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Supplemental Information

Visual Experience-Dependent Oscillations and Underlying Circuit Connectivity Changes Are Impaired in *Fmr1* KO Mice

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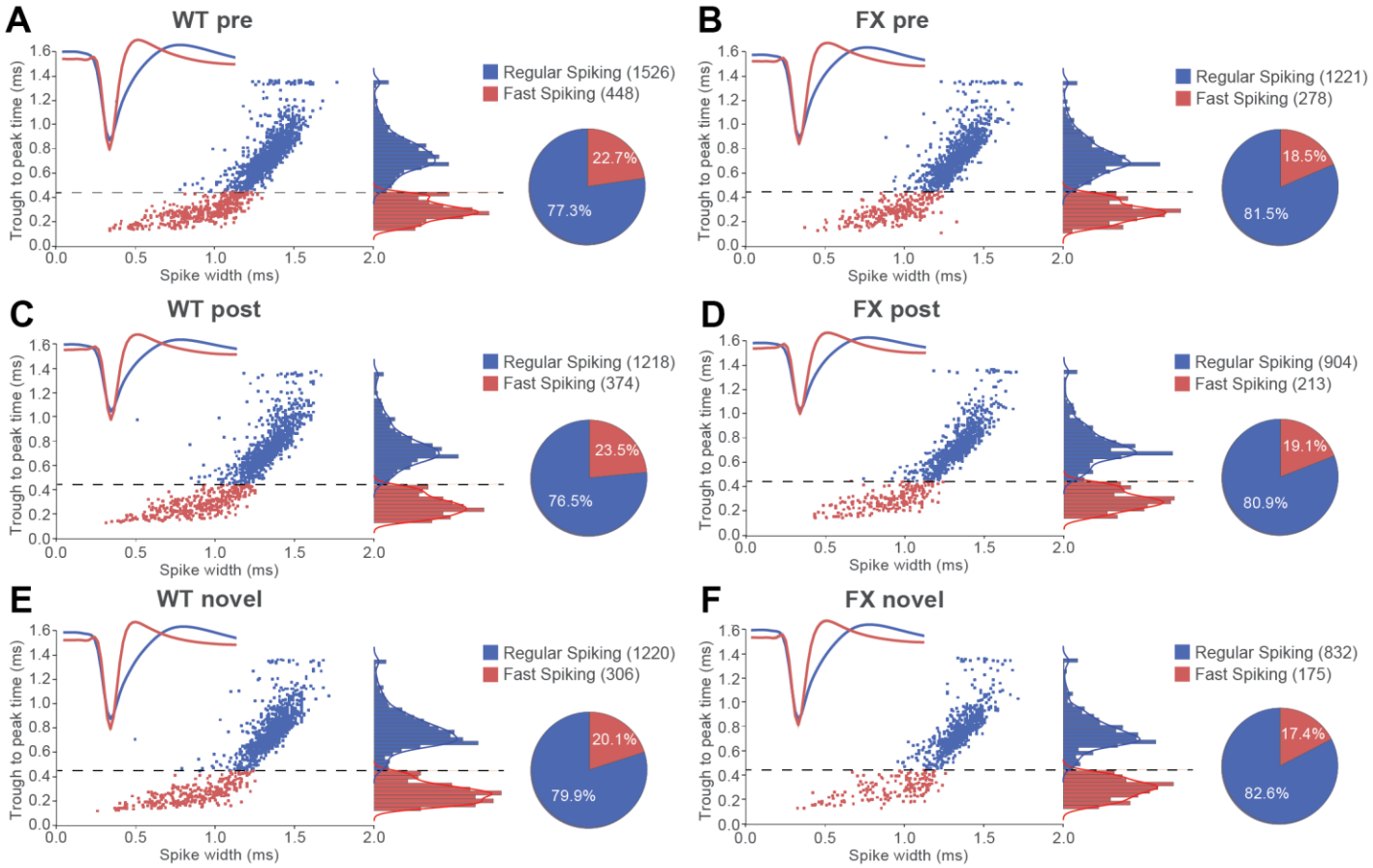

Figure S1. Segregation of regular and fast spiking cells in WT and FX mice for each stimulus condition. Related to Figure 2.

(A) Averaged waveforms, scatterplots and distributions of waveform trough to peak vs spike width times, and pie graphs of the percentage of each neural subtype recorded before the perceptual experience in WT animals. 448 units (22.7%) were FS, while 1526 (77.3%) were RS, across 33 mice.

(B) Units recorded in FX animals pre perceptual experience. FS: 278 (18.5%), RS: 1221 (81.5%) across 25 mice.

(C) Units recorded in WT animals post perceptual experience. FS: 374 (23.5%), RS: 1218 (76.5%) across 31 mice.

(D) Units recorded in FX animals post perceptual experience. FS: 213 (19.1%), RS: 904 (80.9%) across 25 mice.

(E) Units recorded in WT animals in response to novel stimuli. FS: 306 (20.1%), RS: 1220 (79.9%) across 24 mice.

(F) Units recorded in FX animals in response to novel stimuli. FS: 175 (17.4%), RS:832 (82.6%) across 18 mice.

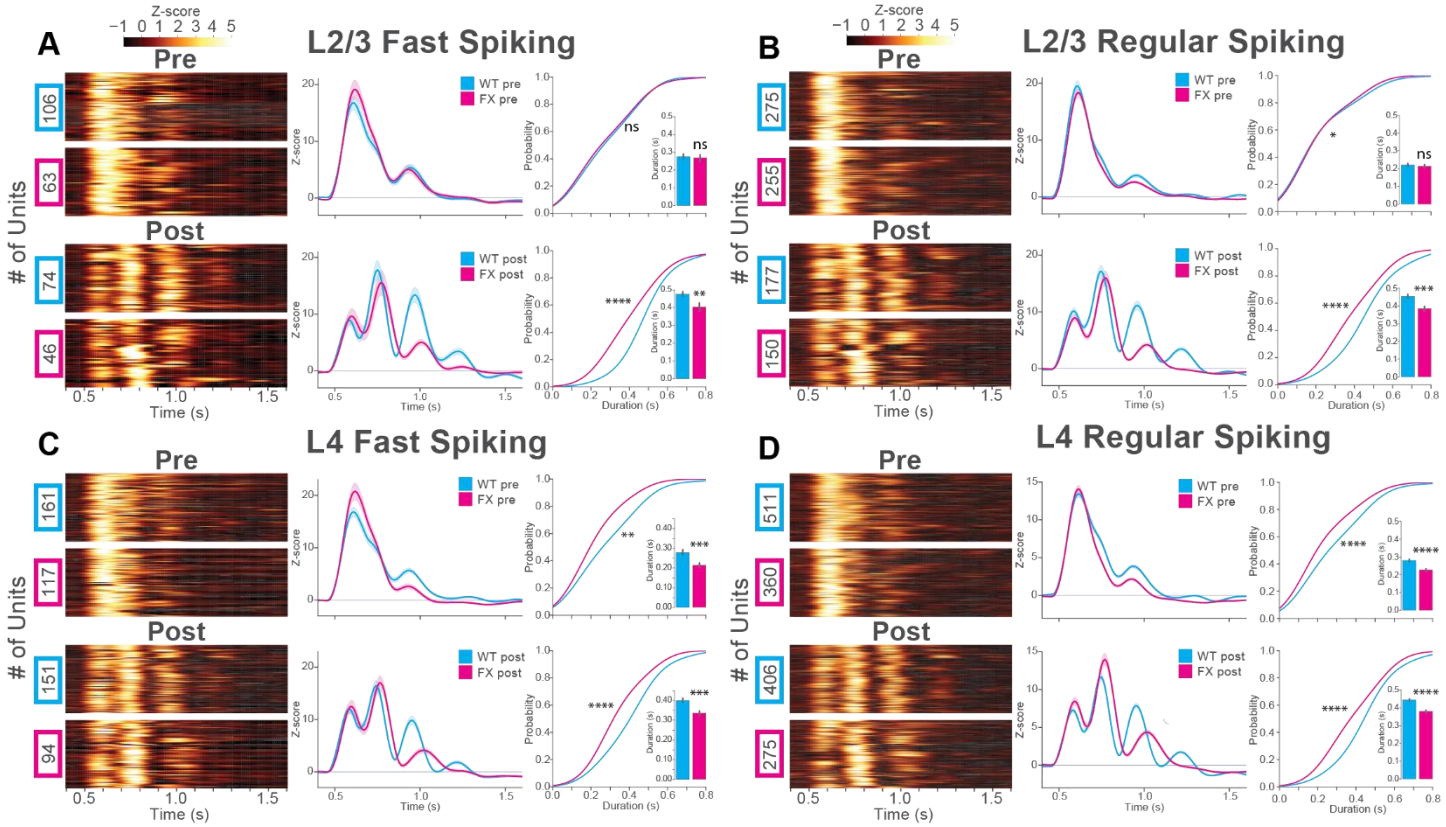

Figure S2. Decreased oscillation duration of regular and fast spiking units in layers 2/3 and 4 of FX mice. Related to Figure 2.

Visually excited units in L2/3 and L4 before and after perceptual experience to grating stimuli. WT (Cyan) 33 mice pre, 31 mice post. FX (magenta) 25 mice pre, 25 mice post. Z-scored firing rates are shown in the heatmaps. Population z-score line plots are shown to the right of the heatmaps. A cumulative distribution (CDF) of oscillation duration is shown to the right of the line plots, with bar graphs of the mean oscillation duration inset.

