Supplementary information on representations during high score preplays that do not align with maze place fields.

The sequential firing patterns observed during ripples in sleep show a diversity of faithfulness to trajectories through the maze, as captured in the distribution of replay (and preplay) scores (**Extended Data Fig. 4a**) in the datasets we analyzed using a commonly used weighted-correlation measure, advocated by several studies [33,34,36]. Here, each event was scored as a percentile compared to its own surrogate distributions generated using a within-ripple-event time-bin shuffle [72] (see **Methods**). These distributions varied from a uniform distribution expected from chance in all datasets (expected median replay score = 50), not only for MAZE, and POST epochs, but also for PRE, consistent with previous reports [12,33,34]. Replay scores during MAZE showed the greatest deviation from chance. While we expected more replay than preplay based on previous reports [33,34,36], POST and PRE replay scores were only marginally different in one out of the three datasets we examined (*Grosmark dataset*: PRE: median = 53.8, POST: median = 57.2, PRE vs POST $p = 3.45\times10^{-12}$, Mann Whitney U Test (MWUT); *Miyawaki dataset*: PRE: median = 50.8 , POST: median = 51.2, PRE vs POST p = 0.47, MWUT; *Giri dataset*: PRE: median = 56.6 , POST: median = 55.6, PRE vs POST p = 0.42, MWUT).

Since replays are considered to simulate trajectories through the maze, we asked whether tunings learned from higher score ripple events in either PRE or POST might show greater fidelity to the maze PFs. We therefore calculated LTs from four subsets of ripples events with replay scores of different percentiles (**Extended Data Fig. 4b, c**). We called the tunings learned from the lowest and highest quartiles “low score” and “high score” LTs, respectively. Remarkably, both the low score and high score LTs from MAZE and POST showed strong fidelity to maze PFs, despite the absence of sequential trajectories in low score events. In contrast, neither high nor low score LTs in PRE showed LTs consistent with the maze PFs (**Extended Data Fig. 4b**). LTs from all quartiles of replay scores showed significant PF fidelity in MAZE and POST but not in PRE (**Extended Data Fig. 4c**), with somewhat stronger PF fidelity in higher score quartiles (PRE: χ^2 = 7.2, p = 0.07; MAZE: χ^2 = 143, $p < 10^{-30}$; POST: χ^2 = 150.7, $p < 10^{-31}$, Friedman test). Likewise, the spatial population vector correlations of low and high score LTs showed a strong correlation with maze PFs for both MAZE and POST epochs, but not for PRE. Overall, these results delineate that even during ripple events in POST with low replay scores, which are typically discarded as non-replays by most measures, the representational structures of neuronal spike trains remain congruent with the place fields on the maze. The firing patterns underlying these events could be detected as “reactivation” using pairwise or ensemble measures [14,49,76], but rather than providing a sequential sweep through space that would be necessary to score high for replay, such ripple events may provide non-continuous, low momentum, or random trajectories through the maze [50,51]. In contrast, however, even during ripple events in PRE that appear to show sequential structure, the neurons cannot be said to represent the same locations as they do on the maze.

To better understand the dichotomy between PRE and POST ripples, we examined the decoded posterior positions and unit rasters of individual ripple events with high replay scores. In high score ripple events in PRE (e.g. examples shown in **Extended Data Fig. 4d**), even though these events appeared to show sequential trajectories leading to high scores, we could not distinguish this sequential structure in the spike trains of units sorted according to their preferred maze locations (such structure was evident in some high score events in POST, e.g. the second two panels). Inspection of individual bins revealed that units which were co-active in time-bins during PRE ripple events possessed highly divergent place fields with relatively low mean correlations with the collective posterior probability distributions, contrary to expectations from a unified population code. In contrast, the place fields of units in POST high and low score events showed a greater resemblance (and stronger mean correlation) with the posteriors in their respective bins, indicative of a coherent population representation. Mean posterior correlations of active PFs in bins during all ripple events in PRE and POST similarly showed no significant difference in between low and high score events in PRE, but they were significantly higher in POST relative to PRE (similar results were observed even when we restricted analysis to the subset of events that featured low jump distances (i.e. more continuous trajectories) between time bins (not shown)[33,36]). The shuffling methods employed to score replays in our and other studies invariably involve assumptions that are violated in real data [11,33,35]. These results highlight the importance of verification, as we propose via Bayesian learned tunings, to ensure that decoded positions are in fact consistent with representations of place fields on the maze.

