep	-2LL	df	AIC	diffLL	diffdf	p
Model: HetACE	8	5863.64	2122	1619.64	-	-	-
Model: HomACE	5	5874.35	2125	1624.35	10.71	3	0.01
Scanning							
Qualitative genetic differences:							
	ep	-2LL	df	AIC	diffLL	diffdf	p
Model: FullHetACE	9	6992.87	2480	2032.87	-	-	-
Model: HetACE	8	6992.87	2481	2030.87	0	1	1

Qualitative environmental differences:

	ep	-2LL	df	AIC	diffLL	diffdf	p
Model: cFullHetACE	9	7006.02	2480	2046.02	-	-	-
Model: HetACE	8	6992.87	2481	2030.87	-13.15	1	1

Quantitative differences:

	ep	-2LL	df	AIC	diffLL	diffdf	p
Model: HetACE	8	6992.87	2481	2030.87	-	-	-
Model: HomACE	5	7048.2	2484	2080.2	55.33	3	0

Perspective taking

Qualitative genetic differences:

	ep	-2LL	df	AIC	diffLL	diffdf	p
Model: FullHetACE	9	7314.24	2592	2130.24	-	-	-
Model: HetACE	8	7314.77	2593	2128.77	0.53	1	0.47

Qualitative environmental differences:

	ep	-2LL	df	AIC	diffLL	diffdf	p
Model: cFullHetACE	9	7336	2592	2152	-	-	-
Model: HetACE	8	7314.77	2593	2128.77	-21.23	1	1

Quantitative differences:

	ep	-2LL	df	AIC	diffLL	diffdf	p
Model: HetACE	8	7314.77	2593	2128.77	-	-	-
Model: HomACE	5	7328.79	2596	2136.79	14.02	3	0

Navigation according to landmarks

Qualitative genetic differences:

	ep	-2LL	df	AIC	diffLL	diffdf	p
Model: FullHetACE	9	7216.09	2581	2054.09	-	-	-
Model: HetACE	8	7216.09	2582	2052.09	0	1	1

Qualitative environmental differences:

	ep	-2LL	df	AIC	diffLL	diffdf	p
Model: cFullHetACE	9	7216.09	2581	2054.09	-	-	-
Model: HetACE	8	7216.09	2582	2052.09	0	1	1

Quantitative differences:

	ep	-2LL	df	AIC	diffLL	diffdf	p
Model: HetACE	8	7216.09	2582	2052.09	-	-	-
Model: HomACE	5	7248.5	2585	2078.5	32.42	3	0

Navigation according to directions

Qualitative genetic differences:

	ep	-2LL	df	AIC	diffLL	diffdf	p
Model: FullHetACE	9	7390.91	2670	2050.91	-	-	-
Model: HetACE	8	7392.27	2671	2050.27	1.36	1	0.24

Qualitative environmental differences:

	ep	-2LL	df	AIC	diffLL	diffdf	p
Model: cFullHetACE	9	7390.91	2670	2050.91	-	-	-
Model: HetACE	8	7392.27	2671	2050.27	1.36	1	0.24

Quantitative differences:

	ep	-2LL	df	AIC	diffLL	diffdf	p
Model: HetACE	8	7392.27	2671	2050.27	-	-	-
Model: HomACE	5	7398.39	2674	2050.39	6.12	3	0.11

Map reading

Qualitative genetic differences:

	ep	-2LL	df	AIC	diffLL	diffdf	p
Model: FullHetACE	9	6980.65	2503	1974.65	-	-	-
Model: HetACE	8	6983.5	2504	1975.5	2.85	1	0.09

Qualitative environmental differences:

	ep	-2LL	df	AIC	diffLL	diffdf	p
Model: cFullHetACE	9	6983.5	2503	1977.5	-	-	-
Model: HetACE	8	6983.5	2504	1975.5	0	1	1

Quantitative differences:

	ep	-2LL	df	AIC	diffLL	diffdf	p
Model: HetACE	8	6983.5	2504	1975.5	-	-	-
Model: HomACE	5	7079.69	2507	2065.69	96.19	3	0

Route memorizing

Qualitative genetic differences:

	ep	-2LL	df	AIC	diffLL	diffdf	p
Model: FullHetACE	9	6769.48	2442	1885.48	-	-	-
Model: HetACE	8	6769.48	2443	1883.48	0	1	1

Qualitative environmental differences:

	ep	-2LL	df	AIC	diffLL	diffdf	p
Model: cFullHetACE	9	6769.48	2442	1885.48	-	-	-
Model: HetACE	8	6769.48	2443	1883.48	0	1	1

Quantitative differences:

	ep	-2LL	df	AIC	diffLL	diffdf	p
Model: HetACE	8	6769.48	2443	1883.48	-	-	-
Model: HomACE	5	6894.1	2446	2002.1	124.63	3	0

Table S3. Confirmatory factor analysis and model fit indices across the six tests of spatial orientation.

Spatial orientation battery	**Factor loadings**	**S.E.**
Navigation directions (cardinal points**)**	0.736	0.017
Navigation landmarks	0.756	0.017
Map reading	0.682	0.019
Route memorizing	0.636	0.021
Large-scale perspective taking	0.582	0.022
Large-scale scanning	0.566	0.024
Model fit indices: $\chi^2 = 69.051(9)$, $p < .00005$, CFI = 0.972 TLI = 0.953, RMSEA = 0.071 SRMR. =0.026		

Table S4. Common pathway model examining the common and specific genetic (A), shared-environmental (C) and nonshared environmental variance (E) across the six tests of spatial orientation and model fit indices.

Variance specific to each test				**Percentages of A, C and E variance in each test captured by the common Navigation factor**		
Measure	**A**	**C**	**E**	**A**	**C**	**E**
Navigation directions	0.181 (0.136; 0.233)	0.001 (-0.000; 0.001)	0.274 (0.228; 0.324)	66%	100%	36%
Navigation landmarks	0.000 (-0.001, 0.001)	0.038 (0.006; 0.096)	0.394 (0.340; 0.451)	88%	53%	28%
Map reading	0.035 (0.000; 0.130)	0.000 (-0.000; 0.000)	0.506 (0.431; 0.586)	88%	100%	20%
Route memorizing	0.058 (0.005; 0.167)	0.001 (-0.078; 0.099)	0.564 (0.478; 0.654)	80%	100%	16%
Large-scale Scanning	0.000 (-0.001; 0.002)	-0.000 (-0.000; 0.000)	0.705 (0.664; 0.748)	100%	100%	10%
Large-scale Perspective-taking	0.047 (0.003; 0.139)	0.000 (0.000; 0.000)	0.597(0.524; 0.675)	82%	100%	15%
Variance common across all tests						
Navigation latent factor	0.634 (0.410; 0.912)	0.083 (-0.005; 0.430)	0.278 (0.206; 0.362)			
Model fit indices: AIC = 39177.976; χ^2 = 269.937 (148), p = 0.0000; CFI = 0.968; TLI = 0.971; RMSEA = 0.030 ; SRMR = 0.049						

Note. All paths are standardized and squared, numbers in parentheses are 95% confidence intervals around the estimates.