(A) L2/3 FS units: 2 sample KS test of duration CDFs, pre, WT vs FX duration: D(159)=0.08, p=0.92. Welch's t-test of mean duration: t(159)=0.27, p=0.78 (units after peak detection: WT pre N=101, FX pre N=60). 2 sample KS test of duration CDFs, post, WT vs FX duration: D(115)=0.41, p=9.05E-9. Welch's unequal variances t-test of mean duration:, t(115)=2.66, p=9.33E-3 (units after peak detection: WT post N=72, FX post N=45). Error bars indicate SEM. *p<0.05, **p<0.01,***p<0.001, ****p<0.0001.

(B) L2/3 RS units: 2 sample KS test of duration CDFs, pre, WT vs FX duration: D(501)=0.14, p=0.01. Welch's t-test of mean duration:, t(501)=0.45, p=0.65. (units after peak detection: WT pre N=264, FX pre N=239). 2 sample KS test of duration CDFs, post, WT vs FX duration: D(311)=0.35, p=3.15E-9. Welch's unequal variances t-test of mean duration: t(311)=3.88, p=1.2E-4 (units after peak detection: WT post N=172, FX post N=139.).

(C) L4 FS units: 2 sample KS test of duration CDFs, pre, WT vs FX duration: D(267)=0.22, p=1.89E-3. Welch's t-test of mean duration: t(267)=3.57, p=4.17E-4 (units after peak detection: WT pre N=154, FX pre N=115). 2 sample KS test of duration CDFs, post, WT vs FX duration: D(234)=0.37, p=1.16E-7. Welch's unequal variances t-test of mean duration:, t(234)=3.84, p=1.59E-4 (units after peak detection: WT post N=145, FX post N=91).

(D) L4 RS units: 2 sample KS test of duration CDFs, pre, WT vs FX duration: D(825)=0.17, p=8.20E-6 (units after peak detection: WT pre N=460, FX pre N=367). Welch's unequal variances t-test of mean duration: t(825)=4.85, p=1.42E-6. (2 sample KS test of duration CDFs, post, WT vs FX duration: D(714)=0.35, p=5.32E-17. Welch's t-test of mean duration: t(714)=5.53, p=4.87E-8 (units after peak detection: WT post N=408, FX post N=308).

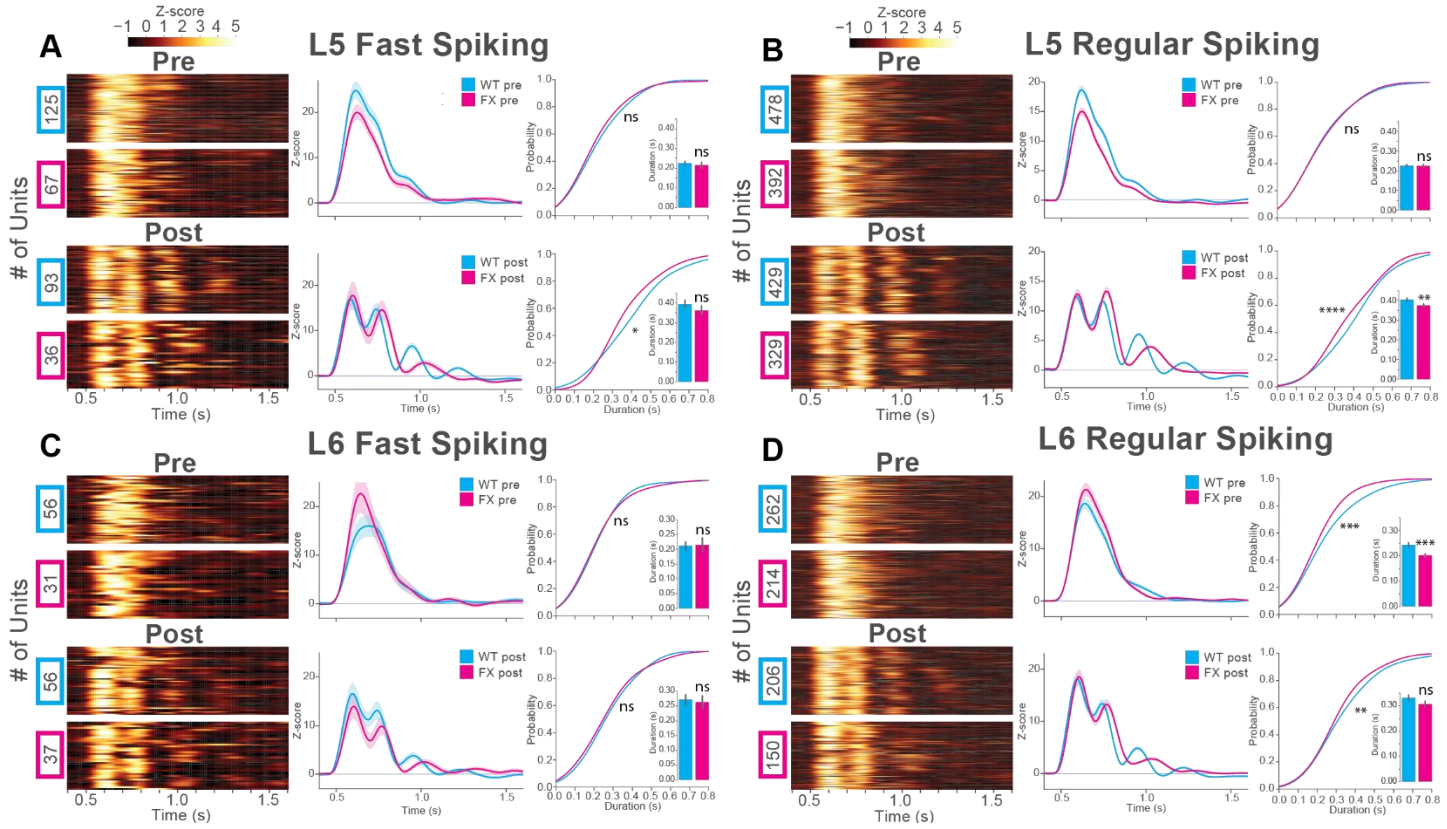

Figure S3. Decreased oscillation duration of regular and fast spiking units in layer 5 and regular spiking units in layer 6 of FX mice after perceptual experience. Related to Figure 2.

Visually excited units in L5 and L6 before and after perceptual experience to grating stimuli. WT (Cyan) 33 mice pre, 31 mice post. FX (magenta) 25 mice pre, 25 mice post. Z-scored firing rates are shown in the heatmaps. Population z-score line plots are shown to the right of the heatmaps. A cumulative distribution (CDF) of oscillation duration is shown to the right of the line plots, with bar graphs of the mean oscillation duration inset.

(A) L5 FS units: 2 sample KS test of duration CDFs, pre, WT vs FX duration: D(190)=0.10, p=0.71. Welch's t-test of mean duration: t(190)=0.49, p=0.62 (units after peak detection: WT pre N=124, FX pre N=66). 2 sample KS test of duration CDFs, post, WT vs FX duration: D(124)=0.27, p=0.03. Welch's unequal variances t-test of mean duration:, t(124)=-1.03, p=0.30 (units after peak detection: WT post N=91, FX post N=35). Error bars indicate SEM. *p<0.05, **p<0.01,***p<0.001, ****p<0.0001.

(B) L5 RS units: 2 sample KS test of duration CDFs, pre, WT vs FX duration: D(825)=0.04, p=0.83. Welch's t-test of mean duration: t(825)=0.12, p=0.90 (units after peak detection: WT pre N=460, FX pre N=367). 2 sample KS test of duration CDFs, post, WT vs FX duration: D(714)=0.23, p=4.74E-9. Welch's unequal variances t-test of mean duration:, t(714)=2.61, p=9.19E-3 (units after peak detection: WT post N=408, FX post N=308).

(C) L6 FS units: 2 sample KS test of duration CDFs, pre, WT vs FX duration: D(83)=0.13, p=0.85. Welch's t-test of mean duration: t(83)=-0.11, p=0.91 (units after peak detection: WT pre N=55, FX pre N=30). 2 sample KS test of duration CDFs, post, WT vs FX duration: D(90)=0.24, p=0.10. Welch's unequal variances t-test of mean duration:, t(90)=0.29, p=0.76 (units after peak detection: WT post N=55, FX post N=37).

(D) L6 RS units: 2 sample KS test of duration CDFs, pre, WT vs FX duration: D(255)=0.15, p=6.94E-3. Welch's t-test of mean duration: t(255)=3.40, p=7.13E-4 (units after peak detection: WT pre N=250, FX pre N=207). 2 sample KS test of duration CDFs, post, WT vs FX duration: D(337)=0.20, p=2.13E-3. Welch's unequal variances t-test of mean duration:, t(337)=1.59, p=0.11 (units after peak detection: WT post N=197, FX post N=142).

