

Supplementary information

Entrainment of prefrontal theta synchrony increases interbrain coupling and enhances social interaction in mouse models of autism

Eunkyu Hwang¹, Soogeun Shin¹, Anjin Lee², Woohyun Kim^{1,3}, Hyung-Geun Yoon¹,
Younghoon Kwon¹, Dongseok Seo¹, Dohoung Kim⁵, Eunjoon Kim^{3,4}, Eunee Lee^{1*}

1.Department of Anatomy, Graduate School of Medical Science, Brain Korea 21 Project,
Yonsei University College of Medicine, Seoul 03722, Republic of Korea

2.Yonsei University College of Medicine, Seoul 03722, Republic of Korea

3.Center for Synaptic Brain Dysfunctions, Institute for Basic Science (IBS),
Daejeon 34141, Republic of Korea.

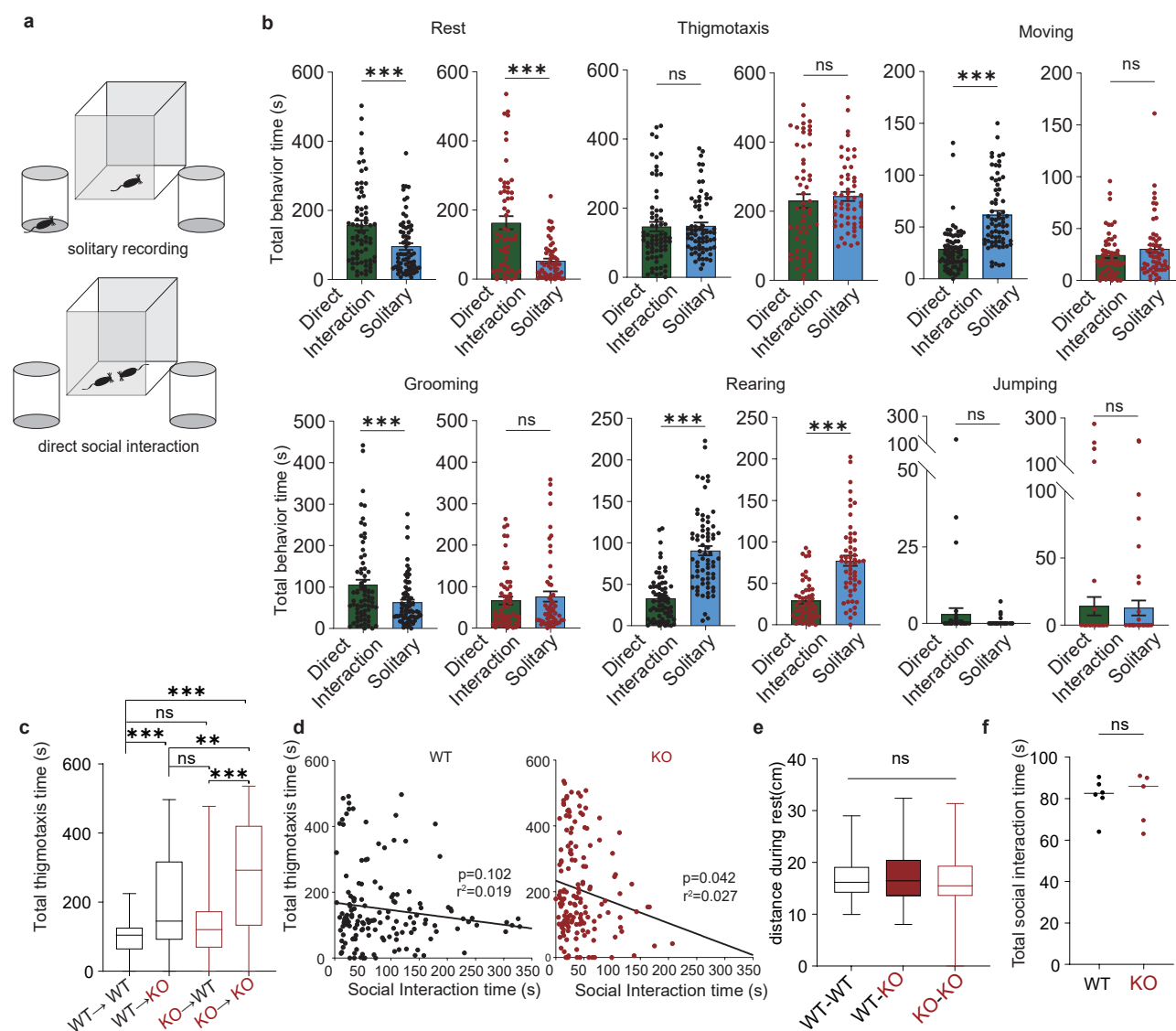
4.Department of Biological Sciences, Korea Advanced Institute for Science and Technology (KAIST),
Daejeon 34141, Republic of Korea.

5.Department of Convergence IT Engineering, Pohang University of Science and Technology,
Pohang 37673, Republic of Korea

*Corresponding author (eunee@yuhs.ac)

Supplementary figure legends

Supplementary figure 1



Supplementary figure 1. Differences in non-social behaviors between Shank2 WT and Shank2^{-/-} (KO) mice

a. Schematic illustration of the solitary recording and direct social interaction test

b. Comparison of total non-social behavior time during direct interaction test and solitary exploration (pair n=WT[69], KO[56], Rest WT: Wilcoxon test $p < 0.0001$, KO: Wilcoxon test $p < 0.0001$, Circling WT: Wilcoxon test $p = 0.635$, KO: Wilcoxon test $p = 0.401$, Moving WT: Wilcoxon test $p < 0.0001$, KO: Wilcoxon test $p = 0.276$, Grooming WT: Wilcoxon test $p = 0.0004$ KO: Wilcoxon test $p = 0.755$, Rearing WT: Wilcoxon test $p < 0.0001$, KO: Wilcoxon test $p < 0.0001$, Jumping WT: Wilcoxon test $p = 0.273$, KO: Wilcoxon test $p = 0.787$).

c. Comparison of circling behavior time during direct interaction test across trial types (pair n=35 [WT-WT], 73[WT-KO], 40 [KO-KO], 73[KO-WT], Kruskal-Wallis test, $p < 0.001$, Dunn's multiple comparisons test).

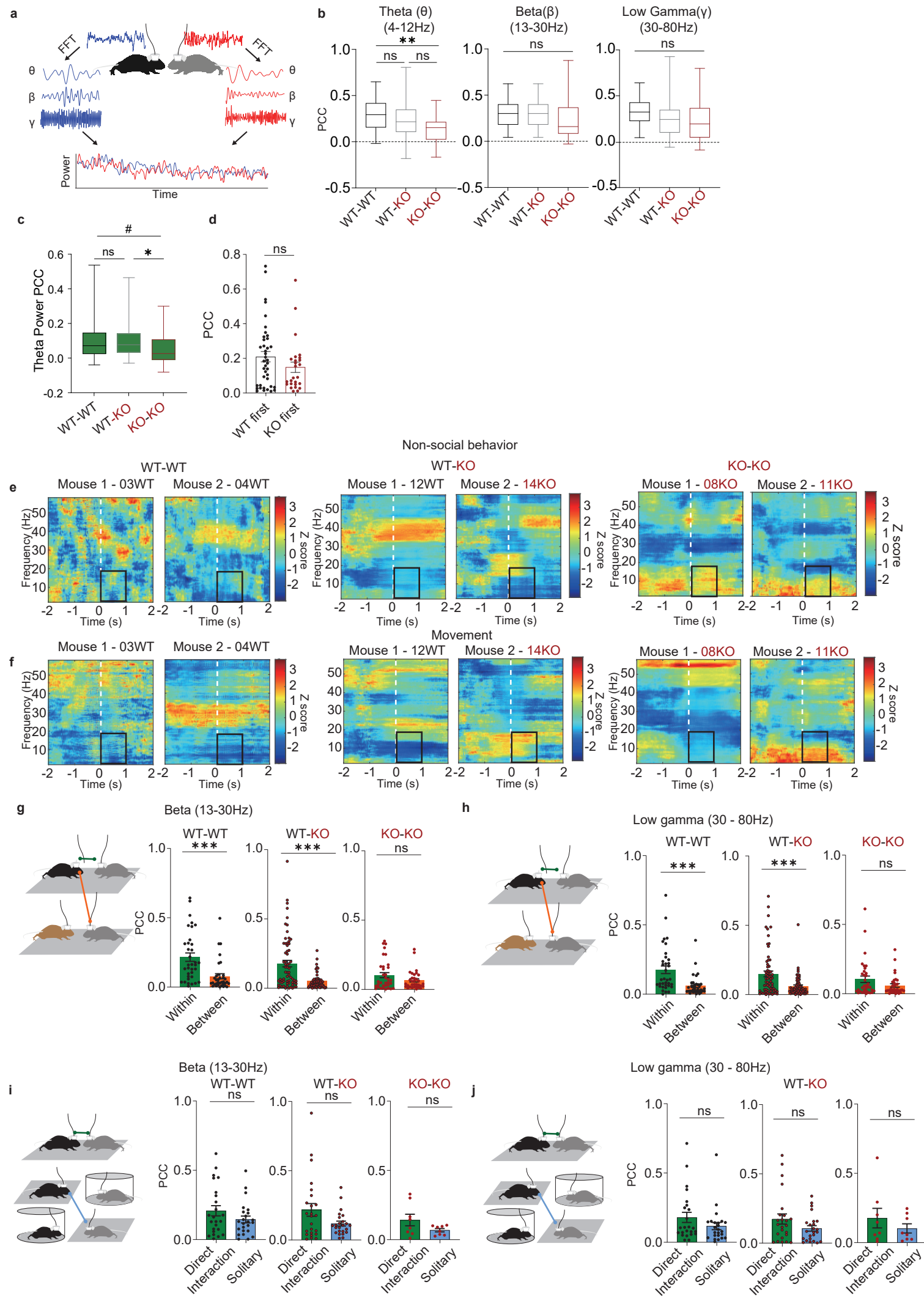
d. Linear regression of total circling time versus social interaction time (pair n=108 [WT], 113 [KO], simple linear regression, WT: $p = 0.102$, $r^2 = 0.019$, KO: $p = 0.042$, $r^2 = 0.027$).