Table S5. Comparative model fit indices for the phenotypic models including all 16 tests of spatial skills (6 tests of spatial orientation and 10 tests of object-based spatial skills)

	Model	CFI	TLI	RMSEA	Chi^2	SRMR	Correlations between latent factors
a	1 Factor	0.890	0.873	0.061	692.730 (104), p < .001	0.059	-
b	1 Factor *accounting for g*[1]	0.894	0.862	0.067	609.795 (104), p < .001	0.053	-
c	2 Factors (Spatial Spy battery and. King's Challenge battery)	0.958	0.951	0.037	316.000 (103), p < .001	0.040	.741
d	2 Factors (Spatial Spy battery and. King's Challenge battery) *accounting for* g^1	0.961	0.949	0.041	288.468 (103), p < .001	0.038	.659
e	2 Factors (Object Manipulation and Spatial Orientation)	0.920	0.907	0.053	529.390 (103), p< .001	0.054	.847
f	2 Factors (Object Manipulation and Spatial Orientation) *accounting for* g^1	0.925	0.901	0.057	461.763 (103), p < .001	0.051	.775
g	3 Factors (Object Manipulation Navigation and Visualization)	0.953	0.944	0.041	351.870 (101), p < .001	0.041	Obj with Or = .726 Or with Sc = .948 Sc with Obj = .858
h	3 Factors (Object Manipulation Navigation and Visualization) *accounting for* g^1	0.957	0.942	0.043	306.307 (101), p < .001	0.038	Obj with Or = .633 Or with Sc = .949 Sc with Obj = .806
i	3 Factors (Object Manipulation Navigation and Visualization) and a second order common Spatial Ability factor	0.953	0.944	0.041	351.870 (101), p < .001	0.041	

j	3 Factors (Object Manipulation Navigation and Visualization) and a second order common Spatial Ability factor *accounting for g*[1]	0.957	0.942	0.043	306.307 (101), p < .001	0.038	-
k	3 Factors (Object Manipulation Navigation and Visualization) and a second order common Spatial Ability factor *accounting for g*[2]	0.951	0.941	0.044	348.789 (114), p < .001	0.041	-

[1] = g included in the model at the level of the indicators; [2] = g included in the model at the level of the first order latent factors. Models h and j and models i and are k represent two different ways f specifying the same model, therefore their model fit indices are identical.

Table S6. Genetic and environmental variance components for the hierarchical model of spatial abilities

	Variance specific to each test		Loading on first order factor	A and E variance captured by the first order factors but not shared with the general spatial ability factor	
Measure	**A**	**E**		**A**	**E**
Navigation from directions (cardinal points)	0.136 (0.094; 0.186)	0.255 (0.214; 0.309)	0.777 (0.755; 0.799)	0.030	0.048
Navigation from landmarks	0.072 (0.025; 0.145)	0.419 (0.356; 0.487)	0.712 (0.685; 0.740)	0.025	0.041
Map reading	0.016; (-0.016; 0.133)	0.511 (0.438; 0.588)	0.687 (0.658; 0.717)	0.023	0.036
Route memorizing	0.059 (0.007; 0.160)	0.565 (0.483; 0.654)	0.612 (0.577; 0.647)	0.018	0.029
Cross-sections	0.075 (0.024; 0.155)	0.556 (0.491; 0.625)	0.606 (0.573; 0.639)	0.100	0.029
2D drawing	0.010 (-0.046; 0.173)	0.470 (0.398; 0.549)	0.721 (0.694; 0.748)	0.139	0.041
Pattern assembly	0.028 (-0.000; 0.128)	0.527 (0.456; 0.602)	0.666 (0.637; 0.696)	0.100	0.029
Shapes rotation	0.051 (0.009; 0.125)	0.476 (0.412; 0.543)	0.688 (0.658; 0.718)	0.128	0.036
Mechanical reasoning	0.150 (0.093; 0.221)	0.473 (0.405; 0.546)	0.614; (0.579; 0.648)	0.100	0.029
Paper folding	0.107 (0.059; 0.169)	0.366 (0.302; 0.429)	0.726 (0.698; 0.754)	0.143	0.042
3D drawing	0.093 (0.046; 0.155)	0.303 (0.250; 0.362)	0.777 (0.752; 0.801)	0.160	0.047
Small-scale perspective taking	0.154 (0.081; 0.250)	0.602 (0.512; 0.697)	0.494 (0.453; 0.535)	0.000	0.000
Large-scale scanning	0.000 (-0.001; 0.002)	0.741 (0.698; 0.783)	0.509 (0.468; 0.550)	0.000	0.000

Large-scale perspective-taking	0.024 (-0.000; 0.136)	0.608 (0.538; 0.688)	0.604 (0.571; 0.636)	0.000	0.000
Elithorne Mazes	0.176 (0.096; 0.284)	0.532 (0.438; 0.636)	0.537 (0.486; 0.604)	0.000	0.000
Mazes	0.134 (0.067; 0.223)	0.577 (0.497; 0.664)	0.537 (0.495; 0.579)	0.000	0.000
Variance captured by the first order factors			**Loading on second order factor**	**A and E variance captured by the general spatial ability factor**	
Navigation latent factor	0.051 (0.011; 0.122)	0.085 (0.041; 0.145)	0.929 (0.904; 0.954)	0.726	0.138
Object-based latent factor	0.265 (0.198; 0.339)	0.075 (0.028; 0.145)	0.812 (0.776; 0.848)	0.551	0.104
Visualization latent factor	0.000 (0.000; 0.000)	0.000 (0.000; 0.000)	1.00 (1.00; 1.000)	0.837	0.163
Variance common to all tests captured by the second order Spatial Ability factor					
Common factor of Spatial ability	0.837 (0.779; 0.894)	0.163 (0.110; 0.225)	-	-	-
Model fit indices: AIC = 82828.772; χ^2 = 1681.128 (1040), p = 0.0000; CFI = 0.941; TLI = 0.944; RMSEA = 0.026 ; SRMR = 0.056					

