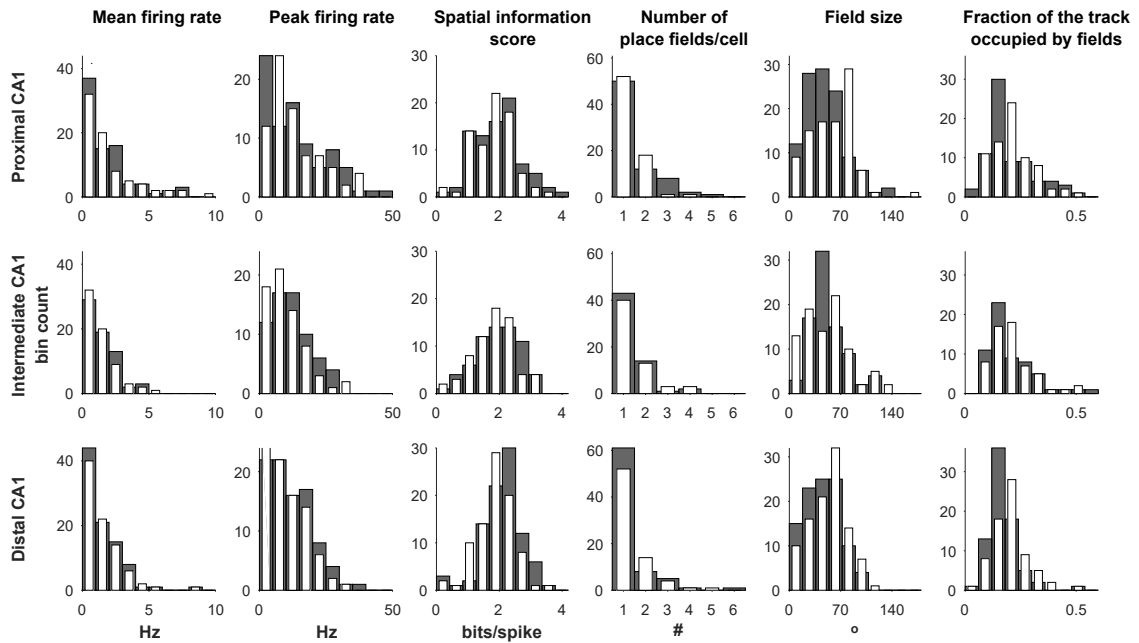
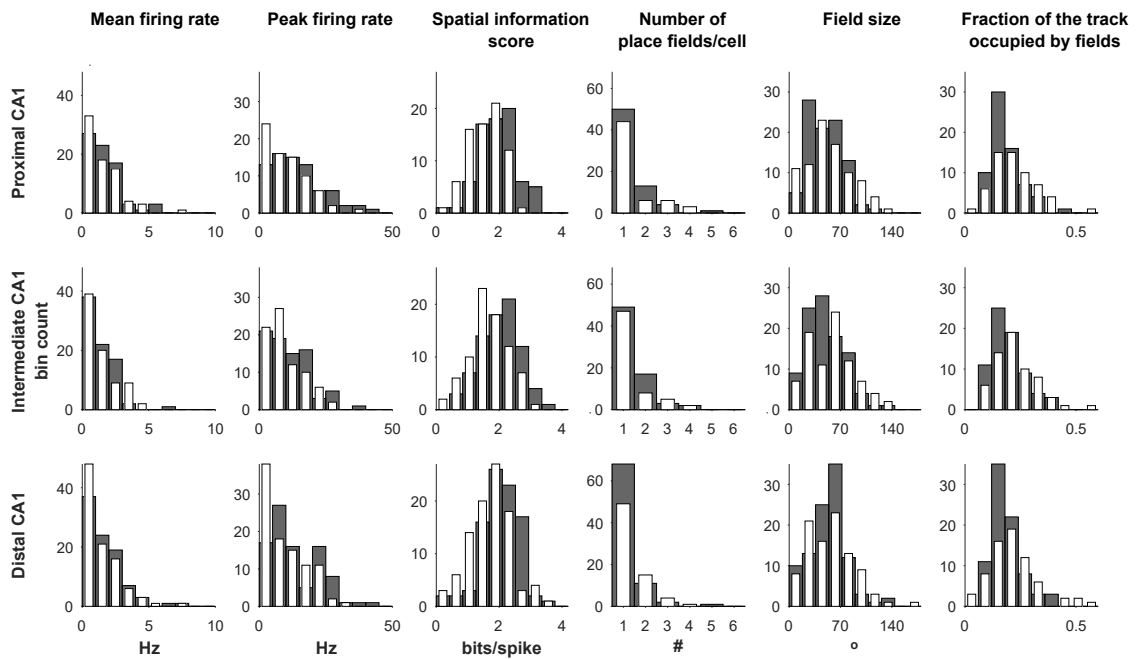