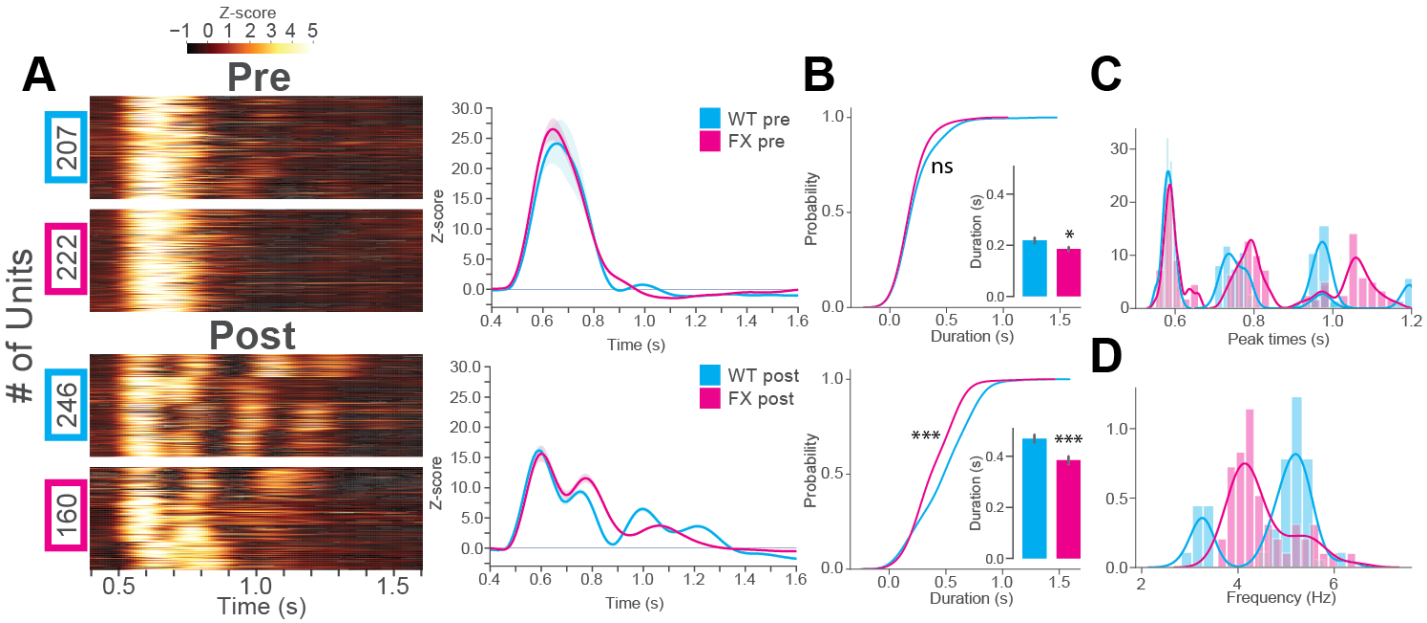

Figure S4. Decreased oscillation durations after perceptual experience in homozygous female FX mice. Related to Figure 2.

(A) Visually excited units across all layers before or after perceptual experience to grating stimuli. WT (Cyan) 4 mice pre, 4 mice post. FX (magenta) 4 mice pre, 4 mice post. Z-scored firing rates are shown in the heatmaps. Population z-score line plots are shown to the right of the heatmaps.

(B) Cumulative distributions (CDF) of oscillation duration, with bar graphs of the mean oscillation duration inset. 2 sample KS test of duration CDFs, pre, WT vs FX duration: $D(427)=0.11$, $p=0.10$. Welch's t-test of mean duration: $t(427)=2.46$, $p=1.42E-2$ (units after peak detection: WT pre N=195, FX pre N=216). 2 sample KS test of duration CDFs, post, WT vs FX duration: $D(404)=0.28$, $p=6.39E-7$. Welch's unequal variances t-test of mean duration:, $t(404)=3.76$, $p=1.96E-4$ (units after peak detection: WT post N=225, FX post N=144). Error bars indicate SEM. *p<0.05, **p<0.01,***p<0.001.

(C) Distributions of peak times across WT and FX unit populations at 3 oscillation cycles for the units in A and B.

(D) Distributions of oscillation frequency for the units in A and B.

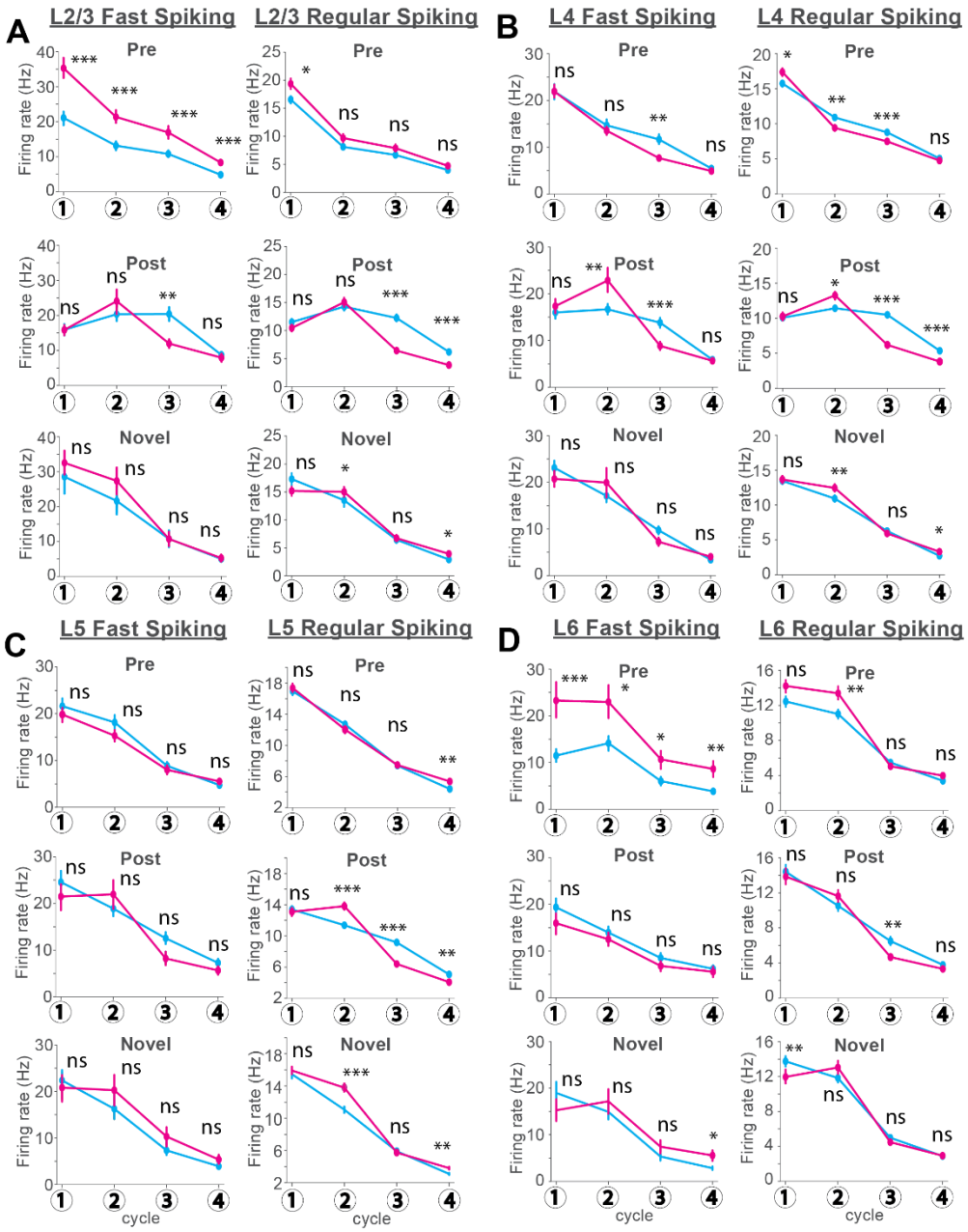

Figure S5. Mean firing rates at each oscillation cycle in WT and FX mice. Related to Figure 2.

(A) Firing rates for L2/3 RS and FS cells at each oscillation cycle and stimulus condition. The units used for this analysis are found in figure S2A and B. See table S1 for statistical analysis. Error bars indicate SEM. *p<0.05, **p<0.01,***p<0.001.

(B) Firing rates for L4 RS and FS cells at each oscillation cycle and stimulus condition. The units used for this analysis are found in figure S2C and D. See table S1 for statistical analysis.

(C) Firing rates for L5 RS and FS cells at each oscillation cycle and stimulus condition. The units used for this analysis are found in figure S3A and B. See table S1 for statistical analysis.

(D) Firing rates for L6 RS and FS cells at each oscillation cycle and stimulus condition. The units used for this analysis are found in figure S3C and D. See table S1 for statistical analysis.