e. Comparison of average distance (cm) between the two mice during rest (pair n=35 [WT-WT], 73 [WT-KO], 40 [KO-KO], Kruskal-Wallis test $p = 0.620$).

f. Comparison of total social interaction time between Shank2 female WT and KO mice (n=6 [WT], n=6[KO], Mann-Whitney test $p = 0.931$).

Box and whisker plots display the median, with boxes spanning the 25th to 75th percentiles, and whiskers indicating minimum and maximum values. Bar plots represent the mean with standard error of the mean (s.e.m.). Points are individual data points. Source data are provided as a Source Data file.

Supplementary figure 2

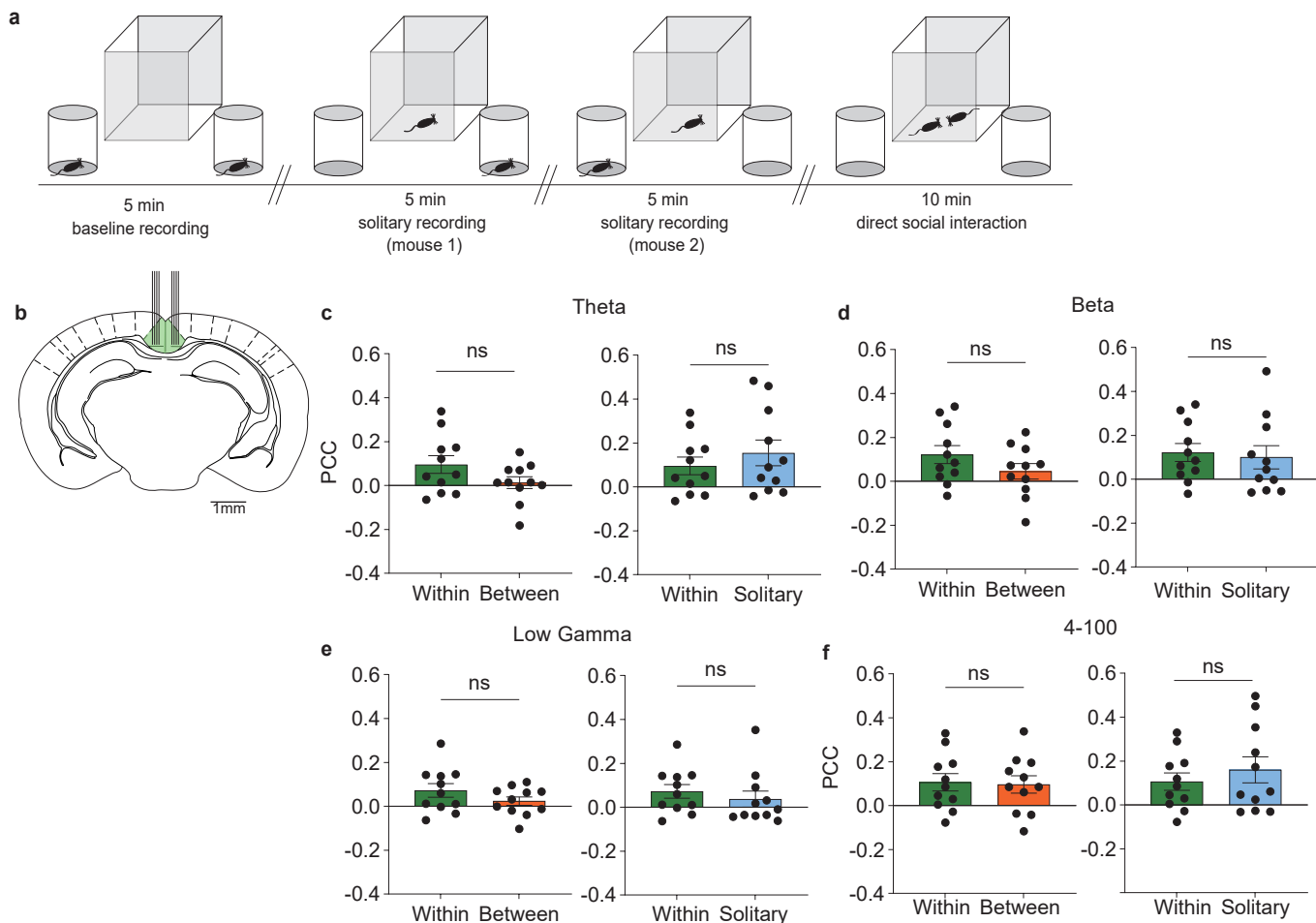


Supplementary figure 2. Interbrain synchrony reduction in Shank2^{-/-} mice is less pronounced in beta and low gamma bands.

- a. Schematic illustrating the analysis of LFP power changes in theta, beta, and low gamma bands between two mice. FFT = fast fourier transform.
- b. Comparison of interbrain correlation (PCC) calculated from power changes in theta, beta, and low gamma bands during social behaviors (pair n=35 [WT-WT], 66[WT-KO]. 34 [KO-KO], theta: Kruskal Wallis test, p=0.042, Dunn's multiple comparisons test, beta: Kruskal Wallis test, p=0.030, Dunn's multiple comparisons test, low gamma: Brown-Forsythe ANOVA test, p=0.075, Welch ANOVA test).
- c. Comparison of interbrain synchrony calculated using wavelet transformation across trial types (pair n=33 [WT-WT], 61[WT-KO], 26 [KO-KO], Kruskal-Wallis test p=0.015, WT-WT vs WT-KO p>0.999, WT-WT vs KO-KO p=0.067, WT-KO vs KO-KO p=0.015, Mann-Whitney test WT-WT vs KO-KO p=0.025).
- d. Evaluation of the effect of the order of solitary exposure on theta power PCC (Mann Whitney test p=0.2421)
- e-f. Representative time-frequency spectrogram across trial types for non-social behavior (a) and general movement (b).
- g, i. Same analysis as Fig. 2d,e but power calculated in the beta frequency band g. (n=35 [WT-WT], 66 [WT-KO]. 34 [KO-KO], WT-WT: Wilcoxon test, within vs between p<0.001, WT-KO: Wilcoxon test, within vs between p<0.001, KO-KO: Wilcoxon test, within vs between p=0.377). i. (n=24 [WT-WT], 24 [WT-KO]. 8 [KO-KO], WT-WT: Wilcoxon test, direct interaction vs solitary p=0.264, WT-KO: paired t-test, within vs between p=0.128, KO-KO: paired t-test, within vs between p=0.148).i
- h, j. Same analysis as Fig. 2d,e but power calculated in the low gamma frequency band. h. (n=35 [WT-WT], 66 [WT-KO]. 34 [KO-KO], WT-WT: Wilcoxon test, within vs between p<0.001, WT-KO: Wilcoxon test, within vs between p<0.001, KO-KO: Wilcoxon test, within vs between p=0.172). j. (n=24 [WT-WT], 24 [WT-KO]. 8 [KO-KO], WT-WT: Wilcoxon test, direct interaction vs solitary p=0.331, WT-KO: paired t-test, within vs between p=0.16, KO-KO: paired t-test, within vs between p=0.844).

Box and whisker plots display the median, with boxes spanning the 25th to 75th percentiles, and whiskers indicating minimum and maximum values. Bar plots represent the mean with standard error of the mean (s.e.m.). Points are individual data points. Source data are provided as a Source Data file.

