Supplementary Information

Supplementary table 1

Supplementary table 1. Spatial configuration of the six presented blocks.

Block	Origin angle	Target angle	Angle between origin and target	Target distance from center (meters/virtual meters)
1	0	315	-45	2.63
2	300	165	-135	2.77
3	240	15	135	2.52
4	180	225	45	2.03
5	120	75	-45	2.68
6	60	195	135	2.75

Supplementary method 1

Trial order of each block:

Disorientation task – 1st learning trial – disorientation task – 2nd learning trial – disorientation task – 3rd learning trial

Disorientation task – 1st probe trial – disorientation task – 2nd probe trial – disorientation task – 3rd probe trial – disorientation task – 4th probe trial

Supplementary table 2

Supplementary table 2. Table of results for probe trials.
Data presented as mean ± s.e.m and 95%-confidence interval. In case main analysis revealed an interaction effect, post-hoc tests were performed with the Holm-Bonferroni-correction.

	Probe trials				
	Stationary		Mobile		
	MTLR (n = 10)	**Control** (n = 20)	**MTLR** (n = 10)	**Control** (n = 20)	
Spatial memory					p-value
Memory score in percent	72.4 ± 5.4 a 60.1 – 84.6	87.6 ± 2.1 b 83.3 – 91.9	89.5 ± 1.8 c 85.4 – 93.5	94.6 ± 1.0 d 93.1 – 96.0	G*S: 0.031 a*b < 0.001 a*c < 0.001 b*d = 0.031 c*d = 0.251
Spatial precision					
Scatter as distance in virtual units	0.23 ± 0.03 a 0.16 – 0.30	0.12 ± 0.01 b 0.10 – 0.15	0.09 ± 0.01 c 0.07 – 0.12	0.06 ± 0.00 d 0.05 – 0.07	G*S: 0.003 a*b < 0.001 a*c < 0.001 b*d = 0.002 c*d = 0.194
Navigation efficiency					
Latency to final location in seconds	25.8 ± 2.7 19.8 – 31.8	27.5 ± 1.8 23.6 – 31.4	16.4 ± 1.6 12.8 – 20.1	18.0 ± 1.4 15.1 – 20.9	G*S: 0.955 S: < 0.001 G: 0.423
Path error to final location in percent	278.8 ± 55.1 154.2 – 403.3	251.2 ± 31.9 184.4 – 318.0	124.3 ± 28.1 60.8 – 187.9	116.2 ± 15.5 83.7 – 148.7	G*S: 0.682 S: < 0.001 G: 0.611
Surface coverage in percent	24.9 ± 2.8 18.5 – 31.4	22.9 ± 1.6 19.6 – 26.1	16.2 ± 1.9 11.9 – 20.5	18.6 ± 1.7 15.1 – 22.2	G*S: 0.128 S: < 0.001 G: 0.929
Navigation strategies					
Search accuracy/ avg. distance to final location in virtual units	0.33 ± 0.02 0.28 – 0.39	0.30 ± 0.01 0.27 – 0.33	0.28 ± 0.02 0.23 – 0.32	0.25 ± 0.02 0.21 – 0.28	G*S: 0.810 S: < 0.001 G: 0.212
Angular velocity/ idPhi (Integrated over the initial 5 seconds)	0.0036 ± 0.0005 0.0024 – 0.0048	0.0041 ± 0.0003 0.0034 – 0.0048	0.0080 ± 0.0004 0.0071 – 0.0088	0.0107 ± 0.0005 0.0096 – 0.0117	G*S: 0.024 a*b = 0.477 a*c < 0.001 b*d < 0.001 c*d < 0.001
Path replication/ distance between paths in virtual units	0.30 ± 0.01 0.27 – 0.32	0.26 ± 0.01 0.25 – 0.28	0.23 ± 0.02 0.19 – 0.26	0.26 ± 0.01 0.24 – 0.28	G*S: 0.002 a*b = 0.063 a*c = 0.002 b*d = 0.759 c*d = 0.079

Supplementary table 3

Supplementary table 3. Table of results for learning trials.

Data presented as mean ± s.e.m and 95%-confidence interval. In case main analysis revealed an interaction effect, post-hoc tests were performed with the Holm-Bonferroni-correction.

