

Supplementary Table 1 The total number of spines analyzed at 0 h, the number of newly-formed spines over 0-8 h, eliminated new spines over 8-16 h and newly-formed spines over 16-24 h in each mouse at postnatal day 21 (P21) (Data related to **Fig.1f, 2a-c** and **Supplementary Fig. 5a**).

ND (during development)																
	# of spines at 0 h	# of new spines over 0-8 h	# of eliminated new spines over 8-16 h	Rate of eliminated new spine over 8-16 h (%)	# of spines at 16 h	# of new spines over 16-24 h	# of new spines formed over 16-24 h and located relative to eliminated (E) or persistent (P) new spines formed over 0-8 h									
							0-2 μ m		2-6 μ m		6-10 μ m		10-20 μ m		> 20 μ m	
							E	P	E	P	E	P	E	P	E	P
Animal 1	143	14	9	64.29	150	12	4	2	0	1	1	0	2	2	5	7
Animal 2 [#]																
L cortex	156	14	10	71.43	158	11	5	1	1	0	0	0	0	0	5	10
R cortex	206	17	13	76.47	197	7	2	0	0	0	0	0	1	0	4	7
Animal 3	159	18	11	61.11	153	9	2	0	2	4	1	2	3	1	1	2
Animal 4	257	11	7	63.64	240	16	4	1	0	0	1	1	3	0	8	14
Animal 5	152	11	7	63.64	151	8	0	0	2	1	1	1	0	0	5	6
Animal 6	151	14	9	64.29	150	11	4	0	0	2	1	1	2	3	4	5
Animal 7	153	14	9	64.29	147	8	5	2	1	1	0	1	0	1	0	5
Total	1377	113	75	66.37	1346	82	26	6	6	9	5	5	12	6	33	56
NREM-d (during development)																
	# of spines at 0 h	# of new spines over 0-8 h	# of eliminated new spines over 8-16 h	Rate of eliminated new spine over 8-16 h (%)	# of spines at 16 h	# of new spines over 16-24 h	# of new spines formed over 16-24 h and located relative to eliminated (E) or persistent (P) new spines formed over 0-8 h									
							0-2 μ m		2-6 μ m		6-10 μ m		10-20 μ m		> 20 μ m	
							E	P	E	P	E	P	E	P	E	P
Animal 1	156	9	5	55.56	151	9	1	0	2	1	0	0	1	0	5	8
Animal 2	260	21	13	61.9	262	17	2	1	1	1	2	1	4	3	8	11
Animal 3	152	17	11	64.71	150	11	3	1	1	2	3	0	1	1	3	7
Animal 4	165	12	8	66.67	164	9	2	1	2	0	1	3	1	0	3	5
Animal 5	137	12	8	66.67	141	9	3	0	0	3	1	0	2	1	3	5
Total	870	71	45	63.38	868	55	11	3	6	7	7	4	9	5	22	36
REMD (during development)																
	# of spines at 0 h	# of new spines over 0-8 h	# of eliminated new spines over 8-16 h	Rate of eliminated new spine over 8-16 h (%)	# of spines at 16 h	# of new spines over 16-24 h	# of new spines formed over 16-24 h and located relative to eliminated (E) or persistent (P) new spines formed over 0-8 h									
							0-2 μ m		2-6 μ m		6-10 μ m		10-20 μ m		> 20 μ m	
							E	P	E	P	E	P	E	P	E	P
Animal 1	151	14	7	50	150	8	0	1	1	0	1	2	2	3	4	3
Animal 2 [#]																
L cortex	167	12	6	50	163	9	2	0	1	1	0	0	0	3	6	5
R cortex	157	13	6	46.15	159	11	2	0	0	1	2	1	1	1	6	8
Animal 3	170	18	5	27.78	169	11	1	2	2	1	0	0	3	2	5	6
Animal 4	173	9	5	55.56	171	13	0	0	1	1	0	0	1	1	11	11
Animal 5	151	8	2	25	148	6	0	0	0	0	2	0	0	1	4	5
Animal 6	157	16	7	43.75	150	10	1	0	2	1	1	2	2	4	4	3
Animal 7	153	13	6	46.15	151	7	0	0	2	2	1	1	3	1	1	3
Total	1279	103	44	42.72	1261	75	6	3	9	7	7	6	12	15	41	44

[#] In these animals, new spine survival and distribution were quantified from both left (L) and right (R) motor cortices. In figures 1f, each point represents data from one animal.