Supplementary figure 3



Supplementary figure 3. Interbrain synchrony in the retrosplenial cortex

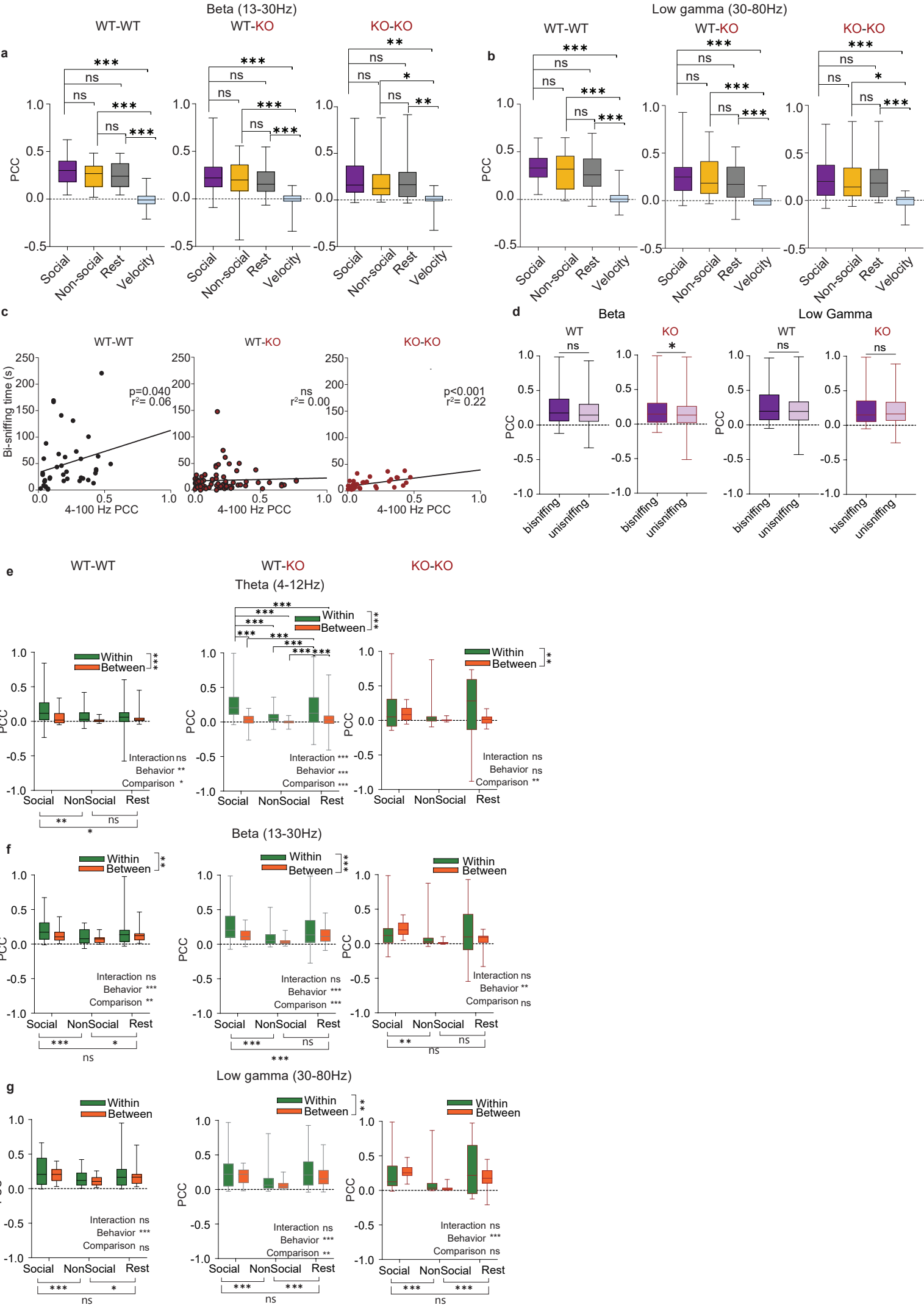
a. Schematic illustration of experimental setup and protocol.

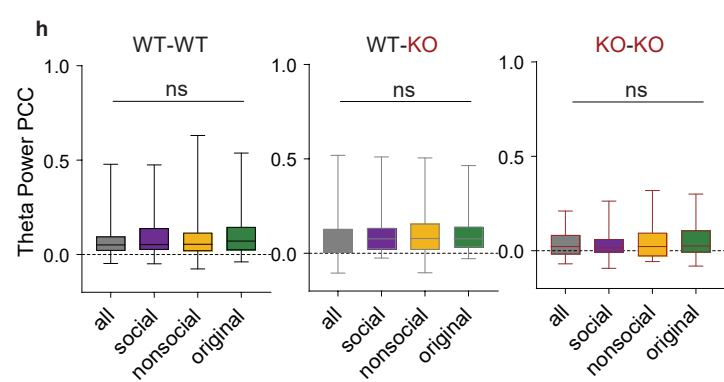
b. Schematic of probe implantation (tetraode) in the RSC. Scale bars = 1mm.

c-f. Same analysis as Fig. 2d-e for theta band PCC (c), beta band PCC (d), low gamma band PCC(e), and wide band (f). (n=11 [WT-WT]). Theta within vs between, paired t-test $p=0.644$, within vs solitary, wilcoxon test $p=0.3203$, Beta within vs between, paired t test $p=0.2183$, within vs solitary Wilcoxon test $p=0.5771$, Low gamma within vs between paired t-test $p=0.2522$, within vs solitary, Wilcoxon test $p=0.2061$, wide band within vs between paired t-test $p=0.8666$, within vs solitary Wilcoxon test $p=0.6377$). Bar plots represent the mean with standard error of the mean (s.e.m.).

Points are individual data points. Source data are provided as a Source Data file.

Supplementary figure 4





Supplementary figure 4. Behavior specific wavelet analysis of interbrain synchrony.

a-b. Same analysis as Fig.3f but power calculated in the beta frequency band (a), and the low gamma frequency band (b). d. (n=33 [WT-WT], 61 [WT-KO], 28 [KO-KO], WT-WT: Friedman test $p < 0.001$, Dunn's multiple comparisons test, WT-KO: Friedman test $p < 0.001$, Dunn's multiple comparisons test, KO-KO: Friedman test $p < 0.001$, Dunn's multiple comparisons test). e. (n=33 [WT-WT], 61 [WT-KO], 28 [KO-KO], WT-WT: Friedman test $p < 0.001$, Dunn's multiple comparisons test, WT-KO: Friedman test $p < 0.001$, Dunn's multiple comparisons test, KO-KO: Friedman test $p < 0.001$, Dunn's multiple comparisons test).

c. Linear regression between 4-100Hz power PCC and bi-sniffing time for each trial type (pair n=35 [WT-WT], 66[WT-KO], 34 [KO-KO], simple linear regression WT-WT: $p = 0.040$, $r^2 = 0.060$, WT-KO: $p = 0.615$, $r^2 = 0.060$, KO-KO: $p < 0.001$, $r^2 = 0.22$).

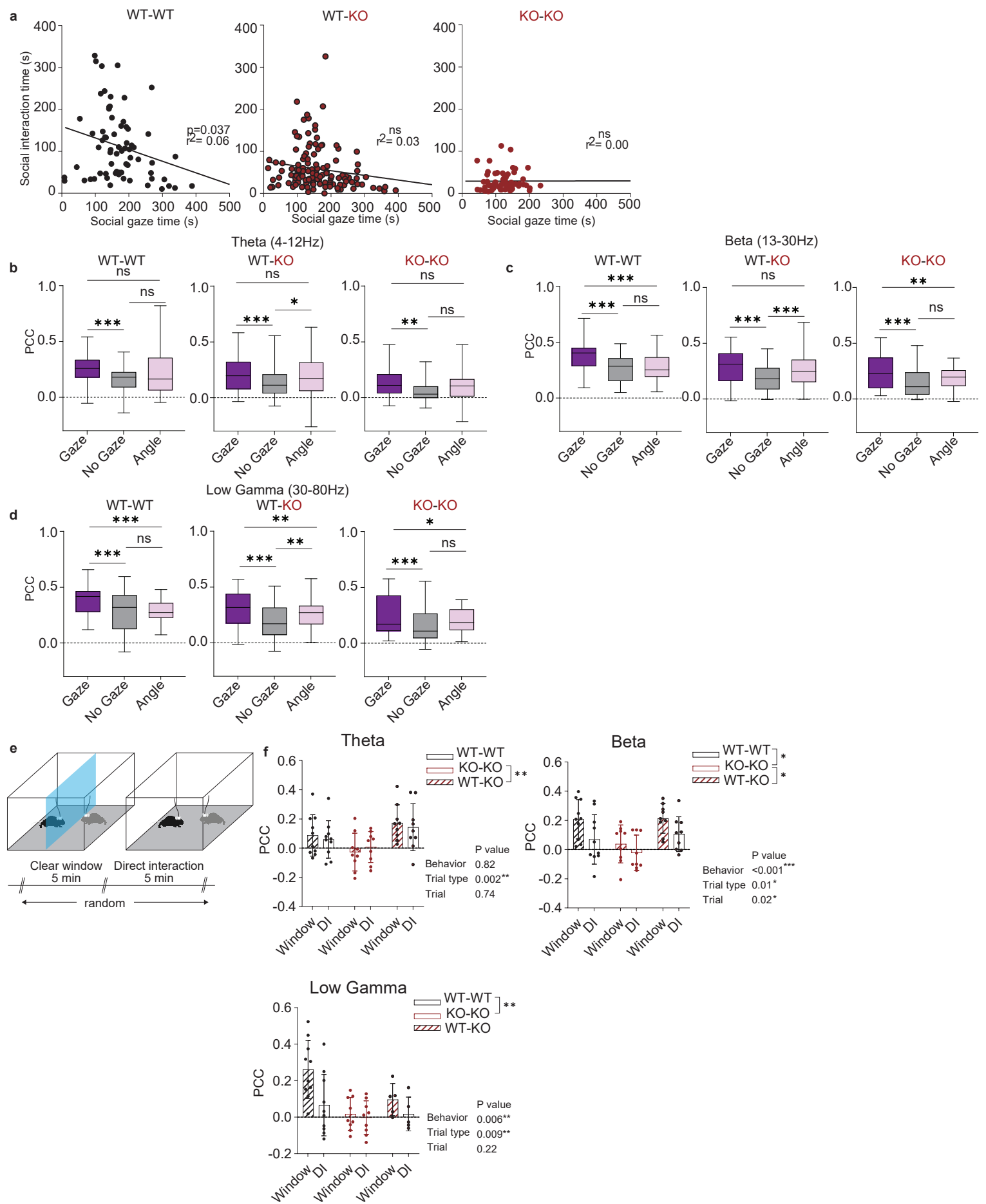
d. Same analysis as Fig.3g but power calculated in the beta (left), low gamma (right) frequency band.