Supplementary Figure 1

45° Mismatch and preceding STD



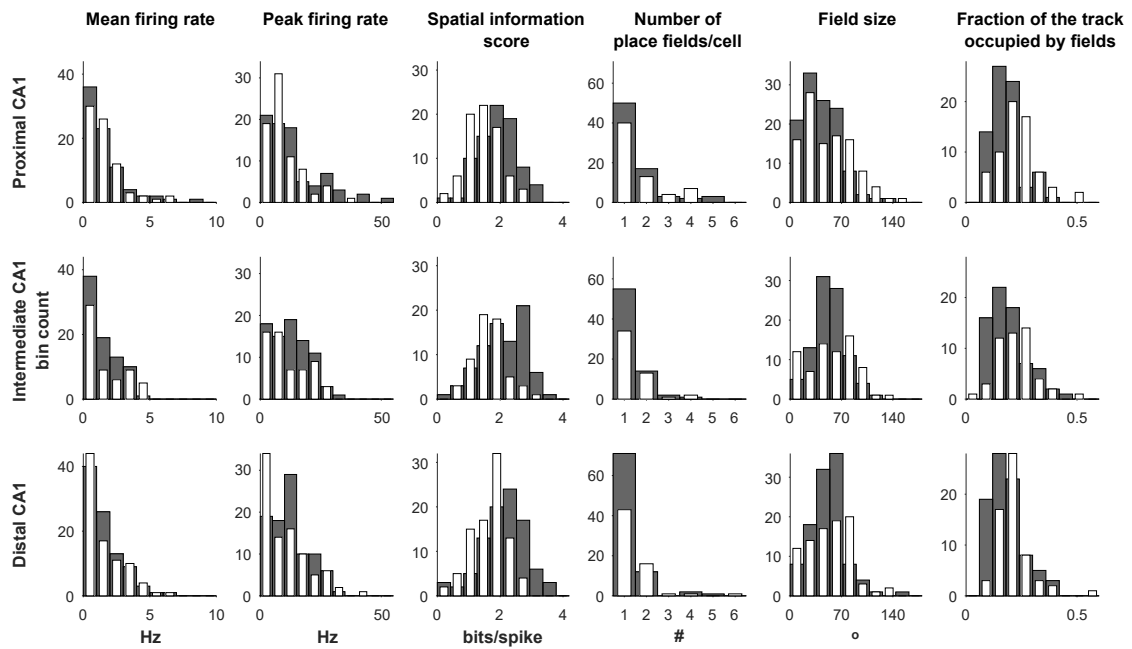
90° Mismatch and preceding STD



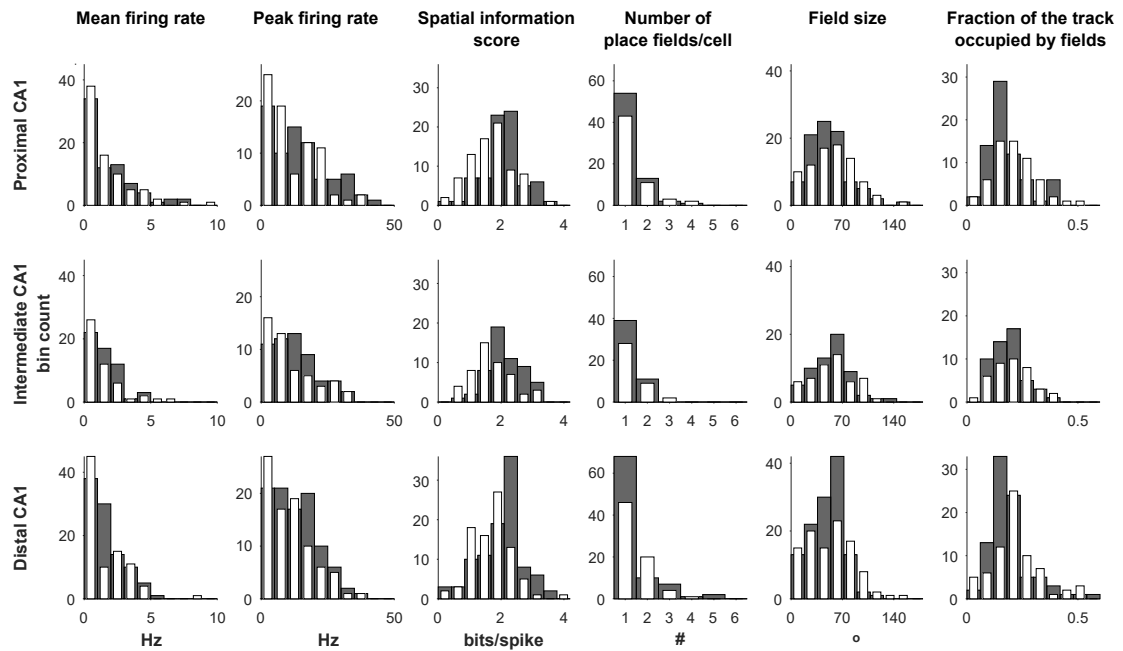
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Supplementary Figure 1 (cont.)