Supplementary Table 2 The total number of spines analyzed at 0 h, the number of newly-formed spines after FW training over 0-8 h and eliminated new spines over 8-24 h in each mouse at postnatal day 30 (P30) (Data related to **Fig. 1k**).

ND (FW running-induced new spines over 0-8 h)						
	# of spines at 0 h	# of new spines over 0-8 h	# of eliminated new spines over 8-16 h	Rate of eliminated new spine over 8-16 h (%)	# of eliminated new spines over 8-24 h	Rate of eliminated new spine over 8-24 h (%)
Animal 1	153	11	5	45.45	6	54.55
Animal 2	152	7	3	42.86	4	57.14
Animal 3	185	10	6	60	6	60
Animal 4	174	11	6	54.55	7	63.64
Animal 5	160	7	3	42.86	4	57.14
Animal 6	188	13	8	61.54	9	69.23
Total	1012	59	31	52.54	36	61.02
NREM-d (FW running-induced new spines over 0-8 h)						
	# of spines at 0 h	# of new spines over 0-8 h	# of eliminated new spines over 8-16 h	Rate of eliminated new spine over 8-16 h (%)	# of eliminated new spines over 8-24 h	Rate of eliminated new spine over 8-24 h (%)
Animal 1	146	12	6	50	8	66.67
Animal 2	282	19	12	63.16	13	68.42
Animal 3	225	16	9	56.25	10	62.5
Animal 4	222	15	9	60	9	60
Animal 5	150	11	5	45.45	6	54.55
Animal 6	211	14	8	57.14	9	64.29
Total	1236	87	49	56.32	55	63.22
REMD (FW running-induced new spines over 0-8 h)						
	# of spines at 0 h	# of new spines over 0-8 h	# of eliminated new spines over 8-16 h	Rate of eliminated new spine over 8-16 h (%)	# of eliminated new spines over 8-24 h	Rate of eliminated new spine over 8-24 h (%)
Animal 1	145	9	3	33.33	5	55.56
Animal 2	156	8	3	37.5	4	50
Animal 3	153	10	4	40	5	50
Animal 4	153	9	2	22.22	4	44.44
Animal 5	157	12	4	33.33	5	41.67
Animal 6	158	11	4	36.36	6	54.55
Total	922	59	20	33.90	29	49.15

Supplementary Table 3 The total number of spines analyzed at 0 h, the number of newly-formed spines over 0-8 h after BW running, eliminated new spines over 8-16h and newly-formed spines over 16-24 h after FW running in each mouse at postnatal day 30 (P30) (Data related to Fig. 1m, 2d-f and Supplementary Fig. 5b)