	Learning trials				
	Stationary		Mobile		
	MTLR (n = 10)	**Control** (n = 20)	**MTLR** (n = 10)	**Control** (n = 20)	
Spatial memory					p-value
Memory score in percent	n.a.	n.a.	n.a.	n.a.	n.a.
Spatial precision					
Scatter as distance in virtual units	n.a.	n.a.	n.a.	n.a.	n.a.
Navigation efficiency					
Latency to final location in seconds	46.7 ± 17.4 7.3 – 86.1	19.8 ± 2.3 15.1 – 24.5	23.9 ± 4.9 12.9 – 34.9	15.4 ± 1.1 13.1 – 17.7	G*S: 0.074 S: 0.012 G: 0.018
Path error to final location in percent	745.5 ± 175.5 348.5 – 1142.5	530.5 ± 207.3 96.6 – 964.5	226.1 ± 65.1 78.8 – 373.3	170.5 ± 21.0 126.6 – 214.4	G*S: 0.606 S: 0.007 G: 0.431
Surface coverage in percent	38.8 ± 3.5 30.9 – 46.8	30.2 ± 1.9 26.1 – 34.3	24.5 ± 1.8 20.4 – 28.6	23.1 ± 1.6 19.8 – 26.4	G*S: 0.069 S: < 0.001 G: 0.039
Navigation strategies					
Search accuracy/ avg. distance to final location in virtual units	0.42 ± 0.01 a 0.39 – 0.45	0.38 ± 0.01 b 0.35 – 0.40	0.34 ± 0.01 c 0.31 – 0.37	0.35 ± 0.01 d 0.33– 0.38	G*S: 0.040 a*b = 0.081 a*c = 0.003 b*d = 0.163 c*d = 0.566
Angular velocity/ idPhi (Integrated over the initial 5 seconds)	0.0060 ± 0.0006 0.0046 – 0.0075	0.0076 ± 0.0004 0.0067 – 0.0084	0.0081 ± 0.0005 0.0070 – 0.0091	0.0105 ± 0.0005 0.0093 – 0.0116	G*S: 0.295 S: < 0.001 G: 0.006
Path replication/ distance between paths in virtual units	n.a.	n.a.	n.a.	n.a.	n.a.

Supplementary table 4

Supplementary table 4. Table of results for influence of session order on experimental variables.

	Learning trials	Probe trials
Spatial memory		
Memory score in percent	n.a.	$F_{(1,27)} = 0.048$, p = 0.828 $\omega^2 = 0.0$
Spatial precision		
Scatter as distance in virtual units	n.a.	$F_{(1,52)} = 0.181$, p = 0.673, $\omega^2 = 0.0$
Navigation efficiency		
Latency to final location in seconds	$F_{(1,27)} = 0.00$, p = 0.996, $\omega^2 = 0.0$	$F_{(1,27)} = 8.096$, p = 0.008, $\omega^2 = 0.20$
Path error to final location in percent	$F_{(1,52)} = 0.00$, p = 0.992, $\omega^2 = 0.0$	$F_{(1,27)} = 21.206$, p < 0.001, $\omega^2 = 0.41$
Surface coverage in percent	$F_{(1,27)} = 1.871$, p = 0.183, $\omega^2 = 0.03$	$F_{(1,27)} = 12.404$, p = 0.002, $\omega^2 = 0.28$
Navigation strategies		
Search accuracy/ avg. distance to final location in virtual units	$F_{(1,52)} = 1.166$, p = 0.285, $\omega^2 = 0.00$	$F_{(1,27)} = 1.462$, p = 0.810, $\omega^2 = 0.02$
Angular velocity/ idPhi (Integrated over the initial 5 seconds)	$F_{(1,27)} = 0.354$, p = 0.557, $\omega^2 = 0.00$	$F_{(1,52)} = 0.427$, p = 0.517, $\omega^2 = 0.00$
Path replication/ distance between paths in virtual units	n.a.	$F_{(1,52)} = 0.162$, p = 0.689, $\omega^2 = 0.00$

Supplementary methods 2

Electroencephalography

To investigate brain activity during spatial navigation, we equipped all participants with high-density electroencephalography (EEG) with 128 channels synchronized to the virtual or physical motion streams using the lab streaming layer (Kothe, 2014), https://github.com/sccn/labstreaminglayer). EEG data was recorded with a nominal sampling rate of 1000 Hz and band-pass filtered from 0.016 Hz to 500 Hz (BrainAmp Move System, Brain Products, Gilching, Germany). An elastic cap with an equidistant layout (EASYCAP, Herrsching, Germany) was used and the data were referenced to an electrode located closest to the FCz electrode of the extended 10% system. Impedances were kept below 20kΩ and electrode locations were digitized using an optical tracking system (Polaris Vicra, NDI, Waterloo, ON, Canada). For the present study, the EEG data will not be reported. Instead, the analyses focus on the behavioral performance and motion profile of participants.