Supplementary Materials: The format of the cognitive map depends on the structure of the environment

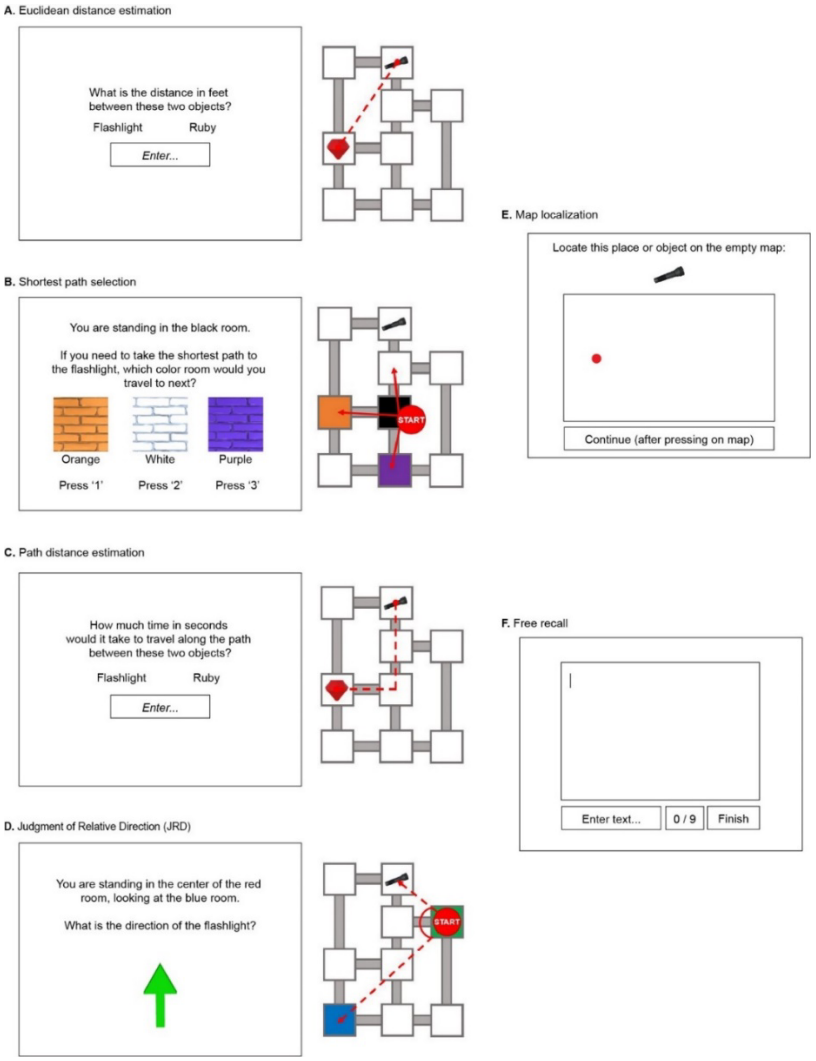

Figure S1: Spatial memory tasks. A-D) Euclidean distance estimation, shortest path selection, path distance estimation, and judgment of relative direction (JRD) tasks. Left – Example trial screen for each task; Right – Schematic depicting the choice the participant needs to make in an example trial. E-F) Map localization and Free recall tasks: Example trial screens.