Figures

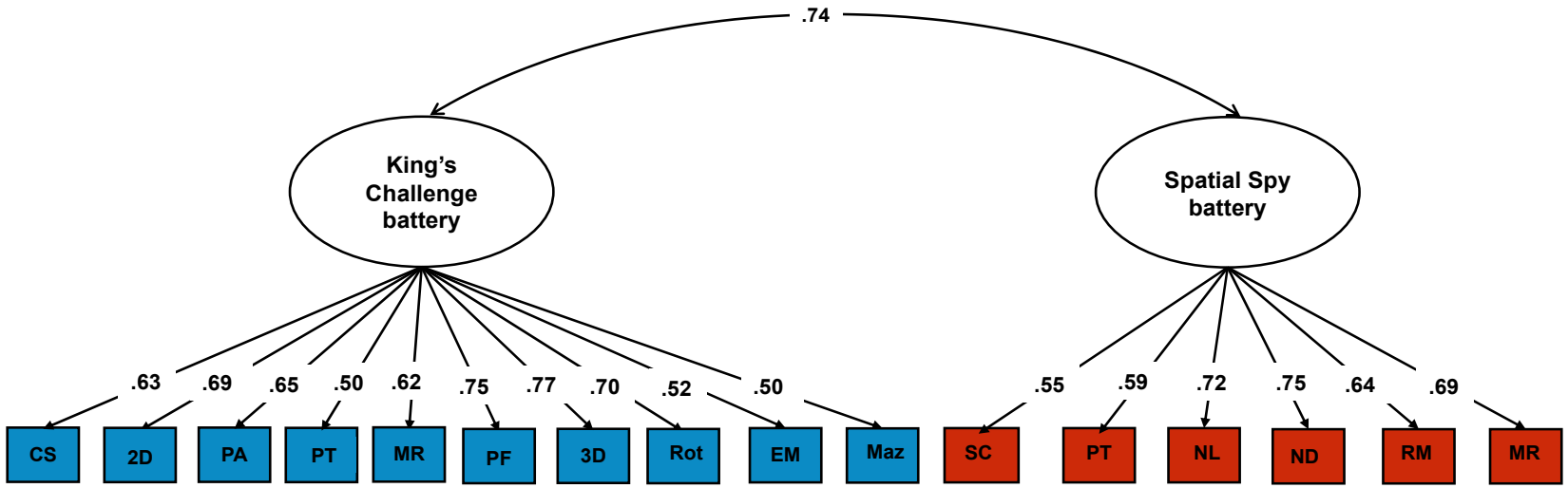

Figure S1. Two-factor model of spatial ability separating across the two spatial batteries administered at two different time points and following two different formats (online traditional psychometric assessment – The King's Challenge battery – vs. virtual environment – The Spatial Spy battery). ND = navigation based on directions, NL = navigation based on landmarks, MR = map reading, RM = route memory, PT = perspective taking, SC = scanning, CS = cross-section, 2d = 2d drawing, PA = pattern assembly, EM =Elithorn Mazes, MR = Mechanical Reasoning, PF = paper folding, 3d = 3d drawing, Rot = mental rotation, PT = perspective taking, Maz = mazes; Model fit indices are reported in Table S5.

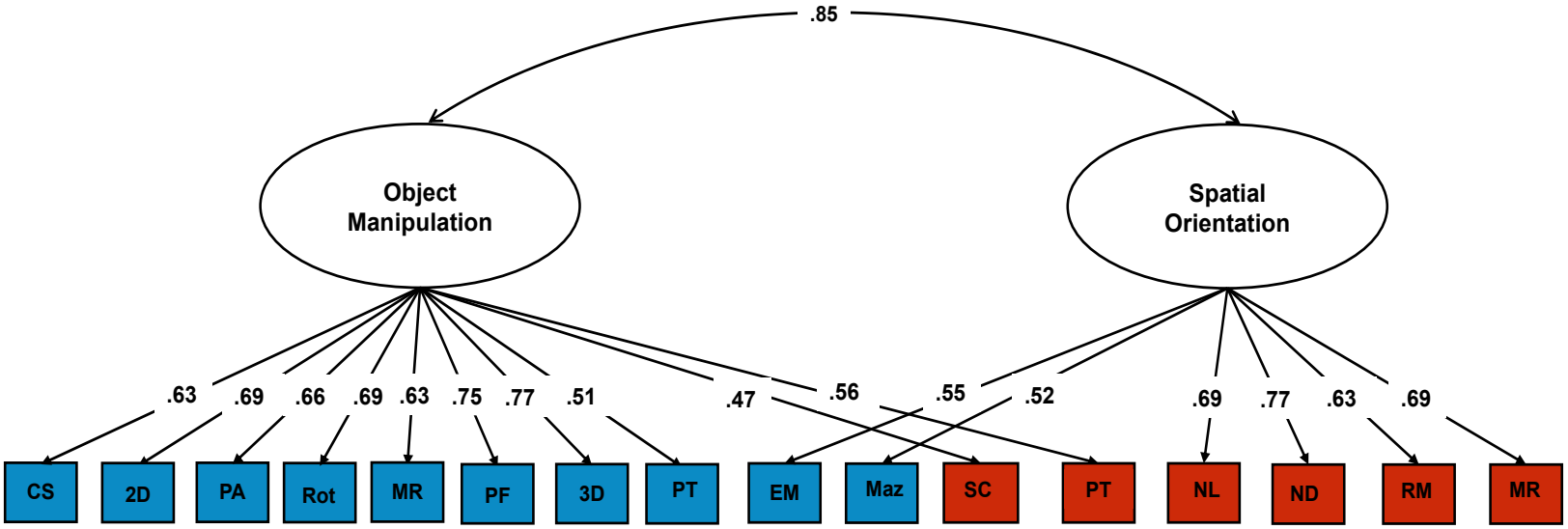

Figure S2. Two-factor model of spatial ability separating objects-based and orienting tests combining putatively separate categories of tests administered across the two batteries. ND = navigation based on directions, NL = navigation based on landmarks, MR = map reading, RM = route memory, PT = perspective taking, SC = scanning, CS = cross-sections, 2d = 2d drawing, PA = pattern assembly, EM =Elithorn Mazes, MR = Mechanical Reasoning, PF = paper folding, 3d = 3d drawing, Rot = mental rotation, PT = perspective taking, Maz = mazes; Model fit indices are reported in Table S5.