135° Mismatch and preceding STD



180° Mismatch and preceding STD



Supplementary Figure 1. Modulation of properties of putative pyramidal cells along the transverse axis of CA1 by double rotation manipulation. Mean firing rates, peak firing rates, spatial information scores, number of place fields per cell, place field sizes, and fraction of the track occupied by place fields in the proximal, intermediate, and distal CA1 during the various MIS sessions (white bars) and the STD sessions preceding them (gray bars) show that these parameters remain comparable across the transverse axis of CA1. A trend of reduced spatial selectivity from STD to MIS sessions can be seen in all three subregions.

Tables

Statistical test	Quantities compared	p	Z	Wilcoxon ranksum	χ^2	Prox CA1 n	Prox CA1 median	Dist CA1 n	Dist CA1 median
Wilcoxon rank sum	Mean firing rate	0.37	0.89	27079		156 neurons	1.24 Hz	180 neurons	1.29 Hz
Wilcoxon rank sum	Peak firing rate	0.34	0.95	27128		156 neurons	11.97 Hz	180 neurons	11.52 Hz
Wilcoxon rank sum	Spatial information score	0.15	-1.45	24997		156 neurons	1.92 bits/spke	180 neurons	2.11 bits/spike
Wilcoxon rank sum	Number of place fields/cell	0.28	1.07	19968		139 place cells	1 place field/cell	140 place cells	1 place field/cell
Wilcoxon rank sum	Field size	0.13	-1.52	30915		181 place fields	44°	176 place fields	47°
Wilcoxon rank sum	Fraction of area occupied by place fields	0.78	-0.28	19272		139 place cells	0.17	140 place cells	0.17
χ^2	Fraction of place cells with 1 place field/cell	0.36			0.85	107 place cells with 1 field out of 139 place cells		115 place cells with 1 field out of 140 place cells	

Supplementary Table 1, related to Figure 2. Statistical comparison of properties of proximal and distal CA1 neurons in the first standard session of the day.