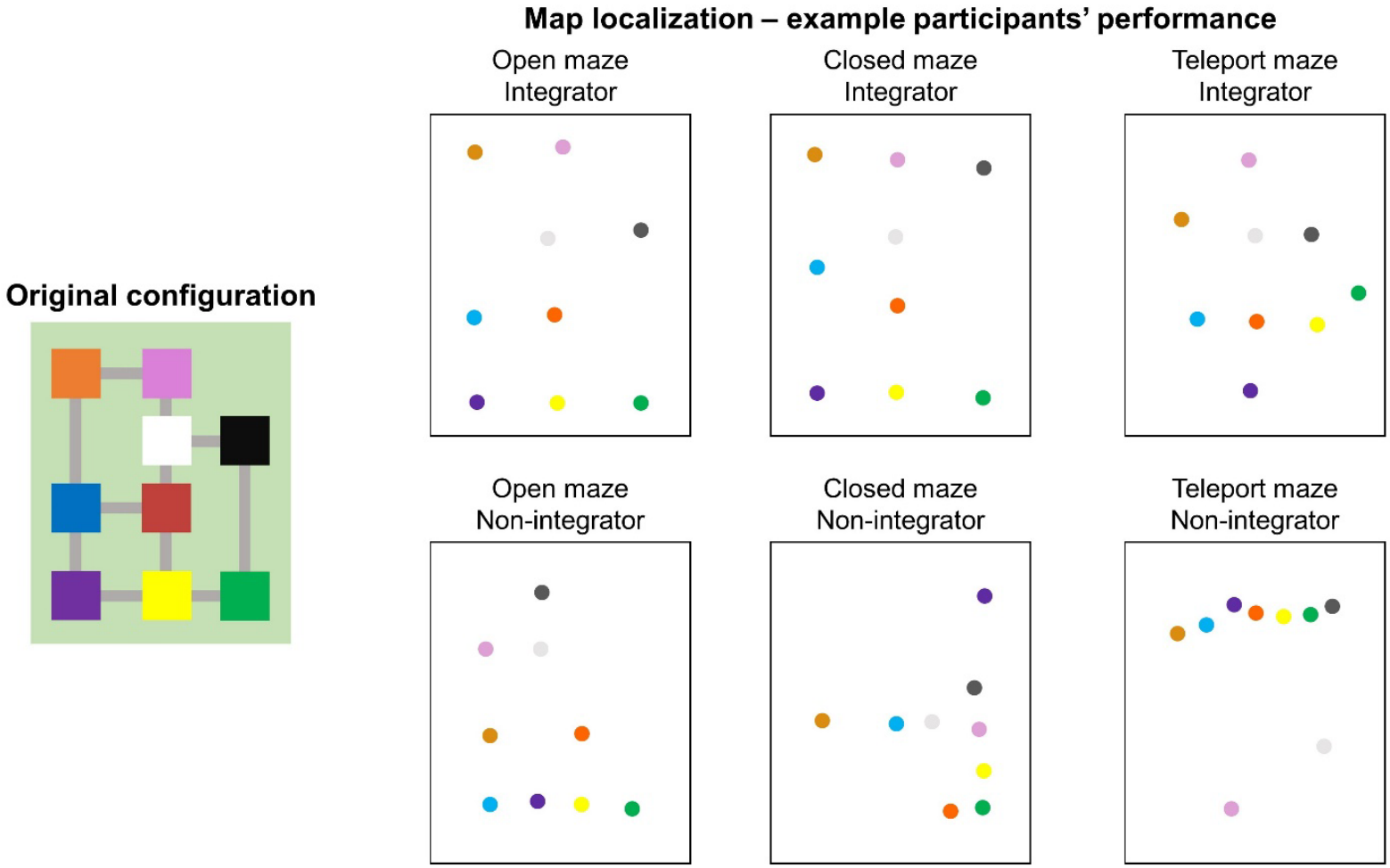

Figure S2: Map localization example performance. Left – the original configuration of rooms in the environment. Right – example configurations rooms in the map localization task, from six example participants (three integrators and three non-integrators, from the three experimental environments; each rectangle represents one participant's performance). Each colored dot represents a participant's localization of the correspondingly colored room on a blank map of the environment. The localization of the nine objects task is not presented here.

Table S1: full statistical results. (Continued on next page)

Red - significant p-values (p<0.05 after FDR correction), strong effect sizes (Cohen's d > 0.8), or strong Bayesian evidence (BF10 > 10). Orange - marginal significance (0.05<p<0.1 after FDR correction), medium effect sizes (0.5<d<0.8), or medium Bayesian evidence (3<BF10<10).