e-g. Same analysis as Fig. 2d, with behavior-matched epochs extracted from "within" and "between" pairs for theta (e), beta (f), and low-gamma (g) frequency bands (n = 33 [WT-WT], 61 [WT-KO], 26 [KO-KO]). Two-way ANOVA, ANOVA tables shown in the inset; Tukey's multiple comparisons test was used for post hoc analysis.)

h. Comparison of interbrain synchrony calculated after removing all periods when the two mice were engaged in same behaviors (all), same social behaviors (social), same non-social behaviors (non-social) (pair n=35 [WT-WT], 66[WT-KO], 34 [KO-KO], WT-WT Friedman test $p = 0.148$, WT-KO Friedman test $p = 0.121$, KO-KO Friedman test $p = 0.422$).

Box and whisker plots display the median, with boxes spanning the 25th to 75th percentiles, and whiskers indicating minimum and maximum values. Bar plots represent the mean with standard error of the mean (s.e.m.). Points are individual data points. Pearson's r was used to calculate r^2 . Source data are provided as a Source Data file.

Supplementary figure 5

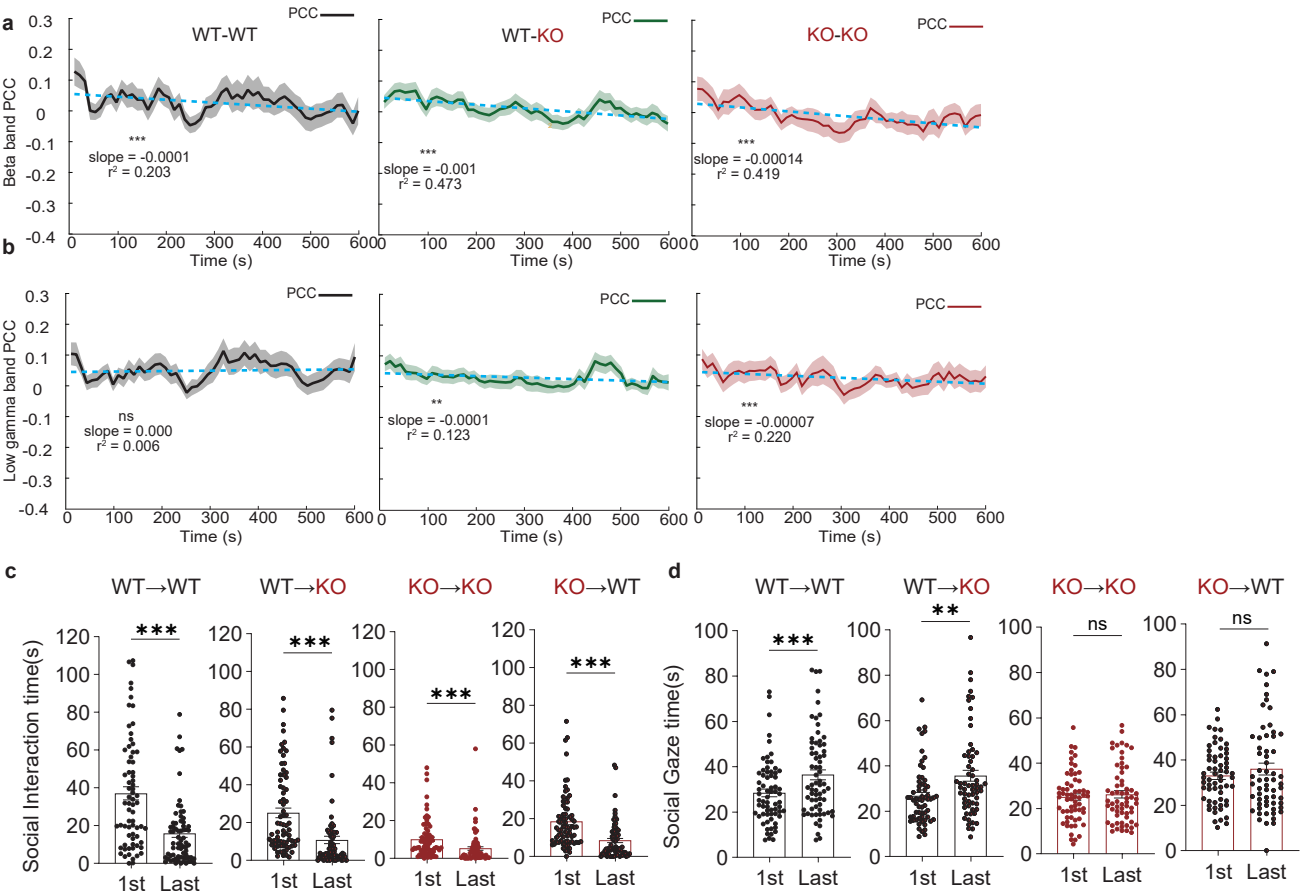


Supplementary figure 5. Social gaze exhibits a distinct temporal profile from social interaction, yet remains correlated with interbrain synchrony

- a. Linear regression of mutual social gaze time versus social interaction time for each trial type. (pair n=35 [WT-WT], 66 [WT-KO], 34 [KO-KO], simple linear regression, WT-WT: $p=0.037$, $r^2=0.064$, WT-KO: $p=0.07$, $r^2=0.027$, KO-KO: $p=0.980$, $r^2<0.001$).
- b-d. Neural correlation between animals compared across gaze, no-gaze, and angle control epochs. (pair n=33 [WT-WT], 61 [WT-KO], 28 [KO-KO]). b. Theta frequency (WT-WT: Friedman test $p<0.001$, Dunn's multiple comparisons test, WT-KO: Friedman test $p<0.001$, Dunn's multiple comparisons test, KO-KO: Friedman test $p=0.005$, Dunn's multiple comparisons test). c. Beta frequency (WT-WT: Friedman test $p<0.001$, Dunn's multiple comparison, WT-KO: Friedman test $p<0.001$, Dunn's multiple comparisons test, KO-KO: Friedman test $p<0.001$, Dunn's multiple comparisons test) d. Low gamma frequency (WT-WT: Friedman test $p<0.001$, Dunn's multiple comparisons test, WT-KO: Friedman test $p<0.001$, Dunn's multiple comparisons test, KO-KO: Friedman test $p<0.001$, Dunn's multiple comparisons test).
- e. Schematic of the "clear window" experiment. In the "clear window" epoch, a transparent barrier was placed in the middle of the behavioral chamber, allowing the animals to see each other but preventing direct interaction. The order of the epochs was counterbalanced.
- f. Comparison of correlations between pairs engaged in direct social interaction ("DI") and "clear window" session ("Window"). PCCs were calculated within the theta, beta, low gamma frequency band (n=10 [WT-WT], 9 [WT-KO], 8 [KO-KO], animal n = 5 WT , 4 KO, Two-way ANOVA, ANOVA tables shown in the inset, Tukey's multiple comparison test was used for post hoc analysis. Theta: KO-KO vs WT-KO $p=0.001$, Beta: WT-WT vs KO-KO $p=0.04$, KO-KO vs WT-KO $p=0.003$, Low Gamma: WT-WT vs KO-KO: $p=0.007$).

Box and whisker plots display the median, with boxes spanning the 25th to 75th percentiles, and whiskers indicating minimum and maximum values. Bar plots represent the mean with standard error of the mean (s.e.m.). Points are individual data points. Pearson's r was used to calculate r^2 . Source data are provided as a Source Data file.