Session	Statistical test	Quantities compared	Regions & sessions compared	p	Z	Wilcoxon ranksum	χ^2	Prox CA1 n, median	Dist CA1 n, median
45° MIS & STD preceding	Wilcoxon rank sum	Mean firing rate	Proximal vs Distal (MIS vs MIS)	0.0768	1.7737	6723		76, 1.26 Hz	86, 1.13 Hz
	Wilcoxon rank sum	Mean firing rate	Proximal STD vs MIS	0.3501	-0.9344	6250		MIS = 76, 1.26 Hz STD = 82, 1.24 Hz	
	Wilcoxon rank sum	Mean firing rate	Distal STD vs MIS	0.7635	-0.3008	7996			MIS = 86, 1.13 Hz STD = 91, 1.08 Hz
	Wilcoxon rank sum	Peak firing rate	Proximal vs Distal (MIS vs MIS)	0.0767	1.7704	6722		76, 10.78 Hz	86, 9.62 Hz
	Wilcoxon rank sum	Peak firing rate	Proximal STD vs MIS	0.6397	-0.4681	6384		MIS = 76, 10.78 Hz STD = 82, 10.99 Hz	
	Wilcoxon rank sum	Peak firing rate	Distal STD vs MIS	0.4021	0.8379	8385			MIS = 86, 9.62 Hz STD = 91, 10.17 Hz
	Wilcoxon rank sum	Spatial information score	Proximal vs Distal (MIS vs MIS)	0.4862	-0.6964	5986		76, 1.85 b/s	86, 1.88 b/s
	Wilcoxon rank sum	Spatial information score	Proximal STD vs MIS	0.2647	1.1153	6840		MIS = 76, 1.85 b/s STD = 82, 2 b/s	
	Wilcoxon rank sum	Spatial information score	Distal STD vs MIS	0.007	2.6958	9018			MIS = 86, 1.88 b/s STD = 91, 2.14 b/s
	Wilcoxon rank sum	Number of place fields/cell	Proximal vs Distal (MIS vs MIS)	0.8422	-0.1991	5180.5		72, 1	72, 1
	Wilcoxon rank sum	Number of place fields/cell	Proximal STD vs MIS	0.3681	0.9001	5512		MIS = 72, 1 STD = 73, 1	
	Wilcoxon rank sum	Number of place fields/cell	Distal STD vs MIS	0.3137	-1.0074	5466.5			MIS = 72, 1 STD = 76, 1
	Wilcoxon rank sum	Field size	Proximal vs Distal (MIS vs MIS)	0.1367	1.4881	9948.5		95, 52°	101, 49°
	Wilcoxon rank sum	Field size	Proximal STD vs MIS	0.0024	-3.0355	10194		MIS = 95, 52° STD = 111, 40°	
	Wilcoxon rank sum	Field size	Distal STD vs MIS	0.0244	-2.2513	9461.5			MIS = 101, 49° STD = 102, 38°
	Wilcoxon rank sum	Fraction of area occupied by place fields	Proximal vs Distal (MIS vs MIS)	0.653	0.4496	5333		72, 0.21	72, 0.19
Wilcoxon rank sum	Fraction of area occupied by place fields	Proximal STD vs MIS	0.2531	-1.143	5039.5		MIS = 72, 0.21 STD = 73, 0.17		
Wilcoxon rank sum	Fraction of area occupied by place fields	Distal STD vs MIS	5.04E-04	-3.4785	4755			MIS = 72, 0.19 STD = 76, 0.16	
	χ^2	Fraction of place cells	Proximal vs Distal (MIS vs MIS)	0.8524			0.0346	45/72	42/72

		with 1 place field/cell							
	χ^2	Fraction of place cells with 1 place field/cell	Proximal STD vs MIS	0.7568			0.0959	MIS = 45/72 STD = 45/73	
	χ^2	Fraction of place cells with 1 place field/cell	Distal STD vs MIS	0.3385			0.9161		MIS = 42/72 STD = 50/76
Session	Statistical test	Quantities compared	Regions & sessions compared	p	Z	Wilcoxon ranksum	χ^2	# of samples in Prox CA1	# of samples in Dist CA1
90° MIS & STD preceding	Wilcoxon rank sum	Mean firing rate	Proximal vs Distal (MIS vs MIS)	0.2014	1.2776	6734		74, 1.13 Hz	96, 1 Hz
	Wilcoxon rank sum	Mean firing rate	Proximal STD vs MIS	0.4351	0.7804	5717		MIS=74, 1.13 Hz STD = 74, 1.41 Hz	
	Wilcoxon rank sum	Mean firing rate	Distal STD vs MIS	0.0622	1.8648	9390			MIS = 96, 1 Hz STD = 92, 1.27 Hz
	Wilcoxon rank sum	Peak firing rate	Proximal vs Distal (MIS vs MIS)	0.4274	0.7936	6580		74, 8.13 Hz	96, 8.3 Hz
	Wilcoxon rank sum	Peak firing rate	Proximal STD vs MIS	0.0298	2.1725	6080		MIS=74, 8.13 Hz STD = 74, 11.56 Hz	
	Wilcoxon rank sum	Peak firing rate	Distal STD vs MIS	0.0047	2.8273	9749			MIS = 96, 8.3 Hz STD = 92, 10.58 Hz
	Wilcoxon rank sum	Spatial information score	Proximal vs Distal (MIS vs MIS)	0.11	-1.5982	5818		74, 1.8 b/s	96, 1.61 b/s
	Wilcoxon rank sum	Spatial information score	Proximal STD vs MIS	1.98E-04	3.7219	6484		MIS=74, 1.8 b/s STD = 74, 2.02 b/s	
	Wilcoxon rank sum	Spatial information score	Distal STD vs MIS	0.0011	3.2563	9909			MIS = 96, 1.61 b/s STD = 92, 2.07 b/s
	Wilcoxon rank sum	Number of place fields/cell	Proximal vs Distal (MIS vs MIS)	0.9197	-0.1009	3788.5		59, 1	69, 1
	Wilcoxon rank sum	Number of place fields/cell	Proximal STD vs MIS	0.8825	-0.1478	4328		MIS = 59, 1 STD = 68, 1	
	Wilcoxon rank sum	Number of place fields/cell	Distal STD vs MIS	0.081	-1.7451	5891.5			MIS = 69, 1 STD = 82, 1
	Wilcoxon rank sum	Field size	Proximal vs Distal (MIS vs MIS)	0.6311	-0.4802	7656.5		86, 45°	95, 53°
	Wilcoxon rank sum	Field size	Proximal STD vs MIS	0.2203	-1.2258	7945		MIS = 86, 45° STD = 93, 41°	
	Wilcoxon rank sum	Field size	Distal STD vs MIS	0.5403	-0.6124	9705			MIS = 95, 53° STD = 101, 48°
	Wilcoxon rank sum	Fraction of area occupied by place fields	Proximal vs Distal (MIS vs MIS)	0.7128	0.3681	3883		59, 0.21	69, 0.2