ND																
	# of spines at 0 h	# of new spines over 0-8 h	# of eliminated new spines over 8-16 h	Rate of eliminated new spine over 8-16 h (%)	# of spines at 16 h	# of new spines over 16-24 h	# of new spines formed over 16-24 h and located relative to eliminated (E) or persistent (P) new spines formed over 0-8 h									
							0-2 μ m		2-6 μ m		6-10 μ m		10-20 μ m		> 20 μ m	
							E	P	E	P	E	P	E	P	E	P
Animal 1 #																
L cortex	157	18	12	66.67	168	16	2	0	1	1	3	1	4	1	6	13
R cortex	153	12	9	75	152	12	3	0	3	1	1	0	2	3	3	8
Animal 2	195	15	10	66.67	192	12	4	1	2	0	3	2	3	3	0	6
Animal 3	156	10	6	60	159	11	3	1	1	1	2	1	2	2	3	6
Animal 4	152	9	5	55.56	153	8	4	1	0	0	0	0	1	0	3	7
Animal 5	155	7	4	57.14	158	7	2	0	0	0	0	0	0	3	5	4
Animal 6	165	13	8	61.54	172	14	4	0	2	5	0	0	4	2	4	7
Total	1133	84	54	64.28	1154	80	22	3	9	8	9	4	16	14	24	51
NREM-d																
	# of spines at 0 h	# of new spines over 0-8 h	# of eliminated new spines over 8-16 h	Rate of eliminated new spine over 8-16 h (%)	# of spines at 16 h	# of new spines over 16-24 h	# of new spines formed over 16-24 h and located relative to eliminated (E) or persistent (P) new spines formed over 0-8 h									
							0-2 μ m		2-6 μ m		6-10 μ m		10-20 μ m		> 20 μ m	
							E	P	E	P	E	P	E	P	E	P
Animal 1	159	8	5	62.5	164	9	3	0	1	0	1	0	0	3	4	6
Animal 2	154	12	8	66.67	152	9	4	0	1	0	0	1	1	1	3	7
Animal 3	152	10	6	60	156	9	2	0	1	1	1	1	1	0	4	7
Animal 4	157	11	7	63.64	160	11	5	1	1	2	0	2	3	1	2	5
Animal 5	152	14	8	57.14	156	11	5	2	1	3	4	0	1	1	0	5
Animal 6	159	15	7	46.67	169	13	3	0	4	2	2	1	0	3	4	7
Total	933	70	41	58.57	957	62	22	3	9	8	8	5	6	9	17	37
REMD																
	# of spines at 0 h	# of new spines over 0-8 h	# of eliminated new spines over 8-16 h	Rate of eliminated new spine over 8-16 h (%)	# of spines at 16 h	# of new spines over 16-24 h	# of new spines formed over 16-24 h and located relative to eliminated (E) or persistent (P) new spines formed over 0-8 h									
							0-2 μ m		2-6 μ m		6-10 μ m		10-20 μ m		> 20 μ m	
							E	P	E	P	E	P	E	P	E	P
Animal 1 #																
L cortex	198	13	5	38.46	204	11	3	1	2	1	1	0	0	2	5	7
R cortex	296	17	9	52.94	306	14	1	0	1	1	2	1	3	2	7	10
Animal 2	164	11	4	36.36	169	6	0	0	0	1	1	1	1	2	4	2
Animal 3	179	16	9	56.25	188	8	2	0	1	2	1	2	2	0	2	4
Animal 4 #																
L cortex	162	8	3	37.5	162	6	1	0	0	0	0	0	0	0	5	6
R cortex	180	17	8	47.06	181	11	0	0	4	3	1	1	2	3	4	4
Animal 5	151	11	5	45.45	152	6	1	1	0	0	0	0	1	1	4	4
Animal 6 #																
L cortex	141	8	3	37.5	149	4	1	0	0	0	1	1	0	0	2	3
R cortex	202	19	11	57.89	201	11	2	0	2	0	2	1	0	1	5	9
Total	1673	120	57	47.5	1712	77	11	2	10	8	9	7	9	11	38	49

In these animals, new spine survival and distribution were quantified from both left (L) and right (R) motor cortices. In Extended Data Fig. 5b, each point represents data from one animal.

Supplementary Table 4 The total number of spines analyzed at 0 h, the number of newly-formed spines over 0-24 h after FW running and eliminated new spines over 24-36 h in each mouse at postnatal day 30 (P30) (Data related **Supplementary Fig. 4c**).