Supplementary figure 6



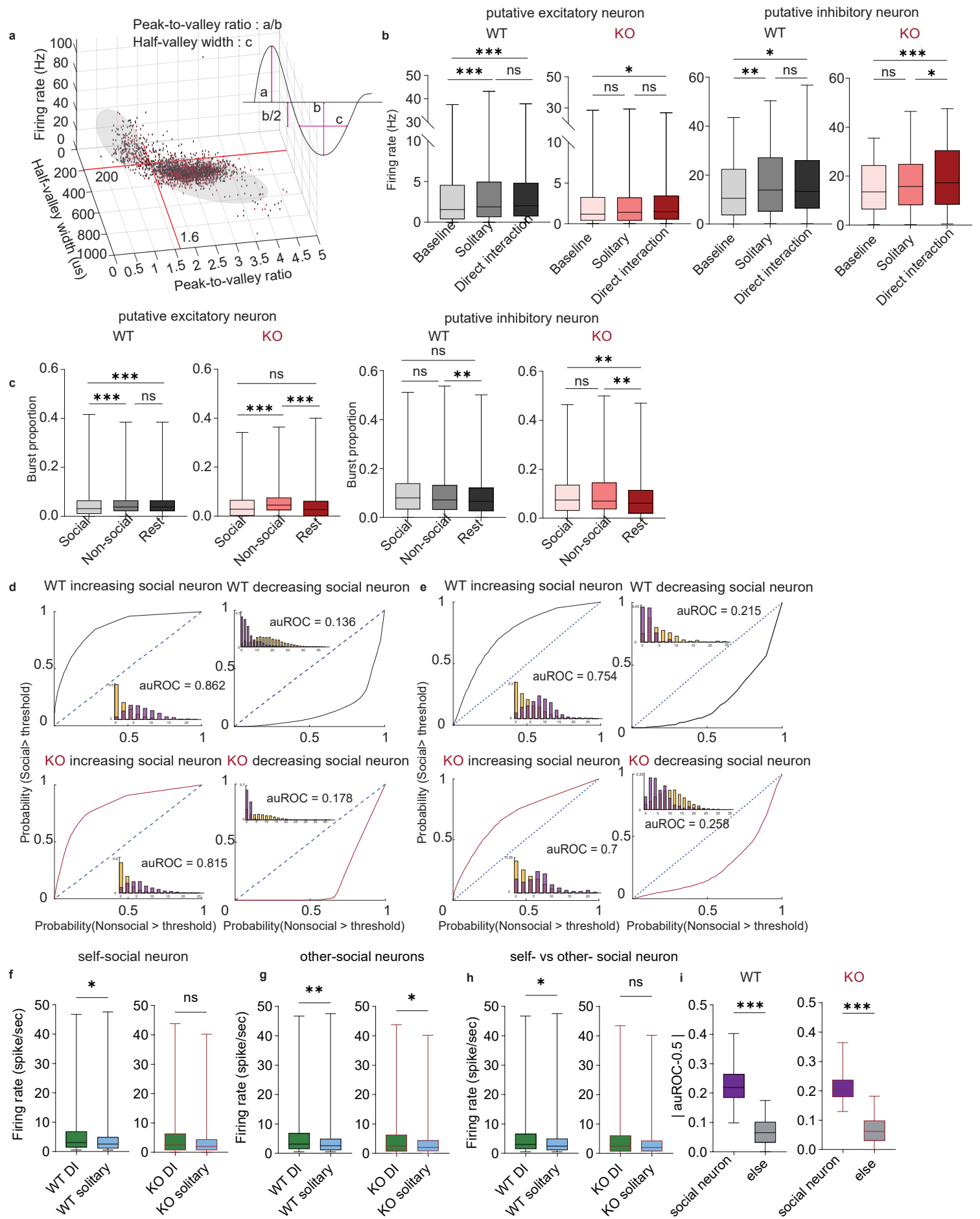
Supplementary figure 6. Temporal analysis of beta and low gamma power PCC, social behavior, social gaze time

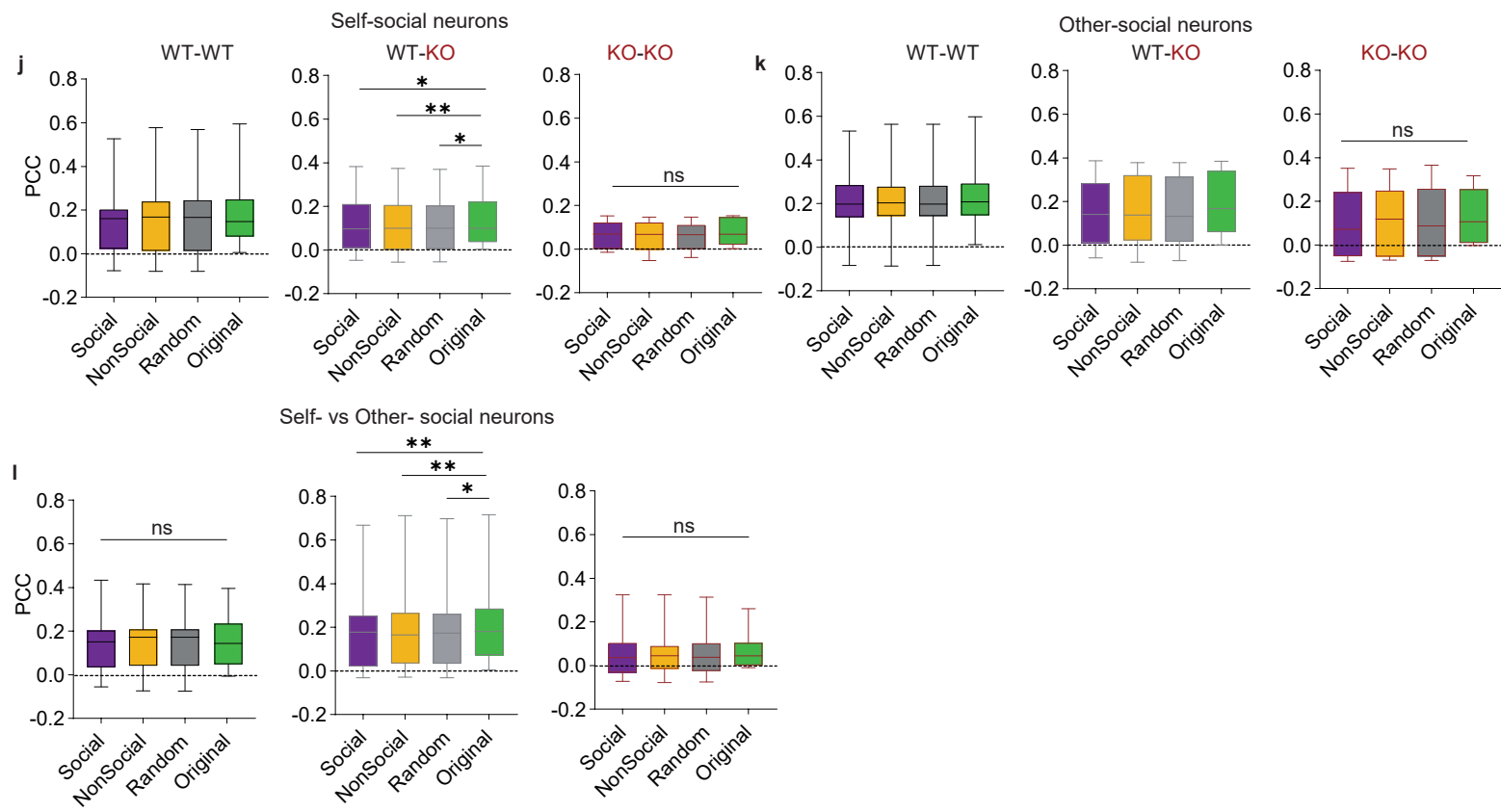
a-b. Same analysis as Fig. 4a but power PCC calculated in the beta (a), and low gamma (b) frequency band.

c-d. Social interaction time (c) and social gaze time (d) during the first 2 minutes ('1st') and the last 2 minutes ('Last') of direct interaction for each trial type (n=70 [WT-WT], 74 [WT-KO], 80 [KO-KO], 74[KO-WT], social interaction time WT-WT Wilcoxon test p<0.0001, WT-KO Wilcoxon test p<0.0001, KO-KO Wilcoxon test p<0.0001, KO-WT Wilcoxon test p<0.0001, social gaze time WT-WT Wilcoxon test p=0.001, WT-KO p=0.001 KO-KO Wilcoxon test p=0.641, KO-WT p=0.437).

Bar plots represent the mean with standard error of the mean (s.e.m.). Points are individual data points. Pearson's r was used to calculate r^2 . Shaded areas indicate standard error of the mean. Source data are provided as a Source Data file.