	Wilcoxon rank sum	Fraction of area occupied by place fields	Proximal STD vs MIS	0.0193	-2.34	3867.5		MIS = 59, 0.21 STD = 68, 0.17	
	Wilcoxon rank sum	Fraction of area occupied by place fields	Distal STD vs MIS	0.056	-1.911	5720			MIS = 69, 0.2 STD = 82, 0.17
	χ^2	Fraction of place cells with 1 place field/cell	Proximal vs Distal (MIS vs MIS)	0.8012			0.0634	35/59	42/69
	χ^2	Fraction of place cells with 1 place field/cell	Proximal STD vs MIS	0.9452			0.0047	MIS = 35/59, STD = 42/68	
	χ^2	Fraction of place cells with 1 place field/cell	Distal STD vs MIS	0.1211			2.4031		Mis = 42/69 STD = 58/82
Session	Statistical test	Quantities compared	Regions & sessions compared	p	Z	Wilcoxon ranksum	χ^2	# of samples in Prox CA1	# of samples in Dist CA1
135° MIS & STD preceding	Wilcoxon rank sum	Mean firing rate	Proximal vs Distal (MIS vs MIS)	0.5473	0.6018	6453		76, 1.15 Hz	88, 1.01 Hz
	Wilcoxon rank sum	Mean firing rate	Proximal STD vs MIS	0.8274	-0.2181	6218		MIS = 76, 1.15 Hz STD = 80, 1.16 Hz	
	Wilcoxon rank sum	Mean firing rate	Distal STD vs MIS	0.4161	0.8132	8750			MIS = 88, 1.01 Hz STD = 93, 1.19 Hz
	Wilcoxon rank sum	Peak firing rate	Proximal vs Distal (MIS vs MIS)	0.9882	-0.0148	6265		76, 7.82 Hz	88, 8.54 Hz
	Wilcoxon rank sum	Peak firing rate	Proximal STD vs MIS	0.1134	1.5831	6727		MIS = 76, 7.82 Hz STD = 80, 10.16 Hz	
	Wilcoxon rank sum	Peak firing rate	Distal STD vs MIS	0.0628	1.8606	9119			MIS = 88, 8.54 Hz STD = 93, 12.29 Hz
	Wilcoxon rank sum	Spatial information score	Proximal vs Distal (MIS vs MIS)	0.0125	-2.4979	5512		76, 1.52 b/s	88, 1.77 b/s
	Wilcoxon rank sum	Spatial information score	Proximal STD vs MIS	7.23E-06	4.4869	7546		MIS = 76, 1.52 b/s STD = 80, 1.95 b/s	
	Wilcoxon rank sum	Spatial information score	Distal STD vs MIS	3.22E-06	4.6564	10104			MIS = 88, 1.77 b/s STD = 93, 2.14 b/s
	Wilcoxon rank sum	Number of place fields/cell	Proximal vs Distal (MIS vs MIS)	0.244	1.1651	4264.5		64, 1	62, 1
	Wilcoxon rank sum	Number of place fields/cell	Proximal STD vs MIS	0.5136	-0.6532	5118.5		MIS = 64, 1 STD = 75, 1	
	Wilcoxon rank sum	Number of place fields/cell	Distal STD vs MIS	0.0671	-1.831	6061.5			MIS = 62, 1 STD = 86, 1
	Wilcoxon rank sum	Field size	Proximal vs Distal (MIS vs MIS)	0.4952	-0.682	10069		106, 37°	88, 51°