Table S1. Mean firing rates at each oscillation cycle, WT vs FX. Related to Figure 2					
Comparison	**Estimate**	**Standard Error**	**DF**	**t or F**	**p**
Pre L2/3 FS					
Fixed Effect: Genotype	N/A	N/A	167	22.56	<.0004
Fixed Effect: Oscillation number	N/A	N/A	501	242.13	<.0004
Fixed Effect: Group * Oscillation	N/A	N/A	501	3.27	0.021
Pre L2/3 FS Cycle 1	0.8283	0.1502	277.4	5.52	<.0004
Pre L2/3 FS Cycle 2	0.6506	0.1502	277.4	4.33	<.0004
Pre L2/3 FS Cycle 3	0.503	0.1502	277.4	3.35	0.0009
Pre L2/3 FS Cycle 4	0.5119	0.1502	277.4	3.41	0.0007
Pre L2/3 RS					
Fixed Effect: Genotype	N/A	N/A	528	3.49	0.0625
Fixed Effect: Oscillation number	N/A	N/A	1584	836.97	<.0004
Fixed Effect: Group * Oscillation	N/A	N/A	1584	0.88	0.452
Pre L2/3 RS Cycle 1	0.1607	0.07027	929.9	2.29	0.0224
Pre L2/3 RS Cycle 2	0.1049	0.07027	929.9	1.49	0.1357
Pre L2/3 RS Cycle 3	0.06649	0.07027	929.9	0.95	0.3443
Pre L2/3 RS Cycle 4	0.1188	0.07027	929.9	1.69	0.0914
Pre L4 FS					
Fixed Effect: Genotype	N/A	N/A	276	0.02	0.8807
Fixed Effect: Oscillation number	N/A	N/A	828	407.7	<.0004
Fixed Effect: Group * Oscillation	N/A	N/A	828	9.97	<.0004
Pre L4 FS Cycle 1	0.1218	0.1103	451	1.1	0.2698
Pre L4 FS Cycle 2	0.103	0.1103	451	0.93	0.3508
Pre L4 FS Cycle 3	-0.2939	0.1103	451	-2.66	0.008
Pre L4 FS Cycle 4	0.01084	0.1103	451	0.1	0.9217
Pre L4 RS					
Fixed Effect: Genotype	N/A	N/A	869	2.13	0.1452
Fixed Effect: Oscillation number	N/A	N/A	2607	1283.71	<.0004
Fixed Effect: Group * Oscillation	N/A	N/A	2607	23.6	<.0004
Pre L4 RS Cycle 1	0.12	0.04944	1444	2.43	0.0153
Pre L4 RS Cycle 2	-0.1607	0.04944	1444	-3.25	0.0012
Pre L4 RS Cycle 3	-0.1684	0.04944	1444	-3.41	0.0007
Pre L4 RS Cycle 4	-0.04283	0.04944	1444	-0.87	0.3864
Pre L5 FS					
Fixed Effect: Genotype	N/A	N/A	190	0.01	0.9302
Fixed Effect: Oscillation number	N/A	N/A	570	267.36	<.0004
Fixed Effect: Group * Oscillation	N/A	N/A	570	2.51	0.058
Pre L5 FS Cycle 1	-0.03074	0.1344	344.2	-0.23	0.8192
Pre L5 FS Cycle 2	-0.1065	0.1344	344.2	-0.79	0.4287
Pre L5 FS Cycle 3	-0.0801	0.1344	344.2	-0.6	0.5515
Pre L5 FS Cycle 4	0.1771	0.1344	344.2	1.32	0.1883
Pre L5 RS					
Fixed Effect: Genotype	N/A	N/A	868	0.4	0.5255
Fixed Effect: Oscillation number	N/A	N/A	2604	1230.74	<.0004
Fixed Effect: Group * Oscillation	N/A	N/A	2604	7.19	<.0004
Pre L5 RS Cycle 1	0.01396	0.05165	1622	0.27	0.7869
Pre L5 RS Cycle 2	-0.06625	0.05165	1622	-1.28	0.1998
Pre L5 RS Cycle 3	0.02132	0.05165	1622	0.41	0.6799
Pre L5 RS Cycle 4	0.1417	0.05165	1622	2.74	0.0061
Pre L6 FS					
Fixed Effect: Genotype	N/A	N/A	85	10.96	0.0014
Fixed Effect: Oscillation number	N/A	N/A	255	95.91	<.0004
Fixed Effect: Group * Oscillation	N/A	N/A	255	1.74	0.1596
Pre L6 FS Cycle 1	0.8063	0.2064	136.5	3.91	0.0001
Pre L6 FS Cycle 2	0.5297	0.2064	136.5	2.57	0.0114
Pre L6 FS Cycle 3	0.4658	0.2064	136.5	2.26	0.0256
Pre L6 FS Cycle 4	0.6101	0.2064	136.5	2.96	0.0037
Pre L6 RS					
Fixed Effect: Genotype	N/A	N/A	474	2.5	0.1147
Fixed Effect: Oscillation number	N/A	N/A	1422	670.39	<.0004
Fixed Effect: Group * Oscillation	N/A	N/A	1422	6.81	0.0004
Pre L6 RS Cycle 1	0.1289	0.06601	947.8	1.95	0.0511
Pre L6 RS Cycle 2	0.1814	0.06601	947.8	2.75	0.0061
Pre L6 RS Cycle 3	-0.07556	0.06601	947.8	-1.14	0.2526
Pre L6 RS Cycle 4	0.1101	0.06601	947.8	1.67	0.0957

Post L2/3 FS					
Fixed Effect: Genotype	N/A	N/A	118	0.33	0.5651
Fixed Effect: Oscillation number	N/A	N/A	354	86.79	<.0004
Fixed Effect: Group * Oscillation	N/A	N/A	354	11.3	<.0004
Post L2/3 FS Cycle 1	0.1053	0.1738	198.3	0.61	0.5454
Post L2/3 FS Cycle 2	0.1646	0.1738	198.3	0.95	0.345
Post L2/3 FS Cycle 3	-0.5649	0.1738	198.3	-3.25	0.0014
Post L2/3 FS Cycle 4	-0.05445	0.1738	198.3	-0.31	0.7545
Post L2/3 RS					
Fixed Effect: Genotype	N/A	N/A	325	16.35	<.0004
Fixed Effect: Oscillation number	N/A	N/A	975	300.33	<.0004
Fixed Effect: Group * Oscillation	N/A	N/A	975	36.09	<.0004
Post L2/3 RS Cycle 1	-0.0958	0.07581	667.5	-1.26	0.2068
Post L2/3 RS Cycle 2	0.05196	0.07581	667.5	0.69	0.4934
Post L2/3 RS Cycle 3	-0.6408	0.07581	667.5	-8.45	<.0004
Post L2/3 RS Cycle 4	-0.3201	0.07581	667.5	-4.22	<.0004
Post L4 FS					
Fixed Effect: Genotype	N/A	N/A	243	0.05	0.8206
Fixed Effect: Oscillation number	N/A	N/A	729	237.28	<.0004
Fixed Effect: Group * Oscillation	N/A	N/A	729	21.81	<.0004
Post L4 FS Cycle 1	0.1206	0.1204	424.9	1	0.317
Post L4 FS Cycle 2	0.3614	0.1204	424.9	3	0.0028
Post L4 FS Cycle 3	-0.4271	0.1204	424.9	-3.55	0.0004
Post L4 FS Cycle 4	0.03915	0.1204	424.9	0.33	0.7451
Post L4 RS					
Fixed Effect: Genotype	N/A	N/A	679	12.79	0.0004
Fixed Effect: Oscillation number	N/A	N/A	2037	510.45	<.0004
Fixed Effect: Group * Oscillation	N/A	N/A	2037	65.31	<.0004
Post L4 RS Cycle 1	-0.01959	0.05341	1321	-0.37	0.7139
Post L4 RS Cycle 2	0.1334	0.05341	1321	2.5	0.0126
Post L4 RS Cycle 3	-0.4951	0.05341	1321	-9.27	<.0004
Post L4 RS Cycle 4	-0.2558	0.05341	1321	-4.79	<.0004
Post L5 FS					
Fixed Effect: Genotype	N/A	N/A	127	0.3	0.5836
Fixed Effect: Oscillation number	N/A	N/A	381	119.65	<.0004
Fixed Effect: Group * Oscillation	N/A	N/A	381	4.34	0.0051
Post L5 FS Cycle 1	-0.06021	0.2048	215.4	-0.29	0.7691
Post L5 FS Cycle 2	0.1995	0.2048	215.4	0.97	0.3312
Post L5 FS Cycle 3	-0.3931	0.2048	215.4	-1.92	0.0563
Post L5 FS Cycle 4	-0.1374	0.2048	215.4	-0.67	0.5031
Post L5 RS					
Fixed Effect: Genotype	N/A	N/A	756	3.95	0.0472
Fixed Effect: Oscillation number	N/A	N/A	2268	821.28	<.0004
Fixed Effect: Group * Oscillation	N/A	N/A	2268	53.89	<.0004
Post L5 RS Cycle 1	-0.0331	0.04897	1515	-0.68	0.4993
Post L5 RS Cycle 2	0.2123	0.04897	1515	4.33	<.0004
Post L5 RS Cycle 3	-0.3468	0.04897	1515	-7.08	<.0004
Post L5 RS Cycle 4	-0.1541	0.04897	1515	-3.15	0.0017
Post L6 FS					
Fixed Effect: Genotype	N/A	N/A	91	2.11	0.1502
Fixed Effect: Oscillation number	N/A	N/A	273	100.09	<.0004
Fixed Effect: Group * Oscillation	N/A	N/A	273	0.37	0.7744
Post L6 FS Cycle 1	-0.2772	0.1718	161.1	-1.61	0.1086
Post L6 FS Cycle 2	-0.1757	0.1718	161.1	-1.02	0.308
Post L6 FS Cycle 3	-0.255	0.1718	161.1	-1.48	0.1398
Post L6 FS Cycle 4	-0.1476	0.1718	161.1	-0.86	0.3915
Post L6 RS					
Fixed Effect: Genotype	N/A	N/A	354	1	0.3188
Fixed Effect: Oscillation number	N/A	N/A	1062	554.12	<.0004
Fixed Effect: Group * Oscillation	N/A	N/A	1062	6.66	0.0002
Post L6 RS Cycle 1	-0.07444	0.07315	691.9	-1.02	0.3092
Post L6 RS Cycle 2	0.08321	0.07315	691.9	1.14	0.2557
Post L6 RS Cycle 3	-0.2106	0.07315	691.9	-2.88	0.0041
Post L6 RS Cycle 4	-0.04135	0.07315	691.9	-0.57	0.572
Novel L2/3 FS					
Fixed Effect: Genotype	N/A	N/A	48	0.97	0.3284
Fixed Effect: Oscillation number	N/A	N/A	144	94.36	<.0004
Fixed Effect: Group * Oscillation	N/A	N/A	144	1.63	0.1853