Supplementary figure 7





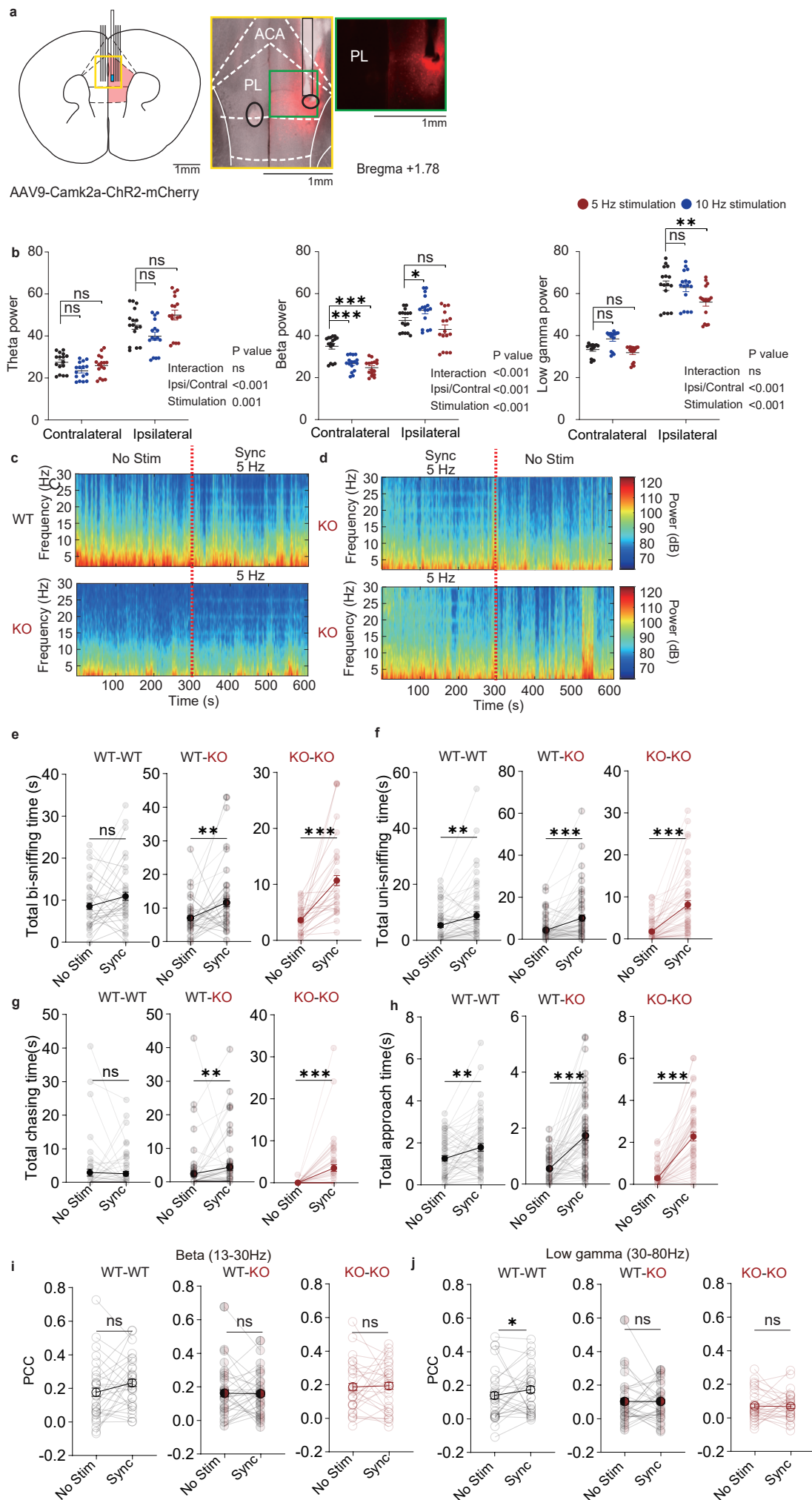
Supplementary figure 7. Properties of mPFC neurons recorded during experimental sessions.

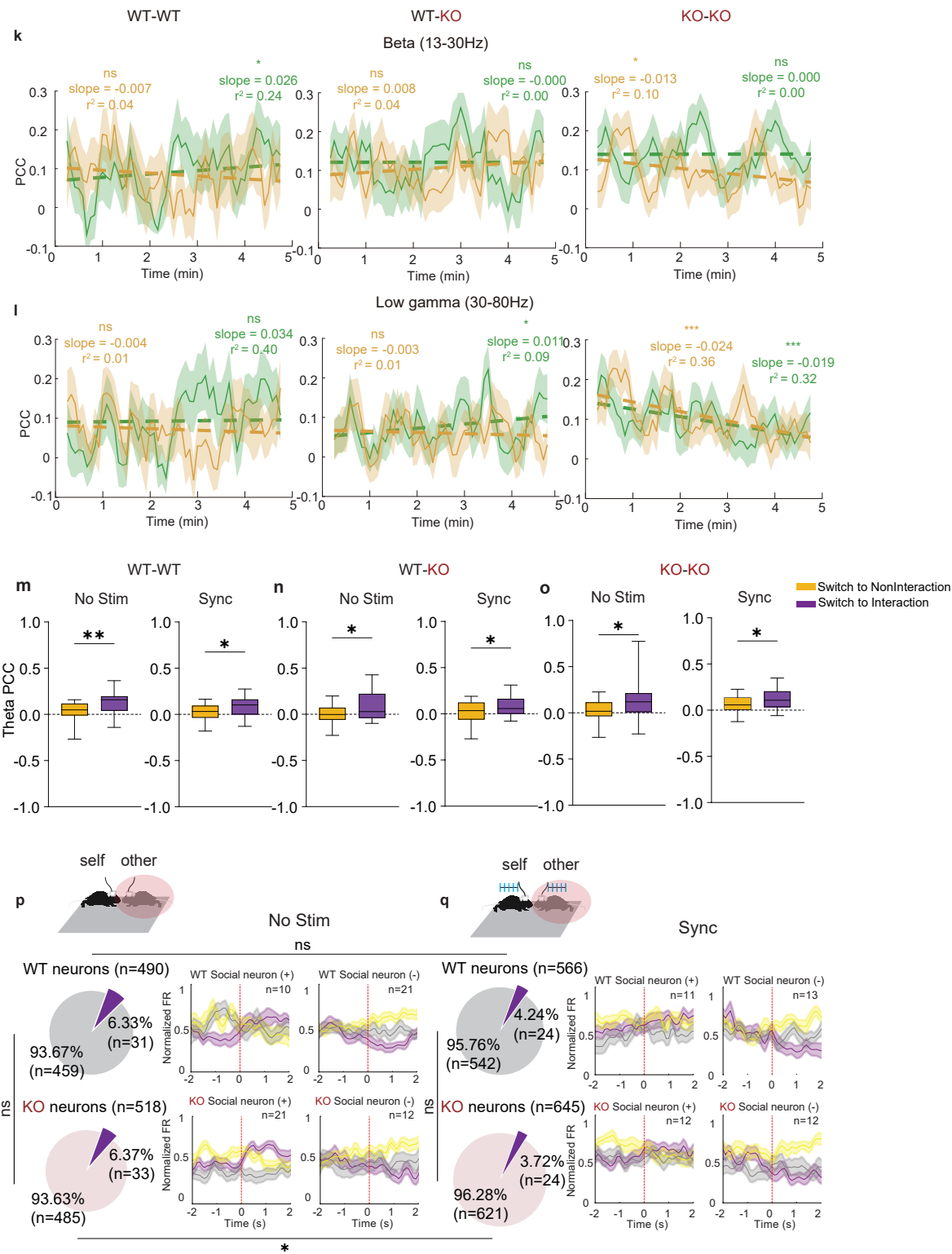
- a. Classification of recorded neurons into putative excitatory (pExc) and putative inhibitory neurons (plnh) based on the half-valley width (200us) and peak-to-valley ratio (1.6) (n=835 [WT-pExc], 555 [KO-pExc], 87 [WT-plnh], 37 [KO-plnh]).
- b. Increased firing rates in pExc and plnh neurons of WT mice during both solitary and direct interaction sessions, but only during direct interaction in Shank2^{-/-} mice (pExh, WT: Friedman test $p < 0.001$, Dunn's multiple comparisons test, KO: Friedman test $p = 0.027$, Dunn's multiple comparisons test), plnh, WT: Friedman test $p = 0.003$, Dunn's multiple comparisons test, KO: Friedman test $p < 0.001$, Dunn's multiple comparisons test).
- c. Comparison of high-frequency burst proportions (< 12 ms ISI) during social, non-social, and rest behaviors in WT and KO mice (pExh, WT: Friedman test $p < 0.001$, Dunn's multiple comparisons test, KO: Friedman test $p < 0.001$, Dunn's multiple comparisons test, plnh, WT: Friedman test $p = 0.002$, Dunn's multiple comparisons test, KO: Friedman test $p = 0.001$, Dunn's multiple comparisons test).
- d-e. Representative receiver operating characteristic curves (ROCs) of increasing (left) and decreasing (right) self-social (d) and other-social (e) behavior encoding neurons. Inset: distribution of instantaneous firing rates (FR) during social behavior and non-social behavior.
- f-h. Average firing rate comparison of self-social neurons (f), other-social neurons (g), and self- vs other- social neurons between direct interaction test and solitary exploration (self-social neurons n=161 [WT], 47 [KO], WT: Wilcoxon test $p = 0.014$, KO: Wilcoxon test $p = 0.090$, other-social neurons n=44 [WT], 26 [KO], WT: Wilcoxon test $p = 0.004$, KO: Wilcoxon test $p = 0.047$, self- vs other- social neurons n=185 [WT], 96 [KO], WT: Wilcoxon test $p = 0.037$, KO: Wilcoxon test $p = 0.309$).
- i. area under ROC curve comparison for WT (left) and KO (right) self- vs other- social neurons (self- vs other- social neurons n=185 [WT], 96 [KO], WT: Mann-Whitney test $p < 0.001$, KO: Mann-Whitney test $p < 0.001$).