Analysis type	Task	Measure	Environment	Mean1	Mean2	SD1	SD2	Test type	Multiple comparisons correction	DF	T	P-value	Effect size (Cohen's d)	Bayes factor (BF10)	Post-hoc power analysis (required sample size per group for 80% power)
Route choice efficiency	**Learning task**	Route length vs. random walk	Open maze	0.70	-	0.03	-	One-sample one-tailed t-test	FDR, across mazes	19	116.1	2.22E-28	25.96	1.29E+25	2
			Closed maze	0.50	-	0.19	-	One-sample one-tailed t-test	FDR, across mazes	19	11.8	2.46E-10	2.65	6.05E+07	3
			Teleport maze	0.14	-	0.19	-	One-sample one-tailed t-test	FDR, across mazes	19	3.3	0.002	0.73	22.44	14
Task accuracy	**Euclidean distance estimation (Fig. 2A)**	Correlation between real and estimated distances	Open maze	0.72	-	0.16	-	One-sample one-tailed t-test	FDR, across mazes	19	20.3	3.53E-14	4.55	4.72E+11	3
			Closed maze	0.42	-	0.34	-	One-sample one-tailed t-test	FDR, across mazes	19	5.5	1.98E-05	1.23	1831.86	6
			Teleport maze	0.22	-	0.24	-	One-sample one-tailed t-test	FDR, across mazes	19	4.1	3.29E-04	0.91	105.42	9
			Comparison: open maze vs. closed maze	0.72	0.42	0.16	0.34	One-way ANOVA	Tukey-Kramer test	38	3.7	0.001	1.16	39.94	13
			Comparison: open maze vs. teleport maze	0.72	0.22	0.16	0.24	One-way ANOVA	Tukey-Kramer test	38	7.8	2.15E-07	2.45	3.24E+06	4
			Comparison: closed maze vs. teleport maze	0.42	0.22	0.34	0.24	One-way ANOVA	Tukey-Kramer test	38	2.1	0.050	0.67	1.71	-
	Map localization (Fig. 2B)	Distance real-estimated vs. random placement distance	Open maze	3.05	-	0.64	-	One-sample one-tailed t-test	FDR, across mazes	19	21.3	1.54E-14	4.76	1.03E+12	2
			Closed maze	1.69	-	1.36	-	One-sample one-tailed t-test	FDR, across mazes	19	5.5	1.80E-05	1.24	1996.57	6
			Teleport maze	1.04	-	0.88	-	One-sample one-tailed t-test	FDR, across mazes	19	5.3	2.22E-05	1.18	1148.94	7
			Comparison: open maze vs. closed maze	3.05	1.69	0.64	1.36	One-way ANOVA	Tukey-Kramer test	38	4.0	2.28E-04	1.27	96.36	11

		Comparison: open maze vs. teleport maze	3.05	1.04	0.64	0.88	One-way ANOVA	Tukey-Kramer test	38	8.2	1.41E-07	2.60	1.19E+07	4
		Comparison: closed maze vs. teleport maze	1.69	1.04	1.36	0.88	One-way ANOVA	Tukey-Kramer test	38	1.8	0.113	0.57	1.07	-
JRD (Fig. 2C)	90 minus angular error	Open maze	50.89	-	27.95	-	One-sample one-tailed t-test	FDR, across mazes	19	8.1	1.29E-07	1.82	2.35E+05	4
		Closed maze	27.95	-	33.07	-	One-sample one-tailed t-test	FDR, across mazes	18	3.7	0.001	0.85	46.80	11
		Comparison: open maze vs. closed maze	50.89	27.95	27.95	33.07	Two-samples two-tailed t-test	-	37	2.3	0.025	0.75	2.53	29
Path distance estimation (Fig. 2D)	Correlation between real and estimated distances	Open maze	0.83	-	0.11	-	One-sample one-tailed t-test	FDR, across mazes	19	34.3	2.27E-18	7.66	4.28E+15	2
		Closed maze	0.51	-	0.31	-	One-sample one-tailed t-test	FDR, across mazes	19	7.3	5.12E-07	1.62	5.09E+04	2
		Teleport maze	0.33	-	0.31	-	One-sample one-tailed t-test	FDR, across mazes	19	4.7	7.53E-05	1.05	386.42	3
		Comparison: open maze vs. closed maze	0.83	0.51	0.11	0.31	One-way ANOVA	Tukey-Kramer test	38	4.2	9.86E-04	1.34	167.18	10
		Comparison: open maze vs. teleport maze	0.83	0.33	0.11	0.31	One-way ANOVA	Tukey-Kramer test	38	6.8	3.63E-07	2.16	2.36E+05	5
		Comparison: closed maze vs. teleport maze	0.51	0.33	0.31	0.31	One-way ANOVA	Tukey-Kramer test	38	1.9	0.074	0.59	1.22	-
Shortest path selection (Fig. 2E)	Percent correct minus chance (0.5)	Open maze	0.42	-	0.06	-	One-sample one-tailed t-test	FDR, across mazes	19	30.2	2.39E-17	6.75	4.63306E+14	2
		Closed maze	0.28	-	0.16	-	One-sample one-tailed t-test	FDR, across mazes	19	7.7	2.05E-07	1.73	1.18E+05	4
		Teleport maze	0.14	-	0.18	-	One-sample one-tailed t-test	FDR, across mazes	19	3.4	0.001	0.77	30.52	12
		Comparison: open maze vs. closed maze	0.42	0.28	0.06	0.16	One-way ANOVA	Tukey-Kramer test	38	3.5	0.012	1.09	24.26	15
		Comparison: open maze vs. teleport maze	0.42	0.14	0.06	0.18	One-way ANOVA	Tukey-Kramer test	38	6.7	2.15E-07	2.11	1.50E+05	5