Novel L2/3 FS Cycle 1	0.4536	0.3105	87.27	1.46	0.1476
Novel L2/3 FS Cycle 2	0.4836	0.3105	87.27	1.56	0.123
Novel L2/3 FS Cycle 3	0.06215	0.3105	87.27	0.2	0.8418
Novel L2/3 FS Cycle 4	0.0443	0.3105	87.27	0.14	0.8869
Novel L2/3 RS					
Fixed Effect: Genotype	N/A	N/A	211	1.78	0.1842
Fixed Effect: Oscillation number	N/A	N/A	633	427.35	<.0004
Fixed Effect: Group * Oscillation	N/A	N/A	633	5.53	0.0009
Novel L2/3 RS Cycle 1	-0.09733	0.1018	435.5	-0.96	0.3395
Novel L2/3 RS Cycle 2	0.2024	0.1018	435.5	1.99	0.0475
Novel L2/3 RS Cycle 3	0.07667	0.1018	435.5	0.75	0.4518
Novel L2/3 RS Cycle 4	0.2622	0.1018	435.5	2.58	0.0103
Novel L4 FS					
Fixed Effect: Genotype	N/A	N/A	214	0.33	0.5674
Fixed Effect: Oscillation number	N/A	N/A	642	364.85	<.0004
Fixed Effect: Group * Oscillation	N/A	N/A	642	4.5	0.0039
Novel L4 FS Cycle 1	-0.162	0.1317	386.7	-1.23	0.2195
Novel L4 FS Cycle 2	0.03545	0.1317	386.7	0.27	0.788
Novel L4 FS Cycle 3	-0.2468	0.1317	386.7	-1.87	0.0618
Novel L4 FS Cycle 4	0.116	0.1317	386.7	0.88	0.3792
Novel L4 RS					
Fixed Effect: Genotype	N/A	N/A	613	1.82	0.1774
Fixed Effect: Oscillation number	N/A	N/A	1839	1185.15	<.0001
Fixed Effect: Group * Oscillation	N/A	N/A	1839	6.3	0.0003
Novel L4 RS Cycle 1	0.01919	0.05428	1189	0.35	0.7237
Novel L4 RS Cycle 2	0.1449	0.05428	1189	2.67	0.0077
Novel L4 RS Cycle 3	-0.04013	0.05428	1189	-0.74	0.4599
Novel L4 RS Cycle 4	0.1207	0.05428	1189	2.22	0.0264
Novel L5 FS					
Fixed Effect: Genotype	N/A	N/A	130	1.39	0.241
Fixed Effect: Oscillation number	N/A	N/A	390	186.5	<.0001
Fixed Effect: Group * Oscillation	N/A	N/A	390	3.73	0.0115
Novel L5 FS Cycle 1	-0.08649	0.1845	208.6	-0.47	0.6397
Novel L5 FS Cycle 2	0.3493	0.1845	208.6	1.89	0.0597
Novel L5 FS Cycle 3	0.2886	0.1845	208.6	1.56	0.1193
Novel L5 FS Cycle 4	0.2158	0.1845	208.6	1.17	0.2435
Novel L5 RS					
Fixed Effect: Genotype	N/A	N/A	793	7.93	0.005
Fixed Effect: Oscillation number	N/A	N/A	2379	1605.3	<.0001
Fixed Effect: Group * Oscillation	N/A	N/A	2379	11.82	<.0001
Novel L5 RS Cycle 1	0.07126	0.04965	1557	1.44	0.1514
Novel L5 RS Cycle 2	0.2546	0.04965	1557	5.13	<.0001
Novel L5 RS Cycle 3	-0.00285	0.04965	1557	-0.06	0.9543
Novel L5 RS Cycle 4	0.142	0.04965	1557	2.86	0.0043
Novel L6 FS					
Fixed Effect: Genotype	N/A	N/A	81	1.05	0.3093
Fixed Effect: Oscillation number	N/A	N/A	243	113.52	<.0001
Fixed Effect: Group * Oscillation	N/A	N/A	243	5.16	0.0018
Novel L6 FS Cycle 1	-0.2047	0.2079	144.7	-0.98	0.3265
Novel L6 FS Cycle 2	0.1858	0.2079	144.7	0.89	0.3729
Novel L6 FS Cycle 3	0.2834	0.2079	144.7	1.36	0.1748
Novel L6 FS Cycle 4	0.4632	0.2079	144.7	2.23	0.0274
Novel L6 RS					
Fixed Effect: Genotype	N/A	N/A	427	0.22	0.6427
Fixed Effect: Oscillation number	N/A	N/A	1281	628.03	<.0001
Fixed Effect: Group * Oscillation	N/A	N/A	1281	7.19	<.0001
Novel L6 RS Cycle 1	-0.1812	0.06699	1040	-2.7	0.007
Novel L6 RS Cycle 2	0.1158	0.06699	1040	1.73	0.0841
Novel L6 RS Cycle 3	-0.07713	0.06699	1040	-1.15	0.2499
Novel L6 RS Cycle 4	0.04634	0.06699	1040	0.69	0.4893

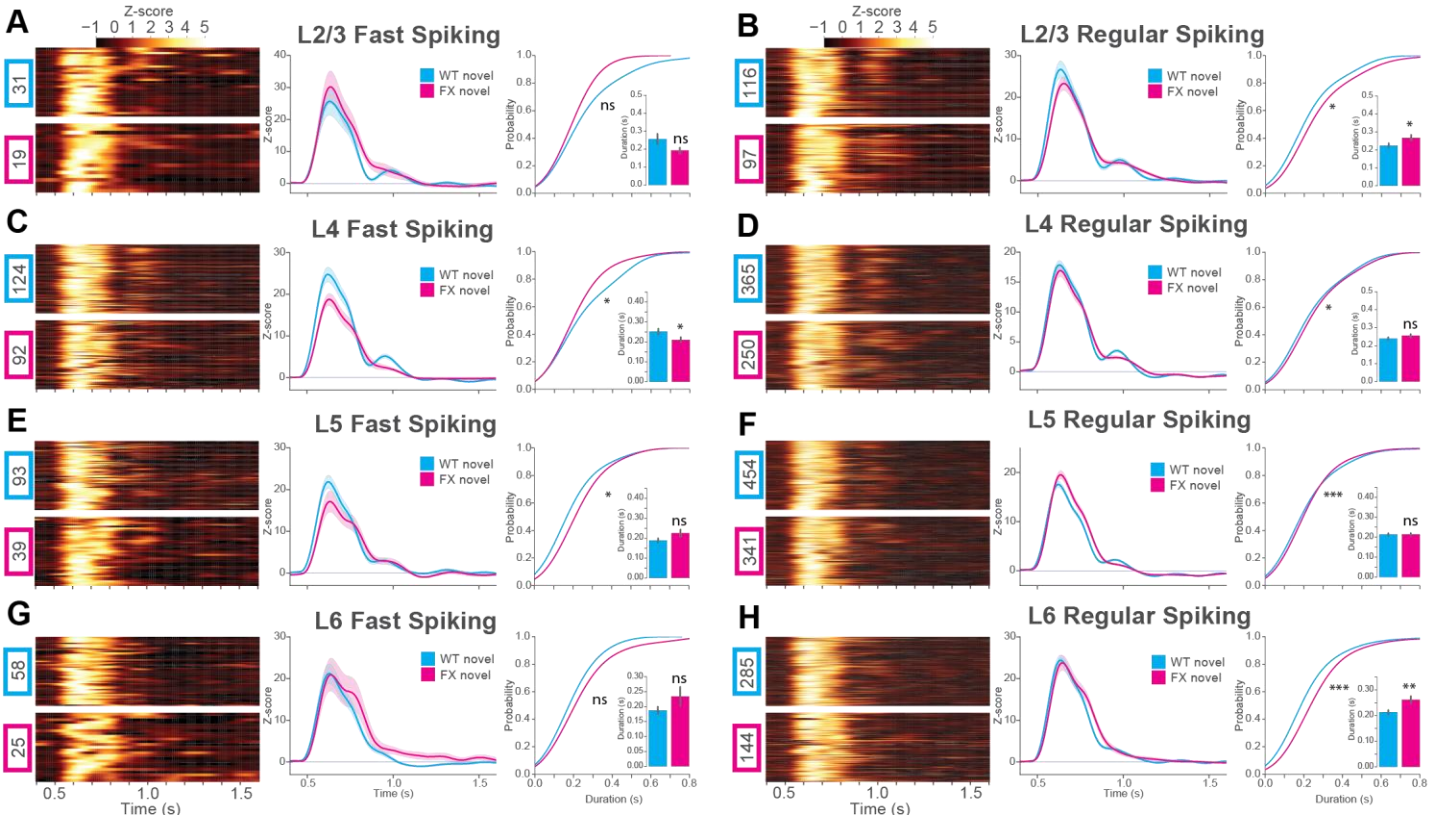

Figure S6. Responses to novel stimuli across all cortical layers and neural subtypes in WT and FX mice. Related to Figure 2.