j-l. Same analysis as Fig. 4f but with self-social neurons (j), other-social neurons (k), and self- vs other- social neurons (l). (self-social neurons pair n=23[WT-WT], 29[WT-KO], 6[KO-KO], WT-WT: Repeated measures ANOVA $p = 0.020$, Tukey's multiple comparisons test, WT-KO: Friedman $p = 0.004$, Dunn's multiple comparisons test, KO-KO: Repeated measures ANOVA $p = 0.519$, other-social neurons pair n=14[WT-WT], 20[WT-KO], 6[KO-KO], WT-WT: Repeated measures ANOVA $p = 0.024$, Tukey's multiple comparisons test, WT-KO: Repeated measures ANOVA $p = 0.042$, Tukey's multiple comparisons test, KO-KO: Repeated measures ANOVA $p = 0.251$, self vs other neurons pair n=22[WT-WT], 36[WT-KO], 12[KO-KO], WT-WT: Repeated measures ANOVA $p = 0.185$, WT-KO: Friedman $p = 0.007$, Dunn's multiple comparisons test, KO-KO: Friedman test $p = 0.321$).

Box and whisker plots display the median, with boxes spanning the 25th to 75th percentiles, and whiskers indicating minimum and maximum values. Source data are provided as a Source Data file.

Supplementary figure 8

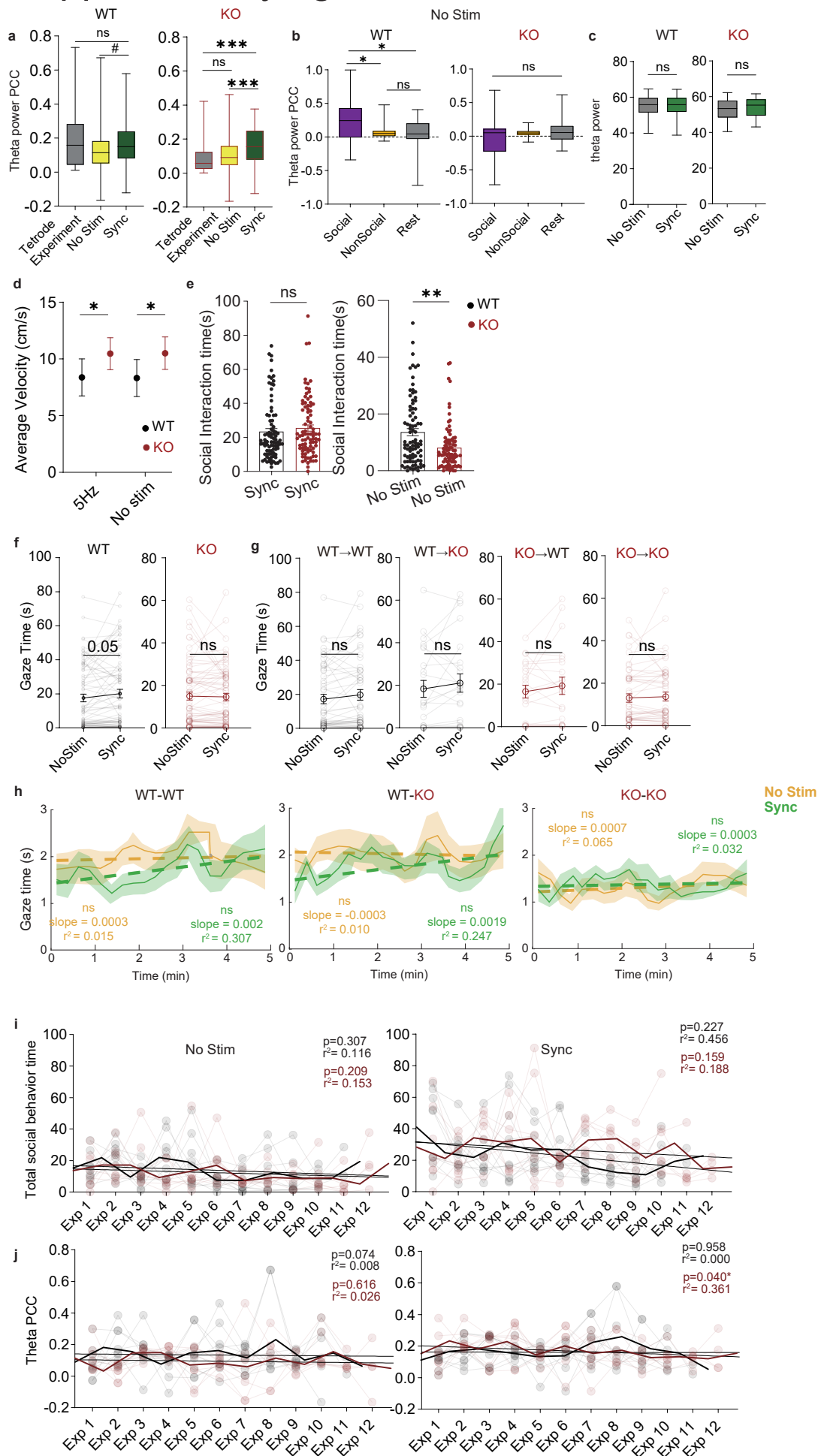




Supplementary figure 8. Characterizing the effect of synchronized and desynchronized optic stimulation

- a. Schematic of viral transduction and probe implantation (optic fiber + tetrode) in the mPFC, with representative histology showing tetrode location, optic fiber, and virus expression. Scale bars = 1mm.
- b. Comparison of theta, beta, and low gamma power between the site of viral injection and optic stimulation and its contralateral hemisphere (Theta: Two way ANOVA, Ipsi vs Contralateral $p<0.001$, Stimulation condition $p<0.001$, Interaction $p=0.0642$, Dunnett's multiple comparisons test, Beta: Two way ANOVA, Ipsi vs Contralateral $p<0.001$, Stimulation condition $p<0.001$, Interaction $p<0.001$, Dunnett's multiple comparisons test, Low gamma: Two way ANOVA, Ipsi vs Contralateral $p<0.001$, Stimulation condition $p<0.001$, Interaction $p=0.0921$, Dunnett's multiple comparisons test).
- c-d. Representative power frequency-time spectrogram for a WT-KO (c) and KO-KO (d) pair of mice.
- e-h. Trial type comparison of social behaviors, bi-sniffing (e), uni-sniffing (f), chasing (g), and approach (h). WT-WT: Wilcoxon test $p=0.115$, WT-KO: Wilcoxon test $p=0.001$, KO-KO: Wilcoxon test $p<0.001$, uni-sniffing WT-WT: Wilcoxon test $p=0.006$, WT-KO: Wilcoxon test $p<0.001$, KO-KO: Wilcoxon test $p<0.001$, chasing WT-WT: Wilcoxon test $p=0.967$, WT-KO: Wilcoxon test $p=0.004$, KO-KO: Wilcoxon test $p<0.001$, approach WT-WT: Wilcoxon test $p=0.006$, WT-KO: Wilcoxon test $p<0.001$, KO-KO: Wilcoxon test $p<0.001$).
- i-j. Trial type comparison of PCC values of beta(i) and low gamma(j) band for each stimulus epoch (beta WT-WT: Wilcoxon test $p=0.059$, WT-KO: Wilcoxon test $p=0.817$, KO-KO: Wilcoxon test $p=0.9371$, low gamma WT-WT: Wilcoxon test $p=0.035$, WT-KO: Wilcoxon test $p=0.790$, KO-KO: Wilcoxon test $p=0.705$).
- k-l. Same analysis as Fig.6g but power calculated within the beta band (k) and the low gamma frequency band (l). $n=56$ [WT-WT], 56 [KO-KO], 62 [WT-KO], simple linear regression Beta PCC: WT-WT No Stim $p=0.17$, $r^2=0.04$ Sync $p=0.034$, $r^2=0.24$, WT-KO No Stim $p=0.125$, $r^2=0.04$ Sync $p=0.990$, $r^2=0.00$, KO-KO No Stim $p=0.019$, $r^2=0.10$ Sync $p=0.969$, $r^2=0.00$, Gamma PCC: WT-WT No Stim $p=0.456$, $r^2=0.01$ Sync $p=0.057$, $r^2=0.40$, WT-KO No Stim $p=0.500$, $r^2=0.01$ Sync $p=0.029$, $r^2=0.09$, KO-KO No Stim $p<0.001$, $r^2=0.36$ Sync $p<0.001$, $r^2=0.3$,
- m-o. Comparison of theta band power correlation during non-social behavior epochs followed by non interaction (non-social behaviors) vs non-social behavior epochs followed by interaction (social behaviors) across stimulation conditions, for all trial types m.WT-WT, n. WT-KO, and o. KO-KO ($n=56$ [WT-WT], 56 [KO-KO], 62 [WT-KO], WT-WT No Stim, Welch's t-test $p=0.0019$, Sync, Welch's t-test $p=0.0108$, WT-KO No Stim, Mann-Whitney test $p=0.0285$, Sync, Welch's t-test $p=0.0371$, KO-KO No Stim, Mann-Whitney test $p=0.0128$, Sync, Welch's t-test $p=0.0272$).
- p-q. Results from the auROC analysis comparing spike responses to other-social and other-non-social behavior, showing the proportion of neurons encoding other-social behavior for each stimulus epoch, no stimulus (No Stim, p), Sync (synchronized stimulation, q). NoStim: Chi-square test WT vs KO $p>0.999$, Sync: Chi-square test WT vs KO $p=0.753$. WT: NoStim vs Sync Chi-square 0.164 , KO: NoStim vs Sync Chi-square test 0.041 . Firing rate responses to self-social behavior (purple), non-social behavior (yellow), and rest (grey) are displayed by genotype (WT: top, KO: bottom) and response direction (increasing (+): left, decreasing (-): right) (Right). Shaded error bar: standard error of the mean plotted with the mean (solid line)
- Interleaved scatter plots display the mean with s.e.m. Box and whisker plots display the median, with boxes spanning the 25th to 75th percentiles, and whiskers indicating minimum and maximum values. Shaded areas indicate standard error of the mean. Source data are provided as a Source Data file.