ND (FW running-induced new spines over 0-24 h)				
	# of spines at 0 h	# of new spines over 0-24 h	# of eliminated new spines over 24-36 h	Rate of eliminated new spine over 24-36 h (%)
Animal 1	113	10	5	50
Animal 2	155	12	7	58.33
Animal 3	167	14	7	50
Animal 4	163	14	8	57.14
Animal 5	156	13	7	53.85
Animal 6	151	13	6	46.15
Animal 7	165	15	8	53.33
Animal 8	163	17	10	58.82
Animal 9	145	11	6	54.55
Total	1378	119	64	53.78
REMD (FW running-induced new spines over 0-8 h)				
	# of spines at 0 h	# of new spines over 0-8 h	# of eliminated new spines over 8-16 h	Rate of eliminated new spine over 8-16 h (%)
Animal 1	158	13	4	30.77
Animal 2	155	12	3	25
Animal 3	161	15	4	26.67
Animal 4	149	13	4	30.77
Animal 5	136	13	5	38.46
Animal 6	171	14	5	35.71
Total	930	80	25	31.25

Supplementary Table 5 The performance (r.p.m.) of FW running at 16 h and 24 h, and performance improvement (%) of FW running over 16-24 h under various conditions (Data related to **Fig. 2I**).

ND			
	FW performance at 16 h (r.p.m.) Average of 40 trials	FW performance at 24 h (r.p.m.) Average of 20 trials	Performance improvement (%)
Animal 1	35.1	47.5	35.33
Animal 2	26.1	38.81	48.72
Animal 3	34.93	49	40.3
Animal 4	27.81	40.57	45.89
Animal 5	31.05	45.52	46.61
Animal 6	34.35	67.85	97.53
Animal 7	26.45	38.8	46.69
Average	30.83	46.86	51.58
NREM-d			
	FW performance at 16 h (r.p.m.) Average of 40 trials	FW performance at 24 h (r.p.m.) Average of 20 trials	Performance improvement (%)
Animal 1	38.88	53.4	37.36
Animal 2	26.13	35.67	36.52
Animal 3	36.88	59.75	62.03
Animal 4	34.5	60.7	75.94
Animal 5	37.83	57.85	52.94
Animal 6	27.2	46.5	70.96
Animal 7	32.93	48.45	47.15
Average	33.48	51.76	54.7
REMD			
	FW performance at 16 h (r.p.m.) Average of 40 trials	FW performance at 24 h (r.p.m.) Average of 20 trials	Performance improvement (%)
Animal 1	24.48	33.95	38.72
Animal 2	34.73	38.33	10.39
Animal 3	26.43	30.65	15.97
Animal 4	25.14	32.05	27.46
Animal 5	42.15	54.1	28.35
Animal 6	31.35	35.95	14.67
Average	30.71	37.51	22.6

Supplementary Table 6 The performance (r.p.m.) of FW running at 0 h and 24 h, and performance improvement (%) of FW running over 0-24 h under various conditions (Data related to **Fig. 3k**).

ND			
	FW performance at 0 h (r.p.m.) Average of 40 trials	FW performance at 24 h (r.p.m.) Average of 20 trials	Performance improvement (%)
Animal 1	23	34.3	49.13
Animal 2	18.1	36.85	103.65
Animal 3	23.64	41.8	76.8
Animal 4	26.67	46.65	74.94
Animal 5	26.29	44.35	68.69
Animal 6	24.68	41.55	68.33
Average	23.73	40.92	73.59
NREM-d			
	FW performance at 0 h (r.p.m.) Average of 40 trials	FW performance at 24 h (r.p.m.) Average of 20 trials	Performance improvement (%)
Animal 1	26.9	47.9	78.04
Animal 2	23.86	37.45	56.98
Animal 3	31.49	53.7	70.54
Animal 4	24.37	42.58	74.75
Animal 5	25.41	46.2	81.79
Animal 6	23.71	42.15	77.79
Average	25.96	45	73.31
REMD			
	FW performance at 0 h (r.p.m.) Average of 40 trials	FW performance at 24 h (r.p.m.) Average of 20 trials	Performance improvement (%)
Animal 1	25.98	48.15	85.36
Animal 2	19.06	27.95	46.68
Animal 3	29.67	38.7	30.45
Animal 4	24.35	40.29	65.47
Animal 5	36.12	50.8	40.63
Animal 6	30.37	35.55	17.07
Animal 7	29.12	33.2	14.00
Average	27.81	39.23	42.81