Visually excited units in all layers in response to novel stimuli. WT (Cyan) 24 mice, FX (magenta) 18 mice. Z-scored firing rates are shown in the heatmaps. Population z-score line plots are shown to the right of the heatmaps. A cumulative distribution (CDF) of oscillation duration is shown to the right of the line plots, with bar graphs of the mean oscillation duration inset.

(A) L2/3 FS units: 2 sample KS test, novel WT vs FX duration: D(47)=0.22, p=0.58. Welch's t-test of mean duration: t(47)=1.82, p=0.07 (units after peak detection: WT pre N=31, FX pre N=18).

(B) L2/3 RS units: 2 sample KS test, novel WT vs FX duration: D(204)=0.20, p=0.02. Welch's unequal variances t-test of mean duration: t(204)=-2.13, p=0.03 (units after peak detection: WT pre N=112, FX pre N=94).

(C) L4 FS units: 2 sample KS test, novel WT vs FX duration: D(207)=0.22, p=0.01. Welch's t-test of mean duration: t(207)=2.14, p=0.03 (units after peak detection: WT pre N=121, FX pre N=88).

(D) L4 RS units: 2 sample KS test, novel WT vs FX duration: D(574)=0.13, p=0.01. Welch's t-test of mean duration: t(574)=-1.28, p=0.19 (units after peak detection: WT pre N=348, FX pre N=228).

(E) L5 FS units: 2 sample KS test, novel WT vs FX duration: D(124)=0.27, p=0.03. Welch's t-test of mean duration: t(124)=-1.61, p=0.11 (units after peak detection: WT pre N=90, FX pre N=36).

(F) L5 RS units: 2 sample KS test, novel WT vs FX duration: D(761)=0.16, p=3.58E-5. Welch's t-test of mean duration: t(761)=-0.12, p=0.89 (units after peak detection: WT pre N=435, FX pre N=328).

(G) L6 FS units: 2 sample KS test, novel WT vs FX duration: D(77)=0.21, p=0.42. Welch's unequal variances t-test of mean duration: t(77)=-1.32, p=0.19 (units after peak detection: WT pre N=57, FX pre N=22).

(H) L6 RS units: 2 sample KS test, novel WT vs FX duration: D(460)=0.26, p=5.43E-6. Welch's unequal variances t-test of mean duration: t(460)=-2.96, p=3.3E-3 (units after peak detection: WT pre N=278, FX pre N=184).

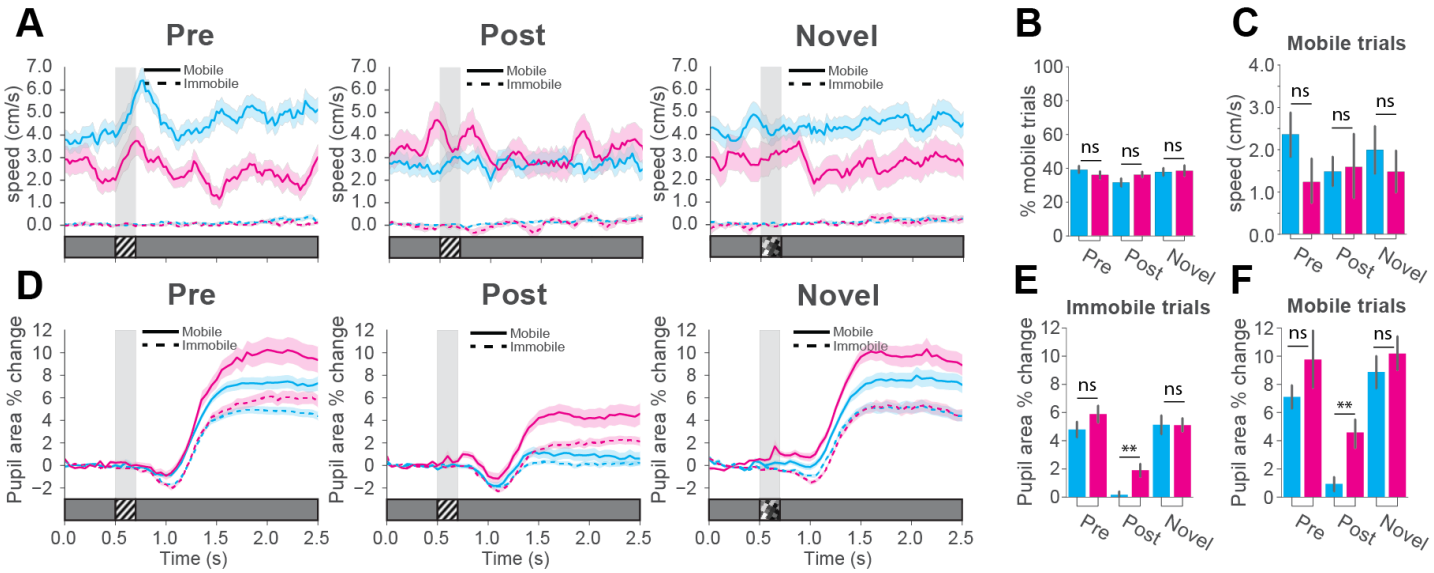

Figure S7. Locomotion and pupillometry. Related to Figures 1 and 2.

(A) Averaged locomotion traces for each recording condition (WT pre (cyan) = 20 mice, FX pre (magenta) = 12 mice, WT post (cyan) = 20 mice, FX post (magenta) = 12 mice, WT novel (cyan) = 20 mice, FX novel (magenta) = 11 mice. Only animals with both mobile and immobile trials are shown.

(B) Quantification of the percentage of mobile trials, averaged across mice for each stimulus condition. No significant differences could be found between WT and FX mice.

(C) Quantification of the mean speed across mice during the post stimulus response period (0.5 to 1.0 s) for mobile trials. T-test, WT pre vs FX pre: t(30)=1.86, p=0.07. WT post vs FX post: t(30)=-0.26, p=0.79. WT novel vs FX novel: t(29)=0.83, p=0.40.

(D) Pupillometry recordings, averaged and presented as pupil area percent change from the baseline period. WT pre (cyan)=34 mice immobile, 22 mobile. FX pre (magenta)=23 mice immobile, 11 mobile. WT post (cyan)=33 mice immobile, 14 mice mobile. FX post (magenta) = 23 mice immobile, 11 mobile. WT novel (cyan)=23 mice immobile, 17 mobile. FX novel (magenta)=16 mice immobile, 11 mice mobile.

(E) Quantification of the sustained surprise response period (1.5 s to 2.5 s) for each recording condition during immobile trials. Welch's t-test, WT pre vs FX pre :t(55)=-1.27, p=0.2. WT post vs FX post: t(54)=-3.33, p=2.04E-3. WT novel vs FX novel: t(37)=0.02, p=0.97.

(F) Quantification of the sustained surprise response period (1.5 s to 2.5 s) for each recording condition during mobile trials. Welch's t-test, WT pre vs FX pre :t(31)=-1.09, p=0.29. WT post vs FX post: t(23)=-3.00, p=9.10E-3. WT novel vs FX novel: t(26)=0.72, p=0.47.