	Wilcoxon rank sum	Field size	Proximal STD vs MIS	0.0566	-1.9061	12023		MIS = 106, 37° STD = 116, 35°	
	Wilcoxon rank sum	Field size	Distal STD vs MIS	0.4998	-0.6748	10371			MIS = 88, 51° STD = 108, 43°
	Wilcoxon rank sum	Fraction of area occupied by place fields	Proximal vs Distal (MIS vs MIS)	0.0358	2.0988	4494.5		64, 0.23	62, 0.2
	Wilcoxon rank sum	Fraction of area occupied by place fields	Proximal STD vs MIS	3.51E-05	-4.1377	4270.5		MIS = 64, 0.23 STD = 75, 0.17	
	Wilcoxon rank sum	Fraction of area occupied by place fields	Distal STD vs MIS	0.0018	-3.1156	5605			MIS = 62, 0.2 STD = 86, 0.17
	χ^2	Fraction of place cells with 1 place field/cell	Proximal vs Distal (MIS vs MIS)	0.533			0.3886	34/64	37/62
	χ^2	Fraction of place cells with 1 place field/cell	Proximal STD vs MIS	0.7381			0.1118	MIS = 34/64 STD = 45/75	
	χ^2	Fraction of place cells with 1 place field/cell	Distal STD vs MIS	0.0918			2.8423		MIS = 37/62 STD = 60/85
Session	Statistical test	Quantities compared	Regions & sessions compared	p	Z	Wilcoxon ranksum	χ^2	# of samples in Prox CA1	# of samples in Dist CA1
180° MIS & STD preceding	Wilcoxon rank sum	Mean firing rate	Proximal vs Distal (MIS vs MIS)	0.7859	0.2716	6518		78, 1.1 Hz	86, 0.95 Hz
	Wilcoxon rank sum	Mean firing rate	Proximal STD vs MIS	0.5778	0.5566	5928		MIS = 78, 1.1 Hz STD = 75 1.3 Hz	
	Wilcoxon rank sum	Mean firing rate	Distal STD vs MIS	0.5876	0.5424	9261			MIS = 86, 0.95 Hz STD = 98 1.16 Hz
	Wilcoxon rank sum	Peak firing rate	Proximal vs Distal (MIS vs MIS)	0.7283	0.3474	6541		78, 7.31 Hz	86, 9.8 Hz
	Wilcoxon rank sum	Peak firing rate	Proximal STD vs MIS	0.0846	1.7245	6248		MIS = 78, , 7.31 Hz STD = 75, 12.02 Hz	
	Wilcoxon rank sum	Peak firing rate	Distal STD vs MIS	0.0669	1.8324	9726			MIS = 86, , 9.8 Hz STD = 98, 11.91 Hz
	Wilcoxon rank sum	Spatial information score	Proximal vs Distal (MIS vs MIS)	0.8939	-0.1334	6394		78, 1.68 b/s	86, 1.71 b/s
	Wilcoxon rank sum	Spatial information score	Proximal STD vs MIS	9.63E-05	3.8997	6844		MIS = 78, 1.68 b/s STD = 75, 2.09 b/s	
	Wilcoxon rank sum	Spatial information score	Distal STD vs MIS	3.22E-04	3.5968	10362			MIS = 86, 1.71 b/s STD = 98, 2.11 b/s
	Wilcoxon rank sum	Number of place fields/cell	Proximal vs Distal (MIS vs MIS)	0.4091	-0.8255	3720		59, 1	71, 1