			Comparison: closed maze vs. teleport maze	0.28	0.14	0.16	0.18	One-way ANOVA	Tukey-Kramer test	38	2.7	0.006	0.86	4.93	23
Free recall order	**Free recall (Fig. 2F)**	Recall relation to inter-item Euclidean distance	Open maze	11.64	-	13.55	-	One-sample one-tailed t-test	FDR, across mazes	19	3.8	0.002	0.86	67.04	10
			Closed maze	5.51	-	9.17	-	One-sample one-tailed t-test	FDR, across mazes	19	2.7	0.011	0.60	7.41	19
			Teleport maze	-0.26	-	7.10	-	One-sample one-tailed t-test	FDR, across mazes	19	0.2	0.564	0.04	0.20	-
		Recall relation to inter-item path distance	Open maze	15.41	-	18.69	-	One-sample one-tailed t-test	FDR, across mazes	19	3.7	0.002	0.82	49.42	11
			Closed maze	7.94	-	12.97	-	One-sample one-tailed t-test	FDR, across mazes	19	2.7	0.010	0.61	8.15	19
			Teleport maze	0.06	-	0.21	-	One-sample one-tailed t-test	FDR, across mazes	19	1.2	0.121	0.27	0.77	-
Evidence for use of graph knowledge	**Learning task (Fig. 3B)**	Shorter graph length preference	Open maze	0.06	-	0.20	-	One-sample one-tailed t-test	FDR, across mazes	19	1.4	0.086	0.32	1.01	-
			Closed maze	0.20	-	0.22	-	One-sample one-tailed t-test	FDR, across mazes	19	4.2	5.02E-04	0.94	133.43	9
			Comparison: open maze vs. closed maze	0.06	0.20	0.20	0.22	Two-samples two-tailed t-test	-	38	2.1	0.042	0.67	1.72	36
	Shortest path selection (Fig. 3C)	Shorter graph length preference	Open maze	0.08	-	0.24	-	One-sample one-tailed t-test	FDR, across mazes	19	1.5	0.072	0.34	1.17	-
			Closed maze	0.18	-	0.24	-	One-sample one-tailed t-test	FDR, across mazes	19	3.3	0.004	0.73	22.32	14
			Comparison: open maze vs. closed maze	0.08	0.18	0.24	0.24	Two-samples two-tailed t-test	-	38	1.2	0.224	0.39	0.56	-
		Shorter graph length preference (using only decision points)	Open maze	0.11	-	0.31	-	One-sample one-tailed t-test	FDR, across mazes	19	1.6	0.068	0.35	1.22	-
			Closed maze	0.25	-	0.25	-	One-sample one-tailed t-test	FDR, across mazes	19	4.5	2.67E-04	1.00	232.93	8
			Comparison: open maze vs. closed maze	0.11	0.25	0.31	0.25	Two-samples two-tailed t-test	-	38	1.6	0.123	0.50	0.82	-
	Euclidean distance estimation (Fig. 3D)	Correlation to Euclidean distance vs. correlation to path distance	Open maze	0.72	0.74	0.16	0.17	Paired-samples two-tailed t-test	FDR, across mazes	19	0.9	0.381	0.20	0.33	-

			Closed maze	0.42	0.46	0.34	0.34	Paired-samples two-tailed t-test	FDR, across mazes	19	3.2	0.009	0.72	10.24	18
			Comparison: open maze vs. closed maze	0.01	0.04	0.06	0.06	Two-samples two-tailed t-test	-	38	1.7	0.093	0.55	0.99	-
	Map localization (Fig. 3E)	Correlation to Euclidean distance vs. correlation to equidistant graph distance	Open maze	0.50	0.65	0.64	0.56	Paired-samples two-tailed t-test	FDR, across mazes	19	5.4	4.83E-05	1.21	766.57	8
			Closed maze	1.86	1.69	1.36	1.07	Paired-samples two-tailed t-test	FDR, across mazes	19	2.2	0.043	0.48	1.56	-
			Teleport maze	2.51	2.17	0.88	0.81	Paired-samples two-tailed t-test	FDR, across mazes	19	5.8	3.98E-05	1.30	1705.63	7
			Comparison: open maze vs. closed maze	-0.15	0.17	0.12	0.35	One-way ANOVA	Tukey-Kramer test	38	3.8	9.36E-04	1.21	58.00	12
			Comparison: open maze vs. teleport maze	-0.15	0.34	0.12	0.26	One-way ANOVA	Tukey-Kramer test	38	7.6	6.51E-07	2.39	1.80E+06	4
			Comparison: closed maze vs. teleport maze	0.17	0.34	0.35	0.26	One-way ANOVA	Tukey-Kramer test	38	1.7	0.107	0.55	1.02	-
Individual variability	**Euclidean distance estimation (Fig. 4B)**	Correlation between real and estimated distances	Comparison: open maze integrators vs. closed maze integrators	0.76	0.71	0.10	0.18	One-way ANOVA	Tukey-Kramer test	25	0.9	0.911	0.35	0.51	-
			Comparison: closed maze integrators vs. closed maze non-integrators	0.71	0.18	0.18	0.23	One-way ANOVA	Tukey-Kramer test	18	5.8	4.95E-07	2.62	820.46	4
			Comparison: closed maze non-integrators vs. teleport maze non-integrators	0.18	0.20	0.23	0.24	One-way ANOVA	Tukey-Kramer test	24	0.3	0.985	0.11	0.38	-
	JRD (Fig. 4C)	90 minus angular error	Comparison: open maze integrators vs. closed maze integrators	55.66	60.38	25.13	22.42	One-way ANOVA	Tukey-Kramer test	24	0.5	0.865	0.20	0.40	-