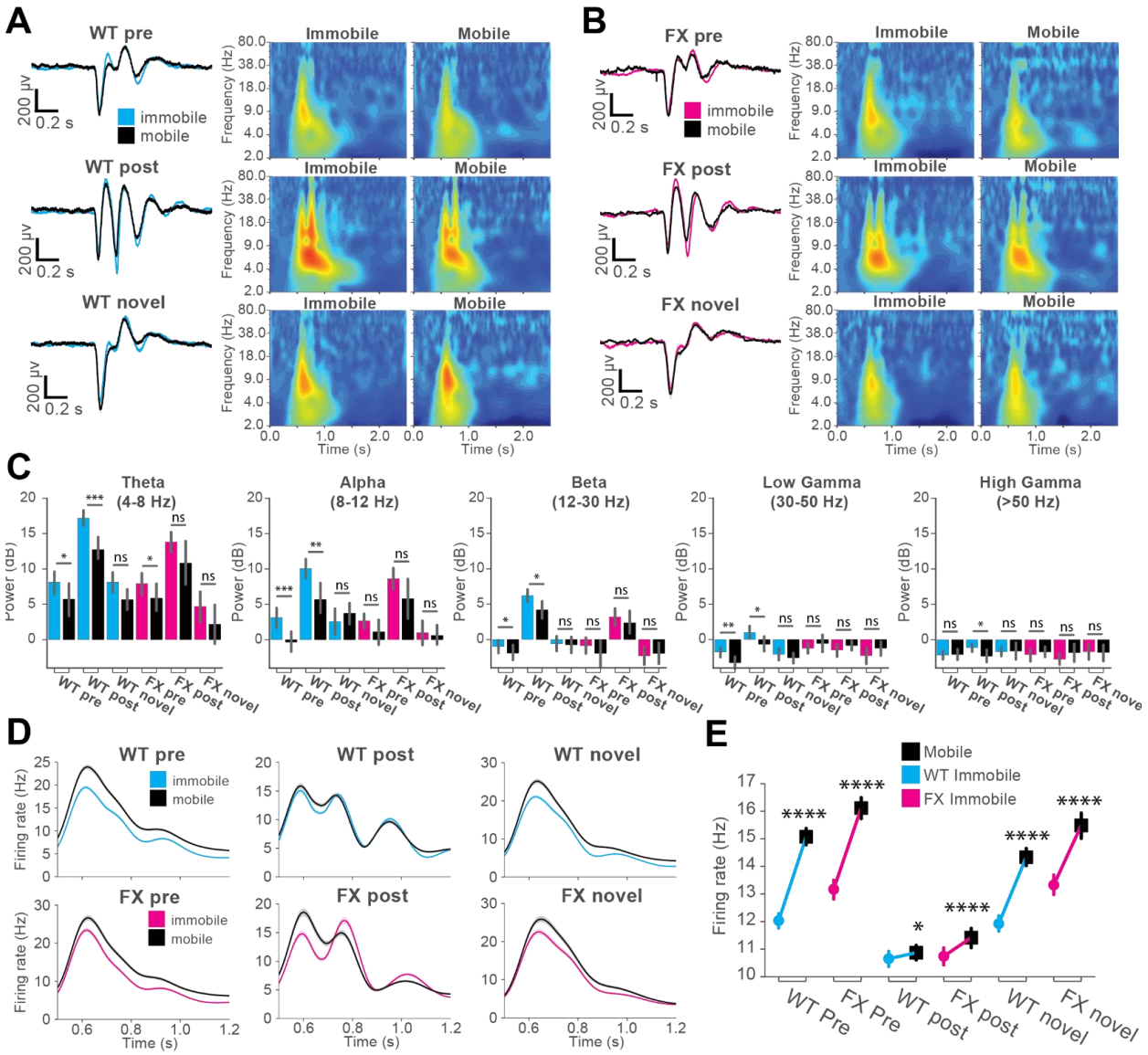

Figure S8. Locomotion decreases the power of low frequency oscillations while increasing firing rates. Related to Figures 1 and 2.

(A) Averaged time frequency spectrograms for WT mice during stationary trials (Cyan) or locomoting trials (black).

(B) Averaged time frequency spectrograms for FX mice during stationary trials (Magenta) or locomoting trials (black).

(C) Bar plots comparing the baseline normalized power between stationary and locomoting trials for each condition across different frequency bands. Mann-Whitney-U test, stationary vs locomoting Theta: WT pre: t=266, p=0.02. WT post: t=65, p=5.42E-5. WT novel: t=114, p=0.02. FX pre: t=84, p=0.01. FX post: t=154, p=0.06. FX novel: t=78, p=0.09.
Alpha: WT pre: t=172, p=2.37E-4. WT post: t=111, p=2.16E-3. WT novel: t=147, p=0.13. FX pre: t=111, p=0.07. FX post: t=155, p=0.06. FX novel: t=96, p=0.27. Beta: WT pre: t=284, p=0.04. WT post: t=136, p=0.01. WT novel: t=183, p=0.46. FX pre: t=126, p=0.15. FX post: t=175, p=0.15. FX novel: t=109, p=0.48. Low Gamma: WT pre: t=234, p=6.35E-3. WT post: t=143, p=0.01. WT novel: t=160, p=0.22. FX pre: t=127, p=0.16. FX post: t=174, p=0.14. FX novel: t=75, p=0.07.
High Gamma: WT pre: t=387, p=0.49. WT post: t=143, p=0.01. WT novel: t=184, p=0.47. FX pre: t=158, p=0.48. FX post: t=143, p=0.01. FX novel: t=184, p=0.47.

(D) Time courses of average firing rates from stationary or locomoting (black) trials for each condition.

(E) Mean firing rates from 0.5 to 1.0s from stationary or locomoting (black) trials for each condition. Only units with both mobile and immobile trials are compared against one another for each condition. A significant increase in firing rate is seen during locomotion for all conditions. Wilcoxon signed-rank test, WT pre, 1404 units : t=190957, p=5.12E-88. FX pre, 813 units: t=66902, p=5.37E-49. WT post, 724 units:, t=120176, p=0.04. FX post, 687 units: t=95999, p=2.04E-5. WT novel, 1188 units: t=165849, p=1.81E-56. FX novel, 757 units: t=67179, p=8.32E-37.

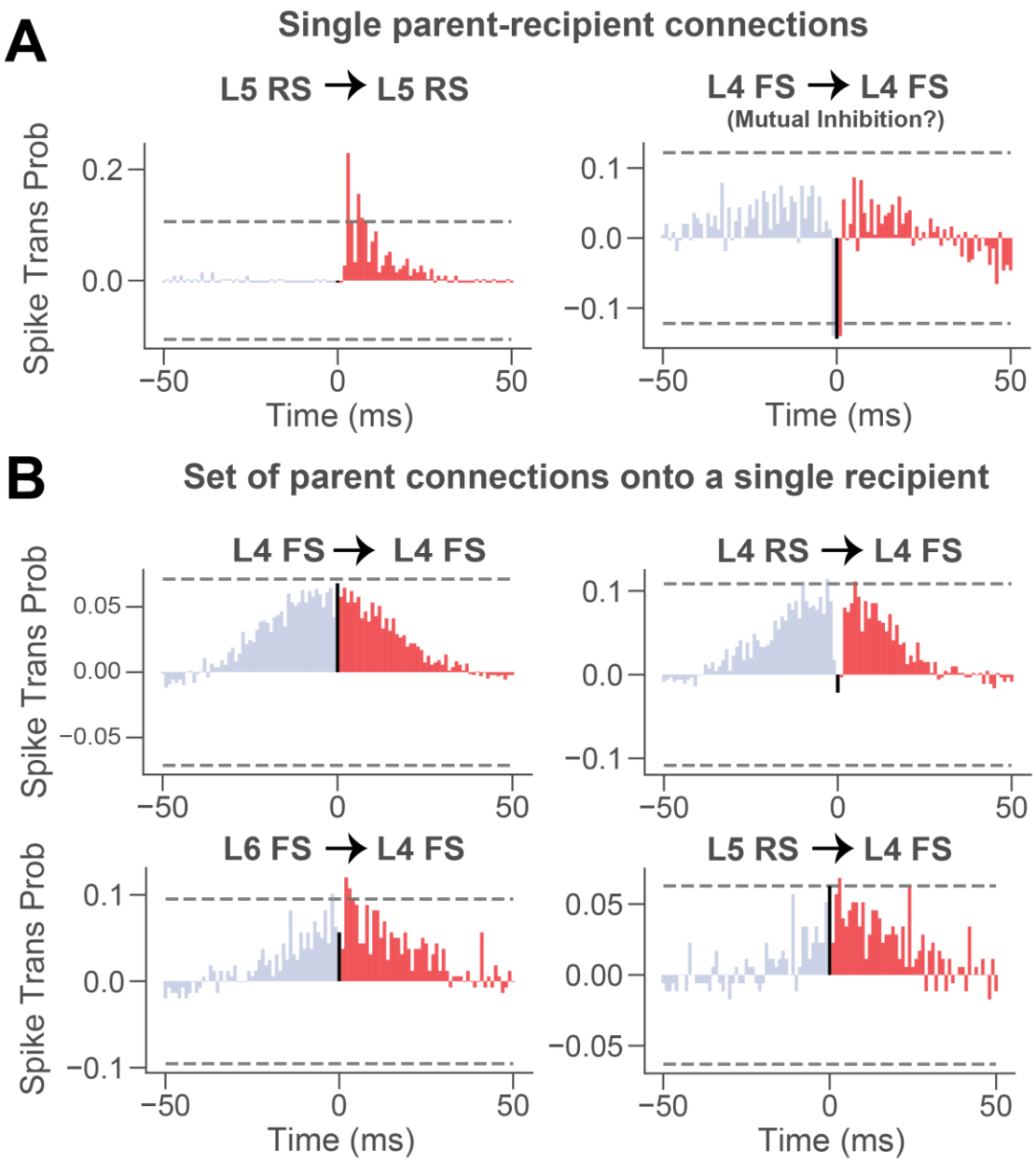

Figure S9. Example cross correlograms of unit pairs. Related to Figure 4.

(A) Example cross correlations of units from directed information analysis with single parent units sending information to single recipient units.

(B) Example cross correlations of units from directed information analysis where a set of 4 parents is predictive of the activity of a single recipient unit. Each correlation shown is between one of the 4 parents and the recipient unit.