	Wilcoxon rank sum	Number of place fields/cell	Proximal STD vs MIS	0.5143	-0.6522	4445.5		MIS = 59, 1 STD = 70, 1	
	Wilcoxon rank sum	Number of place fields/cell	Distal STD vs MIS	0.1727	-1.3636	6728.5			MIS = 71, 1 STD = 88, 1
	Wilcoxon rank sum	Field size	Proximal vs Distal (MIS vs MIS)	0.5493	0.5988	7800.5		82, 43°	102, 42°
	Wilcoxon rank sum	Field size	Proximal STD vs MIS	0.2348	-1.1881	7397		MIS = 82, 43° STD = 90, 44°	
	Wilcoxon rank sum	Field size	Distal STD vs MIS	0.4331	-0.784	13518			MIS = 102, 42° STD = 123, 45°
	Wilcoxon rank sum	Fraction of area occupied by place fields	Proximal vs Distal (MIS vs MIS)	0.8644	0.1707	3901.5		59, 0.2	71, 0.19
	Wilcoxon rank sum	Fraction of area occupied by place fields	Proximal STD vs MIS	0.0096	-2.5889	4002		MIS = 59, 0.2 STD = 70, 0.16	
	Wilcoxon rank sum	Fraction of area occupied by place fields	Distal STD vs MIS	0.0421	-2.0324	6453			MIS = 71, 0.19 STD = 88, 0.17
	χ^2	Fraction of place cells with 1 place field/cell	Proximal vs Distal (MIS vs MIS)	0.4243			0.6385	32/59	37/71
	χ^2	Fraction of place cells with 1 place field/cell	Proximal STD vs MIS	0.7236			0.1251	MIS = 32/59 STD = 49/70	
	χ^2	Fraction of place cells with 1 place field/cell	Distal STD vs MIS	0.1187			2.4342		Mis = 37/71 STD = 58/88
Session	Statistical test	Quantities compared	Regions & sessions compared	p	Z	Wilcoxon ranksum	χ^2	# of samples in Prox CA1	# of samples in Dist CA1

Supplementary Table 2. Statistical comparison of properties of proximal and distal CA1 neurons in MIS sessions with each other and with preceding STD sessions. Notice that the only persistent trend is that of reduced spatial selectivity in both proximal and distal CA1 MIS sessions compared to preceding STD sessions. b/s stands for bits/spike.

Mismatch angle	Prox CA1			Int CA1			Dist CA1		
	U	Critical value of U for p < 0.001	n	U	Critical value of U for p < 0.001	n	U	Critical value of U for p < 0.001	n
45°	20333.32	163.60	58	20298.83	170.54	49	20360.76	163.60	57
90°	19622.83	172.58	41	19918.09	172.58	41	19408.52	170.54	49
135°	20010.00	170.54	48	19098.39	172.58	41	18588.52	172.58	44
180°	17530.99	177.88	35	18459.68	184.05	27	16786.14	163.60	55

Supplementary Table 3. Rao's spacing test statistics (Rao 1976; Russell and Levitin 1995) for single unit rotation data shown in Figure 4. All tests were significant with $p < 0.001$.

Mis ang	Prox CA1					Int CA1					Dist CA1				
	MVA	MVL	p	z	n	MVA	MVL	p	z	n	MVA	MVL	p	z	n
45°	-7°	0.83	< 10 ⁻⁵	40.2	58	2°	0.82	< 10 ⁻⁵	33.5	49	-5°	0.91	< 10 ⁻⁵	46.9	57
90°	35°	0.41	0.0009	6.8	41	-13°	0.67	< 10 ⁻⁵	18.3	41	-14°	0.56	< 10 ⁻⁵	15.3	49
135°	16°	0.25	0.0486	3.0	48	-1°	0.22	0.1331	2.1	41	-45°	0.29	0.0268	3.6	44
180°	107°	0.39	0.0131	4.3	35	-80°	0.15	0.5674	0.6	27	-84°	0.15	0.3085	1.2	55

Supplementary Table 4. Rayleigh test for uniformity for single unit rotation data shown in Figure 4. MVA and MVL denote mean vector angles and lengths, z denotes Rayleigh's z. Negative MVAs denote CW rotation in the direction of the global cues, while positive MVAs denote CCW rotation in the direction of the local cues.

Mismatch angle	Region	Number of points in cluster 1	Number of points in cluster 2
45°	Prox CA1	991	9
	Dist CA1	1	999
90°	Prox CA1	963	37
	Dist CA1	4	996
135°	Prox CA1	534	466
	Dist CA1	0	1000
180°	Prox CA1	995	5
	Dist CA1	2	998

Supplementary Table 5. Number of points from proximal and distal CA1 assigned to clusters 1 and 2 by k-means clustering (k = 2). For ease of visualization, after running the k-means clustering algorithm, the cluster with higher number of points from proximal CA1 was named cluster 1, while the other cluster with higher number of points from distal CA1 was named cluster 2.