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Supplementary Table 1: Summary of recording datasets

Dataset	Animal ID	Sex	Maze type	Number of pyramidal units (stable, PF peak $\geq$ 1 Hz) (stable, PF peak < 1 Hz)
Giri	Rat N	F	L-shape	84 (46)(10)
	Rat S	F	L-shape	78 (50)(11)
	Rat U	M	Semicircular (w/ reMAZE)	174 (131) (21)
	Rat V	M	Linear (w/ reMAZE)	47 (30)(5)
			Semicircular (w/ reMAZE)	78 (49)(4)
				Total 461 (306) (51)
Miyawaki	Rat R	M	Linear	84 (39)(5)
	Rat T	M	Linear	58 (24)(13)
			L-shape	41 (28)(6)
			U-shape	78 (18)(2)
	Rat K	M	Linear	62 (39)(11)
				Total 323(148) (37)
Grosmark	Rat A	M	Linear	148 (72)(72)
			Circular	101 (77)(15)
	Rat B	M	Linear	57 (17)(23)
	Rat C	M	Linear	53 (21)(20)
	Rat G	M	Circular	52 (19)(9)
				Total 411 (206) (139)
				Grand total :1195 (660) (227)

Supplementary Table 2: Behavioral epochs together with the behavior of the animals on the maze

	Epoch durations (hours)				Number of laps		Average speed of animal (cm/s) > 10 (cm/s)	
Session	**PRE**	**MAZE**	**POST**	**reMAZE**	**MAZE**	**reMAZE**	**MAZE**	**reMAZE**
Rat N	2.85	0.91	11.03		35		24.6	
Rat S	0.66	1.02	8.57		5		18.7	
Rat U	2.65	0.92	9.02	0.88	12	9	20.0	20.0
Rat V linear	2.82	0.87	9.01	0.88	11	15	17.7	20.9
Rat V semicircular	2.82	0.89	8.94	0.67	84	51	30.7	30.9
Rat R	3	3.01	3		116		23.7	
Rat T linear	3	3.1	3		28		16.1	
Rat T L shape	3	3	3		25		16.6	
Rat T U shape	3	3.03	3		30		21.1	
Rat K linear	3	3.01	3		28		19.5	
Rat A linear	5.02	0.57	4.09		42		29.6	
Rat A circular	5.37	0.74	4.06		48		32.9	
Rat B	2.98	0.65	2.22		28		26.6	
Rat C	4.44	0.85	4.02		31		22.0	
Rat G	4.66	0.75	4.42		41		31.1	

Supplementary Table 3: Duration of distinct sleep/wake states (in seconds) in each recording session

Session	Epoch	SWS	REM	Active wake	Quiet wake
Rat N	PRE	307.2	0.0	3237.1	6714.6
	POST	7947.5	2583.6	2289.5	1563.4
Rat S	PRE	486.0	0.0	965.0	906.2
	POST	9012.8	1293.7	2481.4	1681.6
Rat U	PRE	1251.9	0.0	4292.8	3987.3
	POST	9429.0	1626.7	2461.7	909.7
Rat V linear	PRE	789.9	0.0	4188.6	5157.7
	POST	8059.3	1566.5	2705.4	2068.1
Rat V semicircular	PRE	1923.7	0.0	3104.8	5105.5
	POST	7563.9	1971.0	2497.9	2348.4
Rat R	PRE	5925.7	519.7	513.4	3271.5
	POST	5923.8	353.0	1536.5	2977.5
Rat T linear	PRE	7277.8	899.4	511.4	2022.2
	POST	5612.0	386.0	1006.2	3474.5
Rat T L shape	PRE	6356.7	983.9	768.7	2360.2
	POST	4205.3	851.6	1616.9	4125.9
Rat T U shape	PRE	6202.9	1316.7	494.7	2785.4
	POST	4376.7	383.8	1686.0	4332.7
Rat K	PRE	8526.7	1870.0	204.0	190.7
	POST	3352.4	361.0	2400.5	4677.5
Rat A linear	PRE	9832.2	1799.8	3717.7	2706.2
	POST	4883.3	838.7	3979.7	4558.2
Rat A circular	PRE	10449.7	1968.5	5004.1	1907.3
	POST	5996.3	549.7	5465.7	2595.0
Rat B	PRE	5891.7	950.5	3297.1	573.4
	POST	2013.2	355.7	4692.0	946.0
Rat C	PRE	5032.8	1679.6	4207.8	5079.9
	POST	5126.8	1291.1	4867.7	3115.8
Rat G	PRE	9022.5	1504.7	3903.7	2328.4
	POST	6854.7	412.9	5666.0	1475.8