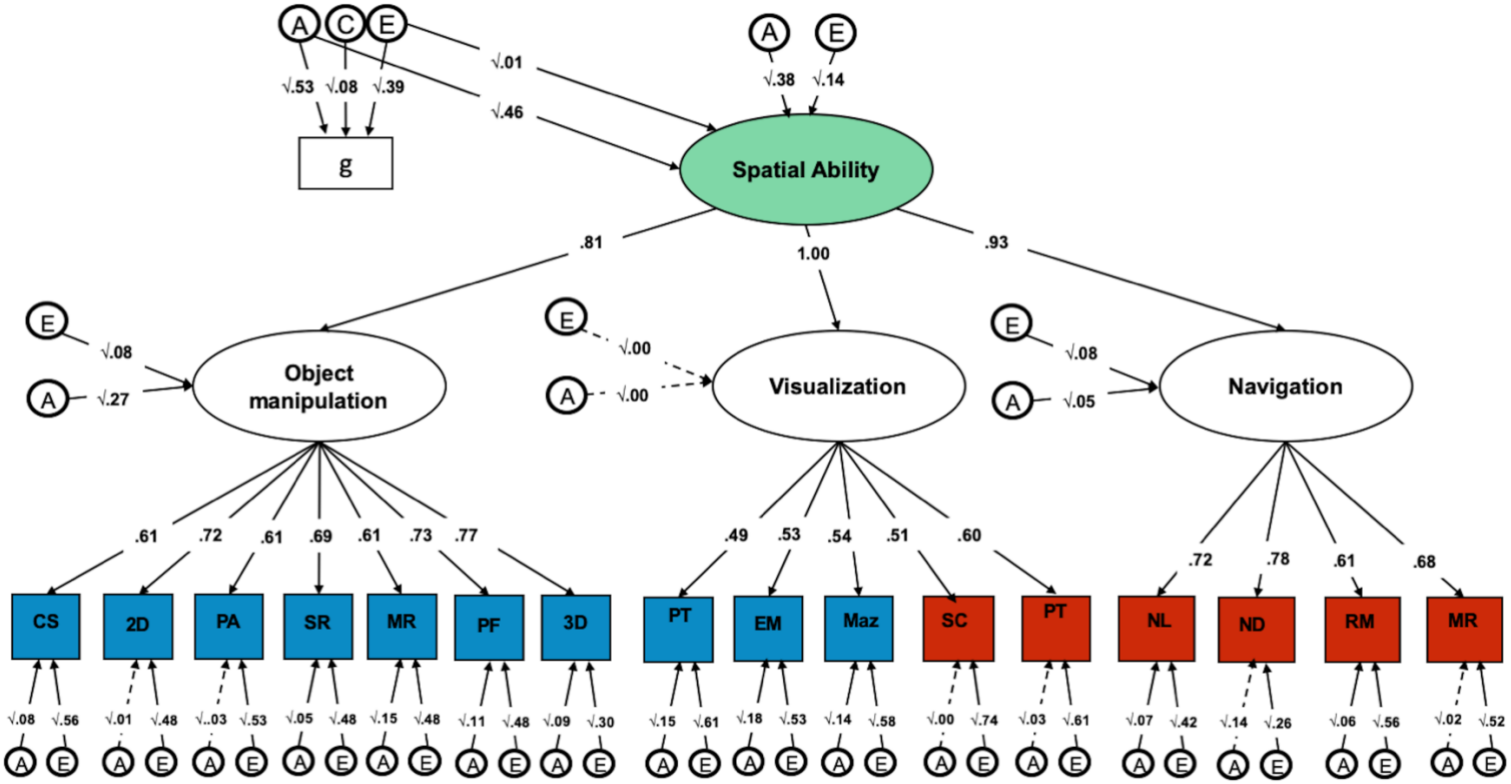

Figure S3. Hierarchical common pathway model exploring the genetic and environmental association between *g* and the common spatial ability factor. ND = navigation based on directions, NL = navigation based on landmarks, MR = map reading, RM = route memory, PT = perspective taking, SC = scanning, CS = cross-sections, 2d = 2d drawing, PA = pattern assembly, EM =Elithorn Mazes, MR = Mechanical Reasoning, PF = paper folding, 3d = 3d drawing, Rot = mental rotation, PT = perspective taking, Maz = mazes, *g* = general cognitive ability; Model fit indices are reported in Table S5.

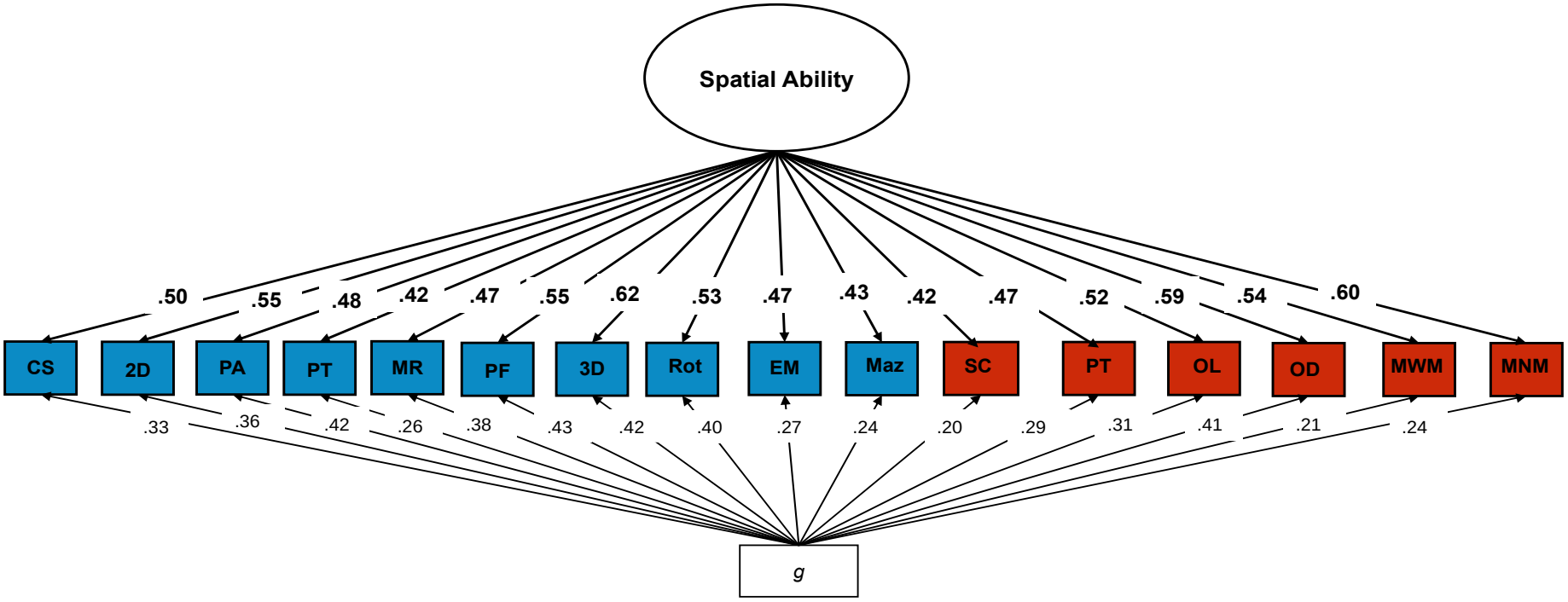

Figure S4. One-factor model of spatial ability including the 16 spatial tests accounting for *g* at the level of the indicator (each test); see Table S5 for model fit indices. ND = navigation based on directions, NL = navigation based on landmarks, MR = map reading, RM = route memory, PT = perspective taking, SC = scanning, CS = cross-sections, 2d = 2d drawing, PA = pattern assembly, EM = Elithorn Mazes, MR = Mechanical Reasoning, PF = paper folding, 3d = 3d drawing, Rot = mental rotation, PT = perspective taking, Maz = mazes, *g* = general cognitive ability.