			Comparison: closed maze integrators vs. closed maze non-integrators	60.38	4.37	22.42	12.80	One-way ANOVA	Tukey-Kramer test	17	6.9	9.04E-06	3.07	6317.17	4
	Path distance estimation (Fig. 4D)	Correlation between real and estimated distances	Comparison: open maze integrators vs. closed maze integrators	0.83	0.79	0.11	0.17	One-way ANOVA	Tukey-Kramer test	25	0.8	0.940	0.30	0.47	-
			Comparison: closed maze integrators vs. closed maze non-integrators	0.79	0.28	0.17	0.19	One-way ANOVA	Tukey-Kramer test	18	6.0	1.20E-06	2.73	1384.55	4
			Comparison: closed maze non-integrators vs. teleport maze non-integrators	0.28	0.22	0.19	0.25	One-way ANOVA	Tukey-Kramer test	24	0.7	0.854	0.27	0.43	-
	Shortest path selection (Fig. 4E)	Percent correct minus chance (0.5)	Comparison: open maze integrators vs. closed maze integrators	0.42	0.44	0.04	0.05	One-way ANOVA	Tukey-Kramer test	25	0.8	0.983	0.32	0.48	-
			Comparison: closed maze integrators vs. closed maze non-integrators	0.44	0.15	0.05	0.09	One-way ANOVA	Tukey-Kramer test	18	8.7	3.47E-07	3.99	1.05E+05	3
			Comparison: closed maze non-integrators vs. teleport maze non-integrators	0.15	0.08	0.09	0.16	One-way ANOVA	Tukey-Kramer test	24	1.4	0.268	0.56	0.71	-
	Map localization (Fig. 4F)	Correlation to veridical distance vs. correlation ot equidistant graph distance	Closed maze integrators	0.50	0.65	0.48	0.41	Paired-samples two-tailed t-test	FDR, across groups	8	2.1	0.068	0.70	1.45	-
			Closed maze non-integrators	2.98	2.55	0.54	0.52	Paired-samples two-tailed t-test	FDR, across groups	10	9.0	8.36E-06	2.71	4560.96	4
			Comparison: closed maze integrators vs. closed maze non-integrators	-0.15	0.43	0.22	0.16	Two-samples two-tailed t-test	-	18	7.0	1.69E-06	3.07	6705.81	4

Correlation of individual SBSOD score to task performance						
	Learning	Euclidean distance estimation	Path distance estimation	Shortest path selection	Map localization	JRD
Open maze	0.08	0.14	0.25	0.08	0.10	0.18
Closed maze	0.56	0.34	0.40	0.46	0.47	0.30
Teleport maze	0.21	0.10	0.33	0.52	0.58	
Correlation of individual PTTA score to task performance						
	Learning	Euclidean distance estimation	Path distance estimation	Shortest path selection	Map localization	JRD
Open maze	0.18	0.25	-0.20	0.12	0.60	0.52
Closed maze	0.54	0.45	0.55	0.35	0.45	0.57
Teleport maze	0.18	0.49	0.33	0.51	0.45	
Correlation of participants' sex to task performance						
	Learning	Euclidean distance estimation	Path distance estimation	Shortest path selection	Map localization	JRD
Open maze	-0.17	-0.13	0.18	0.21	-0.19	0.18
Closed maze	0.36	0.61 *	0.59 *	0.60 *	0.61 *	0.68 *
Teleport maze	0.06	0.18	0.01	0.24	0.21	

Table S2: Correlation of SBSOD and PTTA scores to task performance. Stars indicate significant effects (one-sample two-tailed t-tests, FDR-corrected across tasks and environments for each measure). Sex was coded as 1=male, 0=female; positive correlations indicate better performance for males, whereas negative correlations indicate better performance for females.