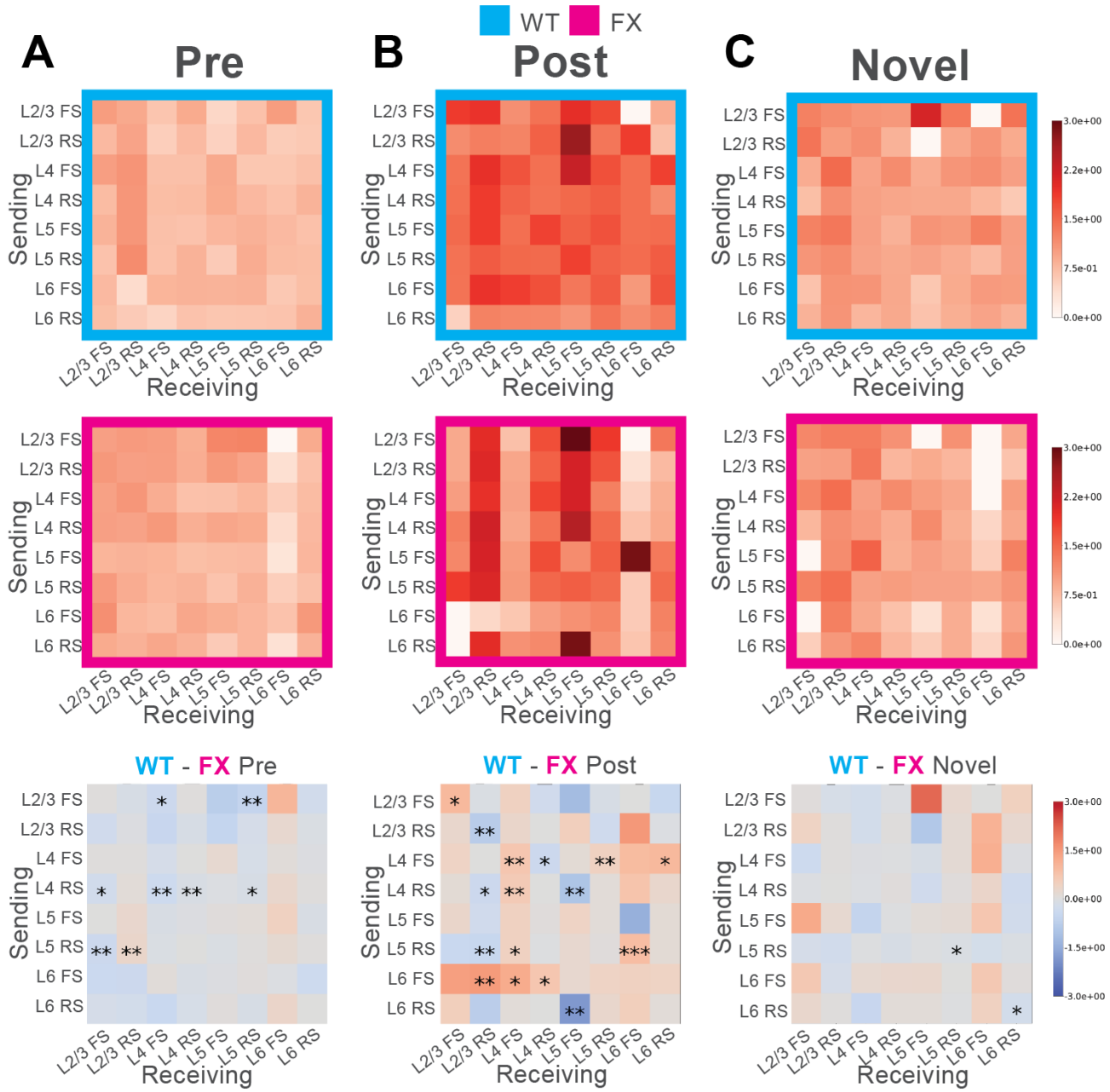

Figure S10. Layer and cell type specific changes in functional connectivity in WT and FX mice. Related to Figure 4.

(A) Functional connectivity (normalized directed information) pre perceptual experience for WT (Cyan) and FX (Magenta) mice, where a Markov order of 30 ms was used to compute directed information values. Darker colors indicate stronger (more predictive) connections. The vertical axis indicates cells in different layers sending information, while the horizontal axis indicates cells receiving that information. Bottom: difference between the WT and FX heatmaps. Monte Carlo simulations (10E6 runs) were used to approximate the permutation test for each square in each difference matrix above. Significance levels: '*' for $p<0.1$ and '**' for $p<0.05$ '***' for $p<0.01$.

(B) Functional connectivity post perceptual experience.

(C) Functional connectivity in response to novel stimuli.

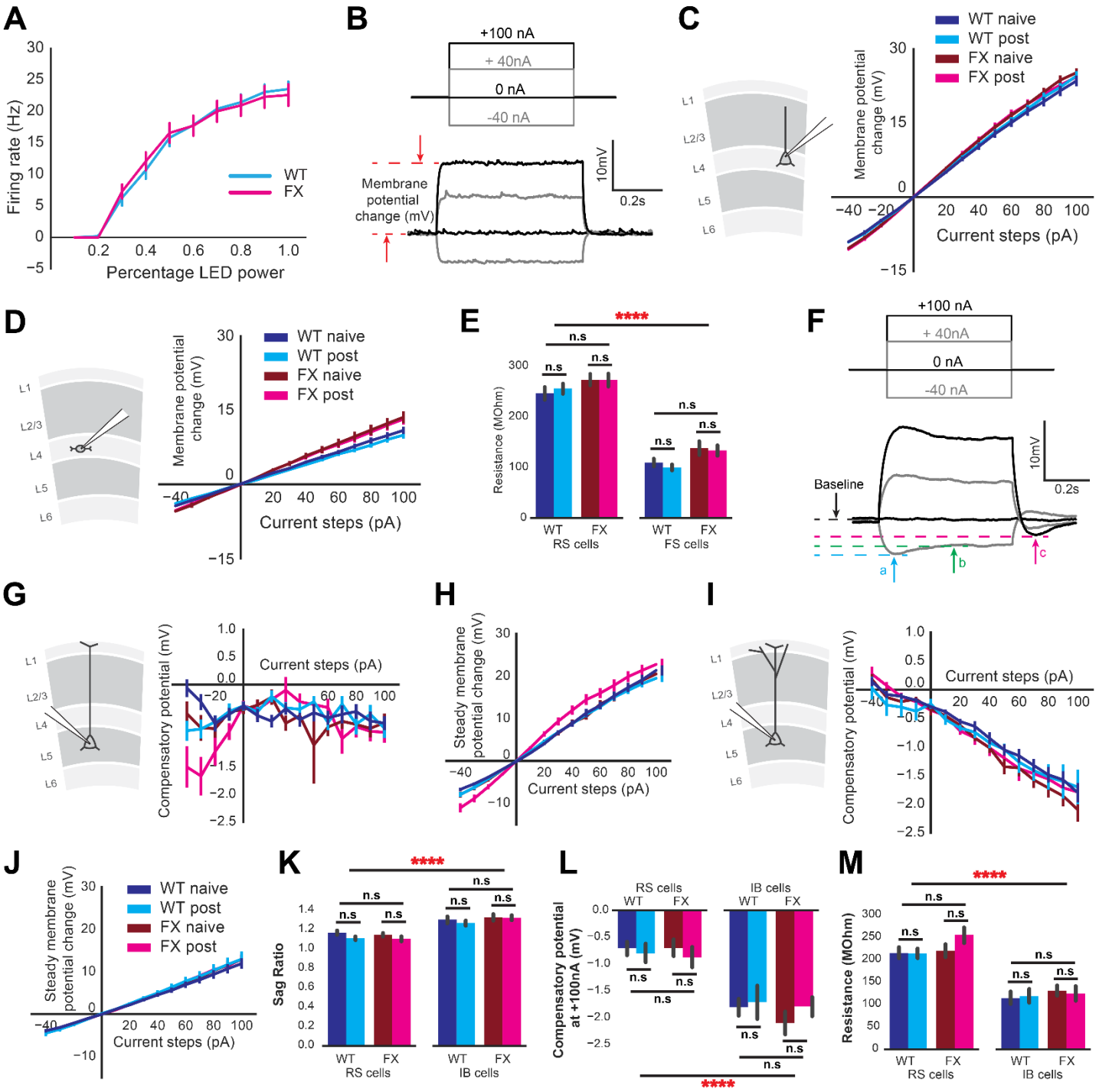

Figure S11. Characterizing layer 5 (L5) patched cell types. Related to Figures 5 and 6.

(A) ChR2-YFP positive L5 neurons in V1 were held under current clamp while full-field LED illumination was applied to measure the action potential frequency. N = 3 animals/21 neurons for WT and 4 animals/28 neurons for FX. Data reported in the curve are mean ± standard error of mean.

(B) Step current injection illustration and representative current-clamp traces from a layer 4 fast-spiking (FS) interneuron.

(C) Averaged current-voltage curve from L4 RS neurons showing the membrane potential change (demonstrated in A) at each current injection step.

(D) Averaged current-voltage curve from L4 FS interneurons showing the membrane potential change (demonstrated in A) at each current injection step.

(E) Mean input resistance for each group. Data reported in bar graphs are mean ± standard error of mean. Statistical significance on means was reported from three-way ANOVA followed by Tukey's HSD tests.

(F) Representative current-clamp traces from a layer 5 intrinsically-bursting (IB) neuron.

(G) Averaged compensatory current-voltage curve from L5 RS neurons showing the absence of rebound potential at the offset of step current injection.

(H) Averaged steady phase current-voltage curve from L5 RS neurons. The slope of the curves represents input resistance.

(I) Averaged compensatory current-voltage curve from L5 IB neurons showing the presence of rebound potential at the offset of step current injection (demonstrated in b).

(J) Averaged steady phase current-voltage curve from L5 IB neurons. The slop of the curves represents input resistance.

(K) Mean sag ratio (defined in B) for each group.

(L) Mean hyperpolarizing compensatory potential at the offset of +100nA current injection for each group.

(M) Mean input resistance for each group. Data reported in bar graph are mean ± standard error of mean. Statistical test on means was three-way ANOVA followed by multiple comparison test using Tukey's honest significant difference criterion.