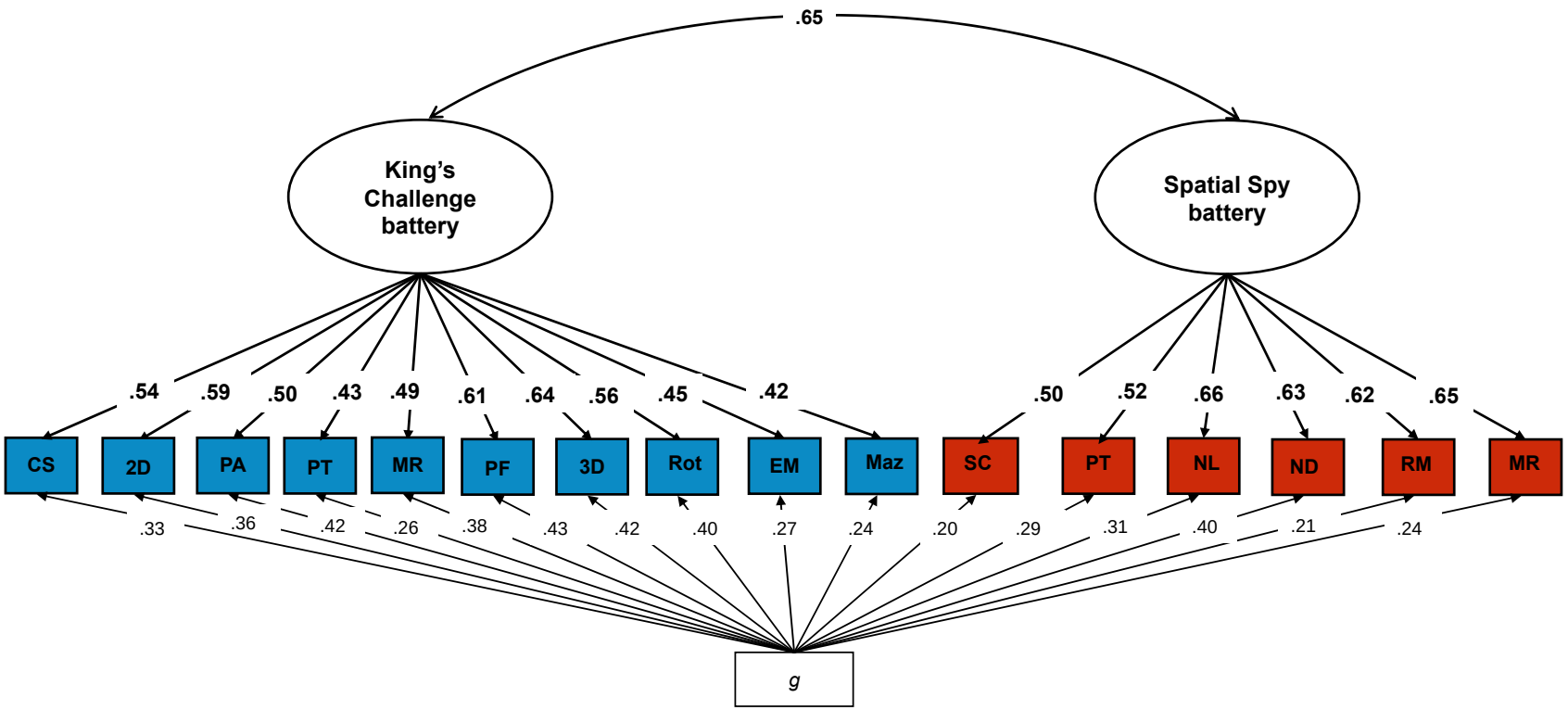

Figure S5. Two-factor model of spatial ability separating the two batteries accounting for *g* at the level of the indicators (each test). Model fit indices are reported in Table S5. ND = navigation based on directions, NL = navigation based on landmarks, MR = map reading, RM = route memory, PT = perspective taking, SC = scanning, CS = cross-section, 2d = 2d drawing, PA = pattern assembly, EM =Elithorn Mazes, MR = Mechanical Reasoning, PF = paper folding, 3d = 3d drawing, Rot = mental rotation, PT = perspective taking, Maz = mazes, *g* = general cognitive ability.

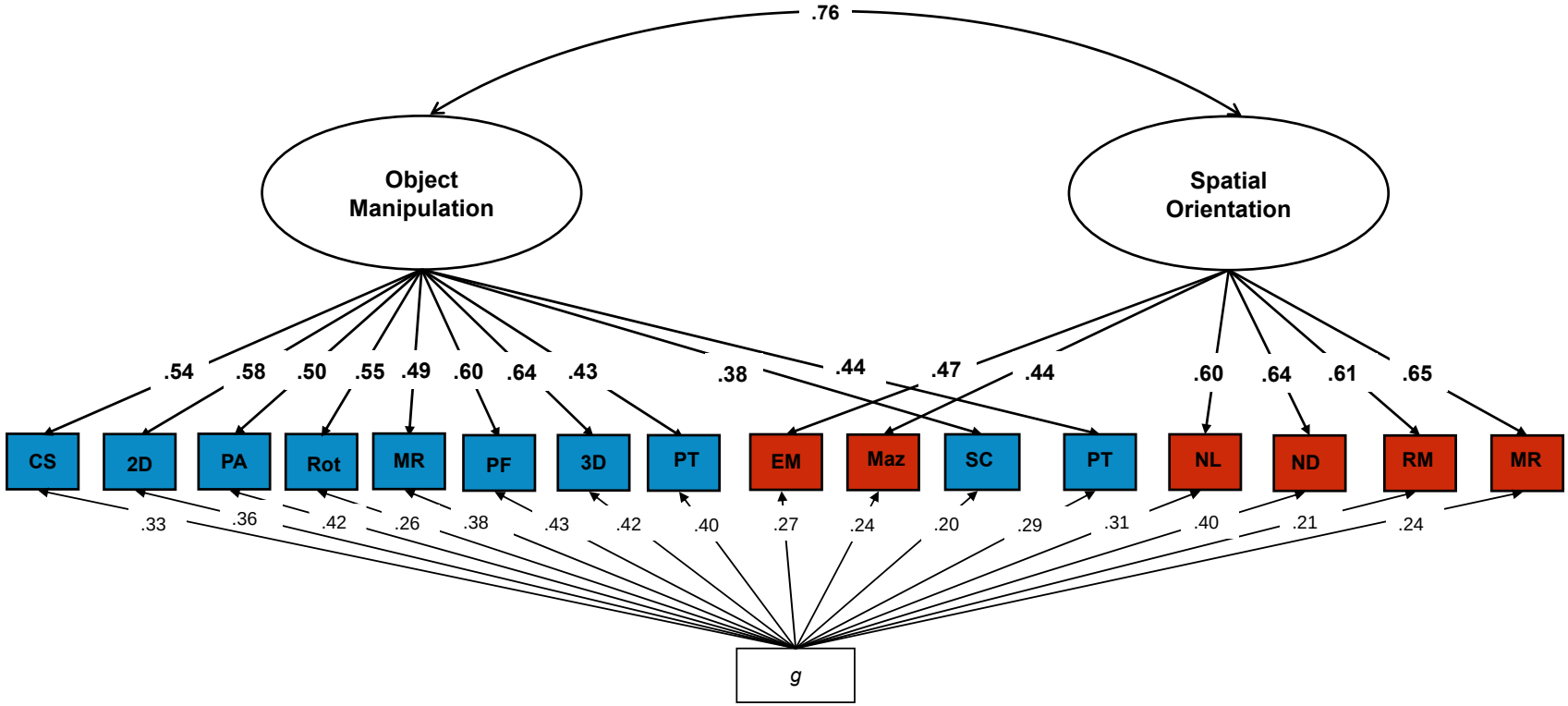

Figure S6. Two-factor model of spatial ability separating objects-based and orienting tests combining putatively different aspects of spatial skills across the two batteries accounting for *g* at the level of the indicators (each test). Model fit indices are reported in Table S5. ND = navigation based on directions, NL = navigation based on landmarks, MR = map reading, RM = route memory, PT = perspective taking, SC = scanning, CS = cross-sections, 2d = 2d drawing, PA = pattern assembly, EM =Elithorn Mazes, MR = Mechanical Reasoning, PF = paper folding, 3d = 3d drawing, Rot = mental rotation, PT = perspective taking, Maz = mazes, *g* = general cognitive ability.

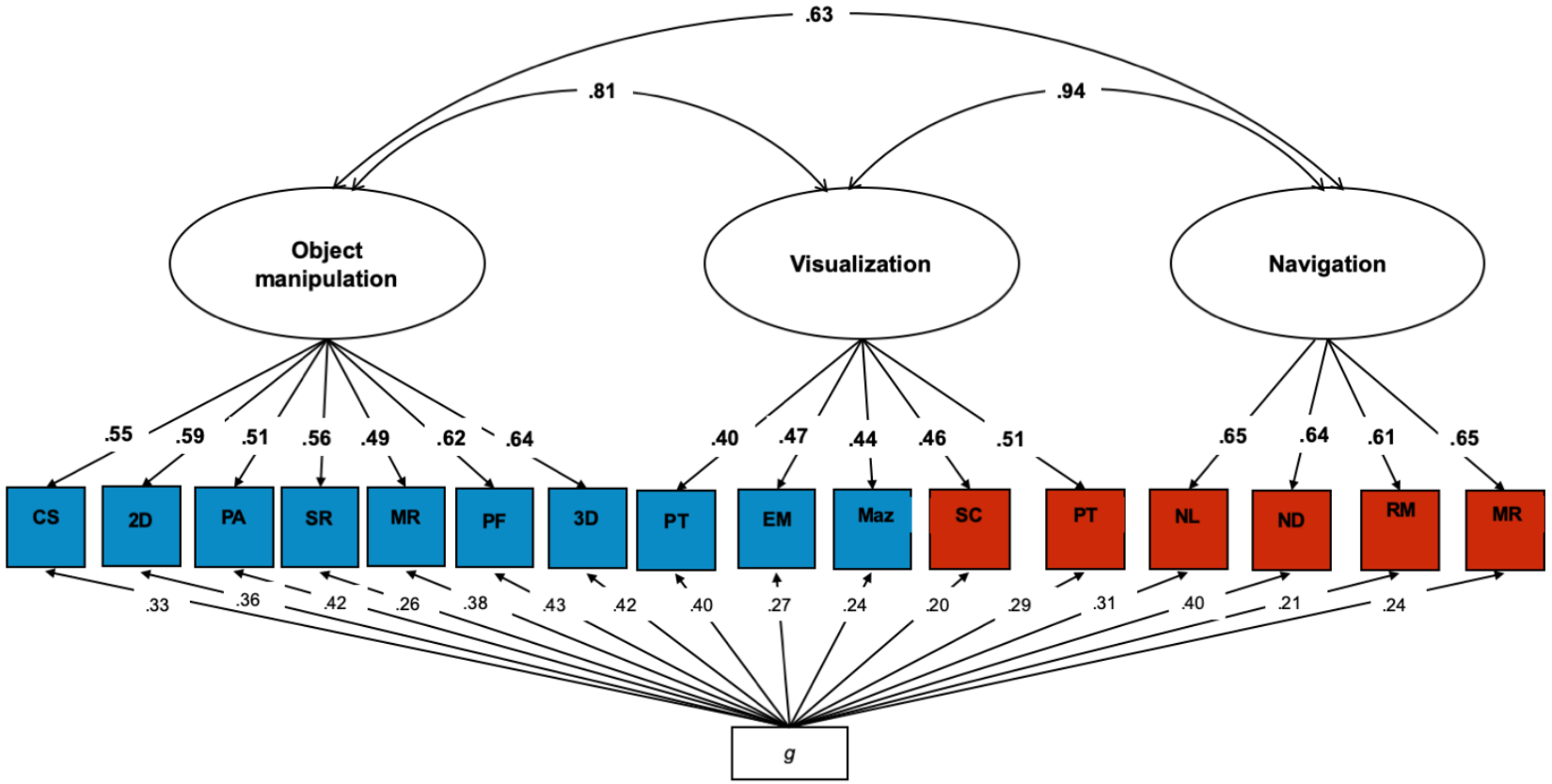

Figure S7. Three-factor model of spatial ability separating objects-based, navigation and visualization tests across the two batteries accounting for *g*. Model fit indices are reported in Table S5. ND = navigation based on directions, NL = navigation based on landmarks, MR = map reading, RM = route memory, PT = perspective taking, SC = scanning, CS = cross-sections, 2d = 2d drawing, PA = pattern assembly, EM =Elithorn Mazes, MR = Mechanical Reasoning, PF = paper folding, 3d = 3d drawing, Rot = mental rotation, PT = perspective taking, Maz = mazes, *g* = general cognitive ability.

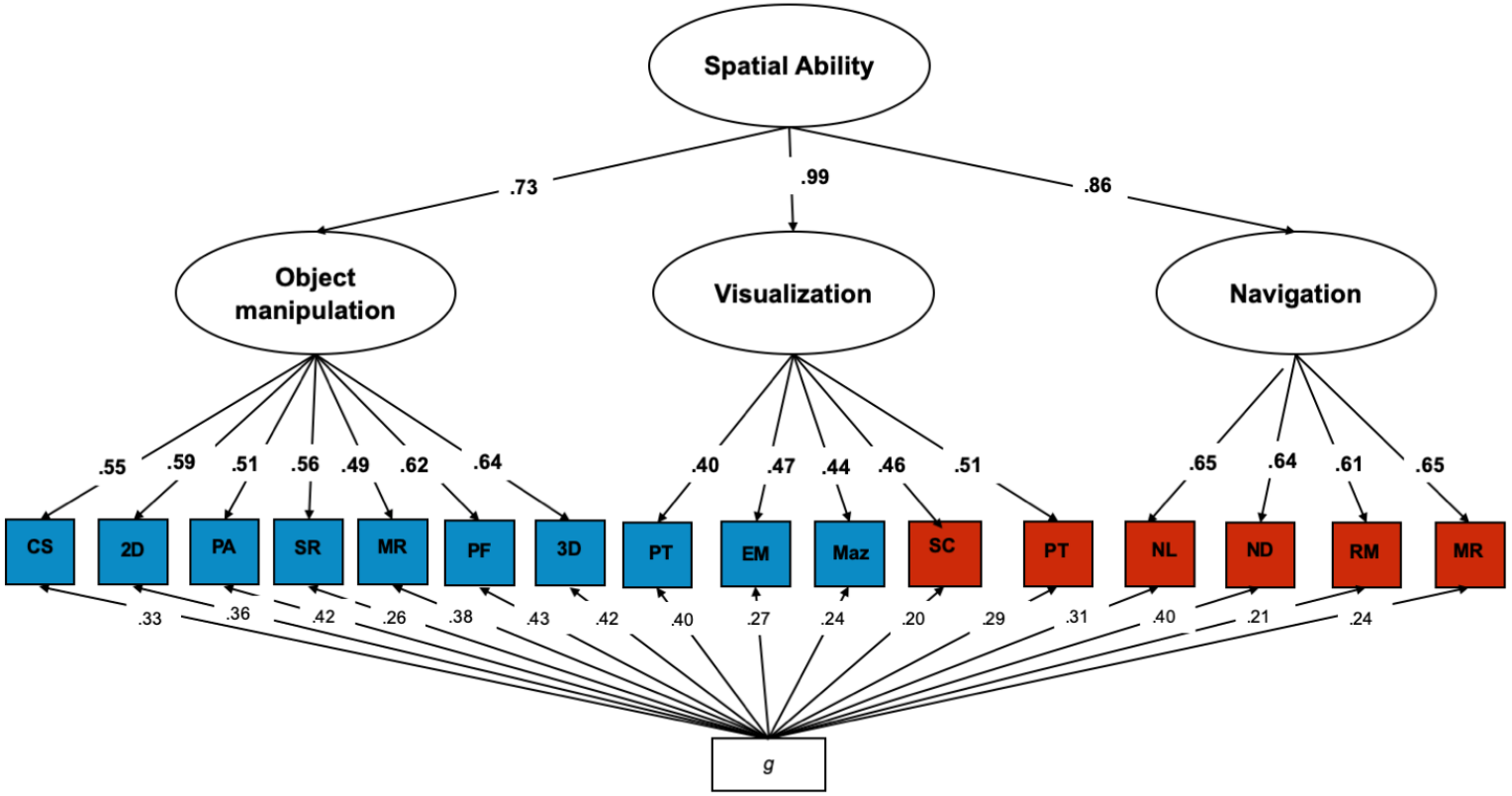

Figure S8. Hierarchical model including three first-order spatial factors (Navigation, Object-based and Visualization) and a second-order common factor of Spatial ability, accounting for *g* at the level of the indicators (each test). Model fit indices are reported in Table S5. ND = navigation based on directions, NL = navigation based on landmarks, MR = map reading, RM = route memory, PT = perspective taking, SC = scanning, CS = cross-sections, 2d = 2d drawing, PA = pattern assembly, EM =Elithorn Mazes, MR = Mechanical Reasoning, PF = paper folding, 3d = 3d drawing, Rot = mental rotation, PT = perspective taking, Maz = mazes, *g* = general cognitive ability.

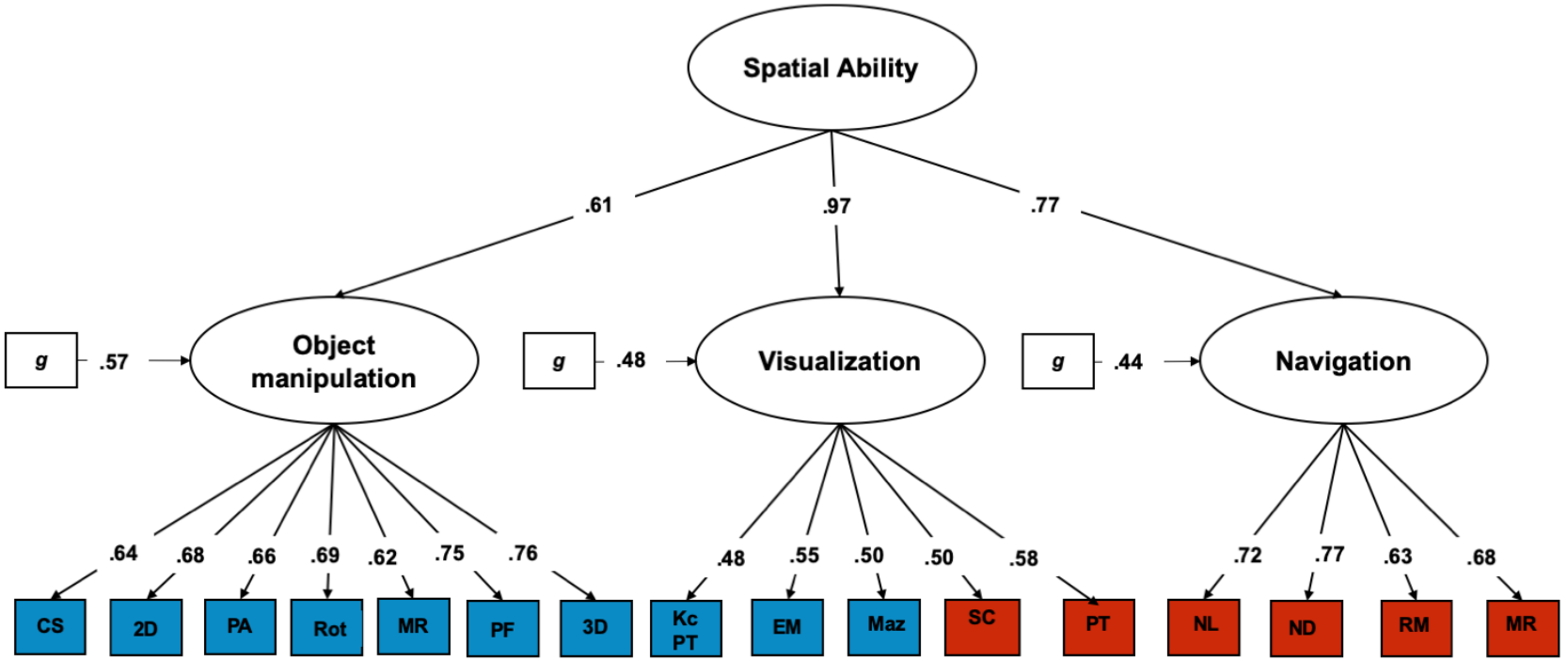

Figure S9. Hierarchical model including three first-order spatial factors (Navigation, Object-based and Visualization) and a second-order common factor of Spatial ability, accounting for *g* at the level of the first-order factors. Model fit indices are reported in Table S5. ND = navigation based on directions, NL = navigation based on landmarks, MR = map reading, RM = route memory, PT = perspective taking, SC = scanning, CS = cross-sections, 2d = 2d drawing, PA = pattern assembly, EM =Elithorn Mazes, MR = Mechanical Reasoning, PF = paper folding, 3d = 3d drawing, Rot = mental rotation, PT = perspective taking, Maz = mazes, *g* = general cognitive ability.

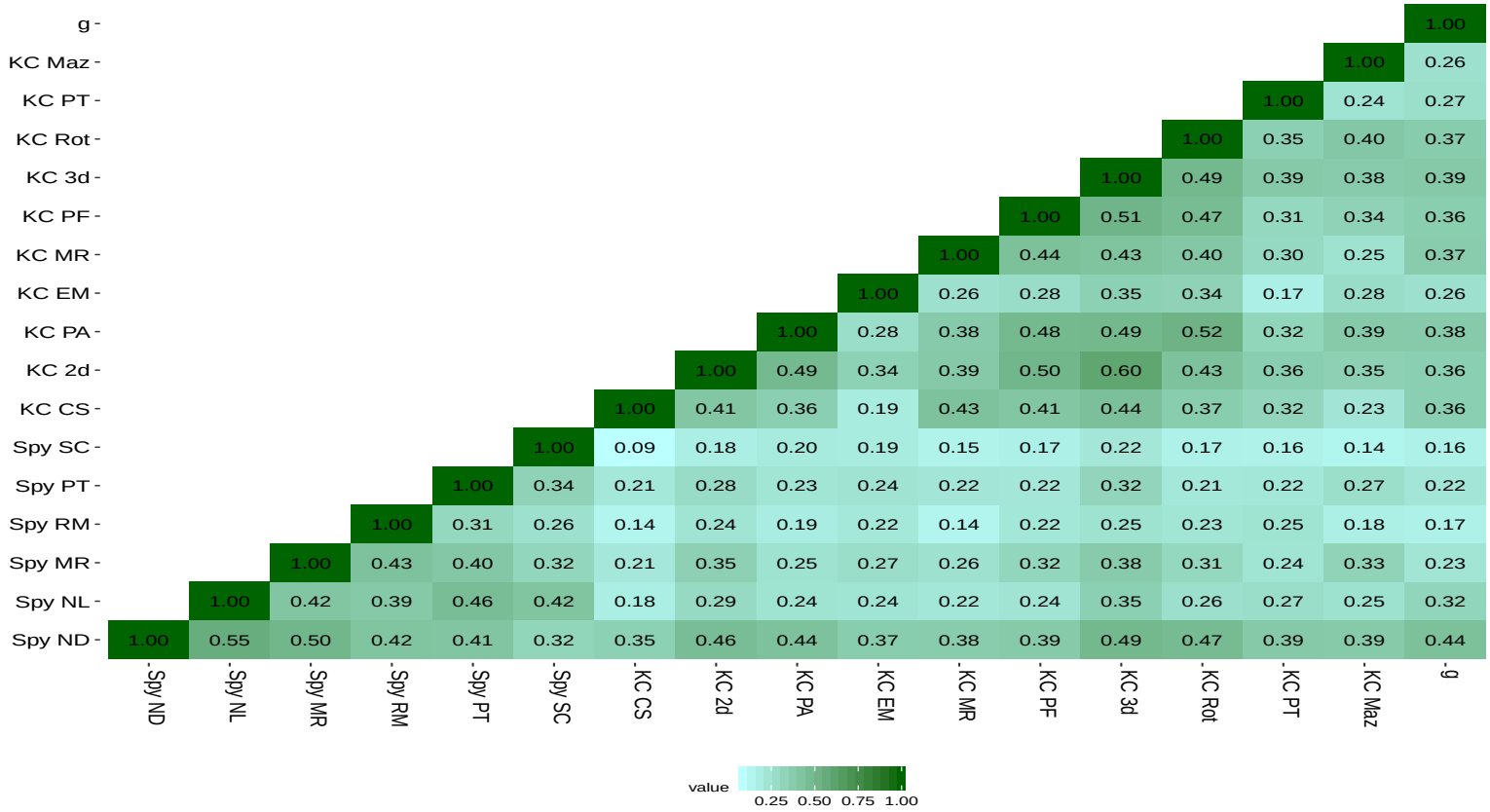

Figure S10. Correlations between all spatial tests and general cognitive ability using data from the other half of the phenotypic sample. Spy = Spatial Spy battery (large-scale), KC = King's Challenge battery (small-scale), ND = navigation based on directions, NL = navigation based on landmarks, MR = map reading, RM = route memory, PT = perspective taking, SC = scanning, CS = cross-sections, 2d = 2d drawing, PA = pattern assembly, EM =Elithorn Mazes, MR = Mechanical Reasoning, PF = paper folding, 3d = 3d drawing, Rot = mental rotation, PT = perspective taking, Maz = mazes, *g* = general cognitive ability. All correlations were significant at the $p < .001$ level; variables were residualized for age and sex and standardized prior to analysis.

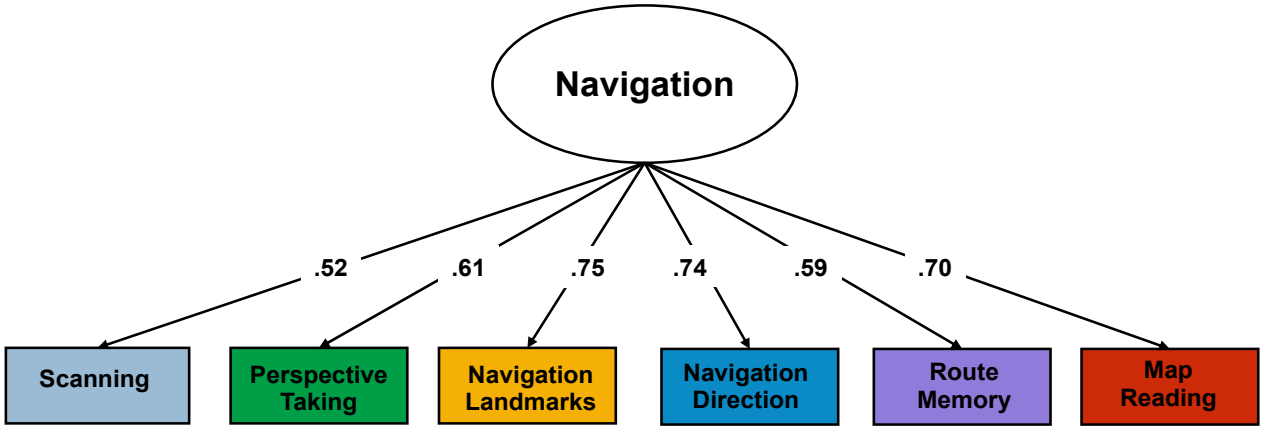

Figure S11. Factor structure of navigation abilities conducted examining the other half of the sample; CFI = 0.968, TLI = 0.947, RMSEA = 0.073, SRMR = 0.027.

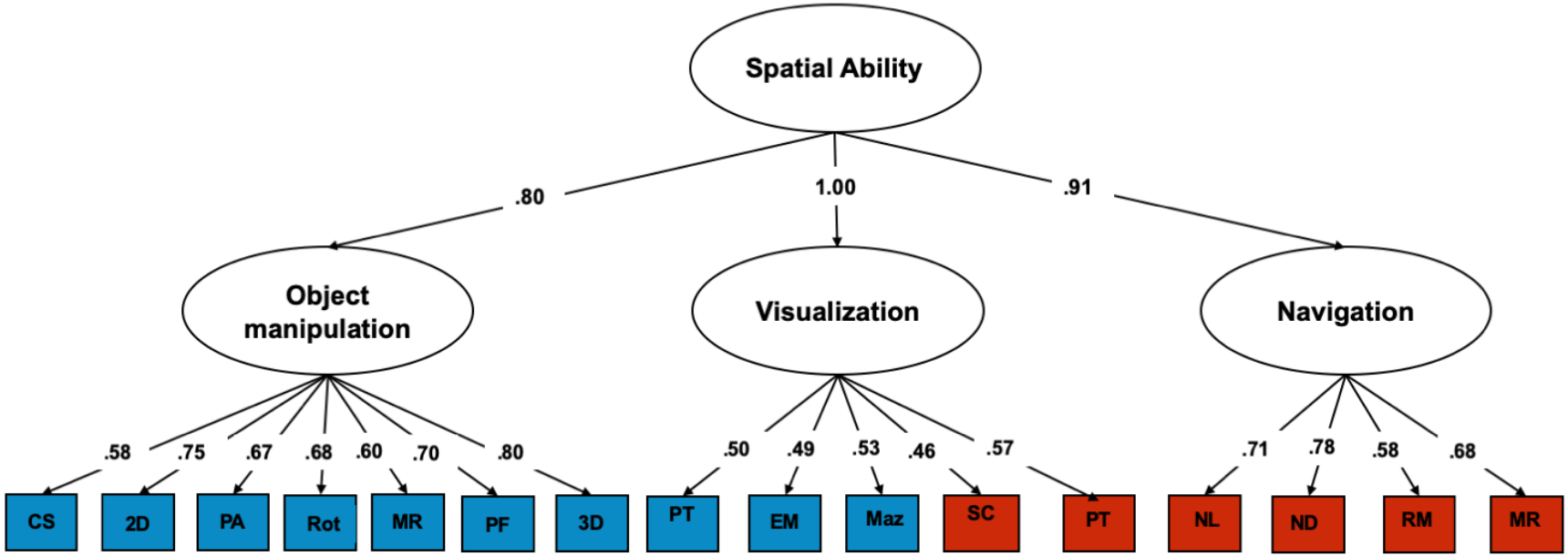

Figure S12. Hierarchical model of spatial abilities conducted in the other half of the sample; CFI = 0.939, TLI = 0.928, RMSEA = 0.046, SRMR = 0.050.