Supplementary figure 9

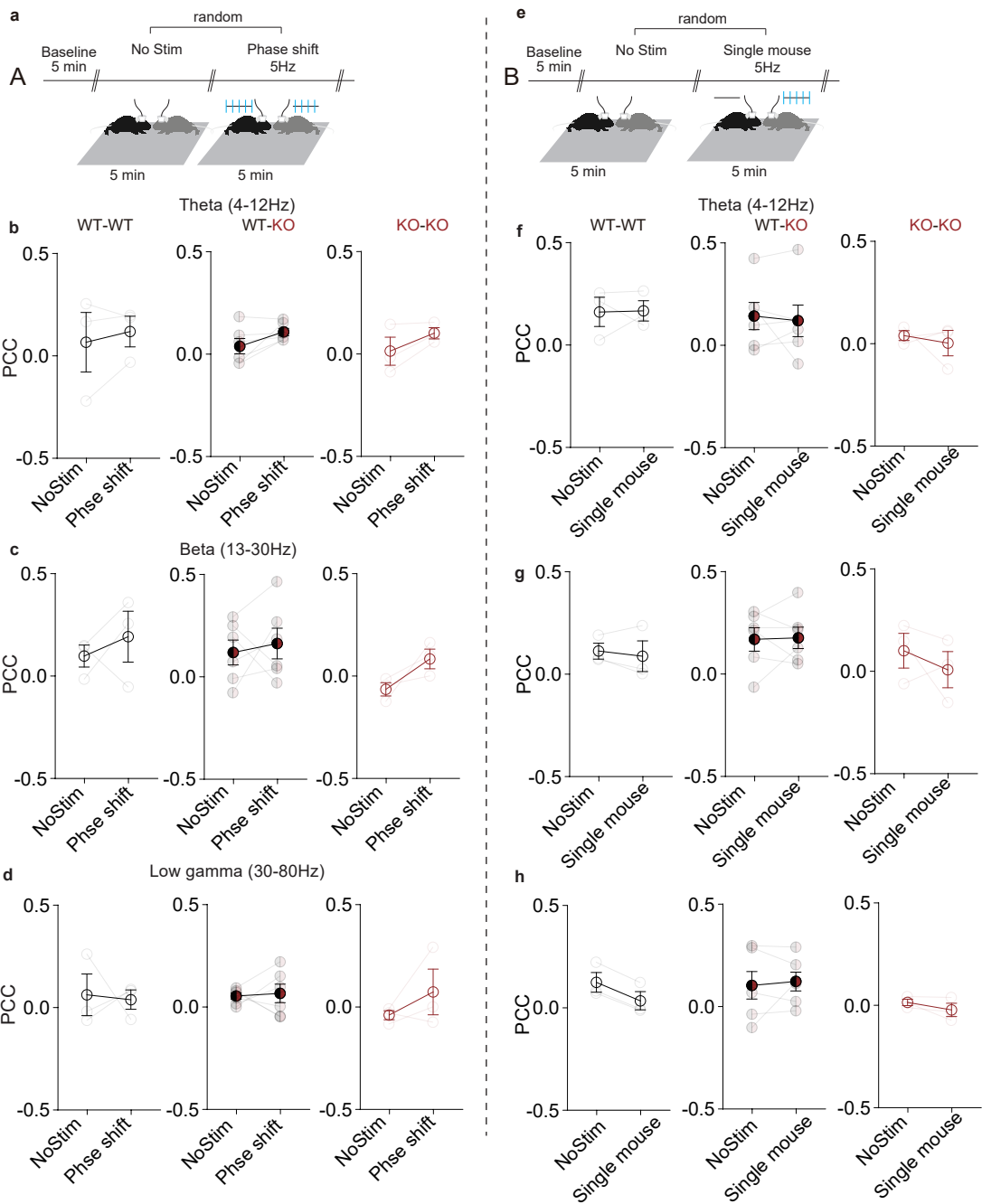


Supplementary figure 9. Social gaze and social information processing during continuous optogenetic stimulation

- a. Comparison of interbrain synchrony level between optrode No Stim and Sync epochs with tetrode session, (optrode pair n=87 [WT], 87[KO], tetrode pair n = 68 [WT] 67 [KO], WT Kruskal-Wallis test p=0.082, No Stim vs Sync Mann-Whitney test p= 0.033, KO Kruskal-Wallis test p<0.001, Dunn’s multiple comparisons test)
- b. Comparisons of correlation during social (S), non-social (NS), rest (Rest) bouts from NoStim epochs of each genotype. PCC was calculated within the theta band (pair n = 75 [WT], 76[KO], WT Friedman test p=0.014, Dunn’s multiple comparisons test KO Friedman test p=0.829)
- c. Genotype comparison of theta oscillation power between stimulation conditions (n=87 [WT], n=87 [KO], WT: Mann-Whitney test p=0.937, KO: Mann-Whitney test p=0.669)
- d. Average velocity comparison between different light stimulation epochs (n=7 [WT], 7 [KO], Two-way ANOVA, Stimulation p=0.89, Genotype p=0.02, Interaction p=0.61, Sidak’s multiple comparisons test 5Hz: WT vs KO p=0.03, No Stim WT vs KO p=0.03)
- e. Genotype comparison of social interaction time during Sync (left) and No Stim (right) (pair n=87 [WT], n=87 [KO], Sync: Mann Whitney test p=0.234, No Stim: Mann Whitney test p=0.002)
- f. Genotype comparison of total gaze time across the 2 epochs (pair n=87 [WT], n=87 [KO], WT: Wilcoxon test p=0.052, KO: Wilcoxon test p=0.983).
- g. Trial type comparison of total gaze time across the 2 epochs (n=56 [WT-WT], 56 [KO-KO], 62 [WT-KO], WT-WT: Wilcoxon test p=0.085 , WT-KO: Wilcoxon test p=0.360, KO-WT: Wilcoxon test p=0.333, KO-KO: Wilcoxon test=0.454)
- h. Gaze time as plotted to show changes over 5 minutes for each of the light stimulation epochs during the direct interaction test (n=56 [WT-WT], 56 [KO-KO], 62 [WT-KO], simple linear regression WT-WT No Stim p=0.73, r²=0.015 Sync p=0.096, r²=0.307, WT-KO No Stim p=0.787, r²=0.010 Sync p=0.144, r²=0.247, KO-KO No Stim p=0.479, r²=0.065 Sync p=0.619, r²=0.032,).
- i-j. Total social interaction time (i) and theta band power PCC values (j) across experiments showing the effect of continuous and repeated optogenetic stimulation for each mouse during No Stim (left) and Sync (right) epochs (n=9 [WT], n=8 [KO], simple linear regression Behavior No Stim: WT p=0.307, r²=0.116, KO p=0.209, r²=0.153, Sync: WT p=0.227, r²=0.456, KO p=0.159, r²=0.188, PCC No Stim: WT p=0.074, r²=0.008, KO p=0.616, r²=0.026, Sync: WT p=0.958, r²=0.000 KO p=0.040, r²=0.361)

Interleaved scatter plots display the mean with s.e.m. Box and whisker plots display the median, with boxes spanning the 25th to 75th percentiles, and whiskers indicating minimum and maximum values. Source data are provided as a Source Data file.

Supplementary figure 10



Supplementary figure 10. Phase shifted 5Hz stimulation seems to increase interbrain synchrony

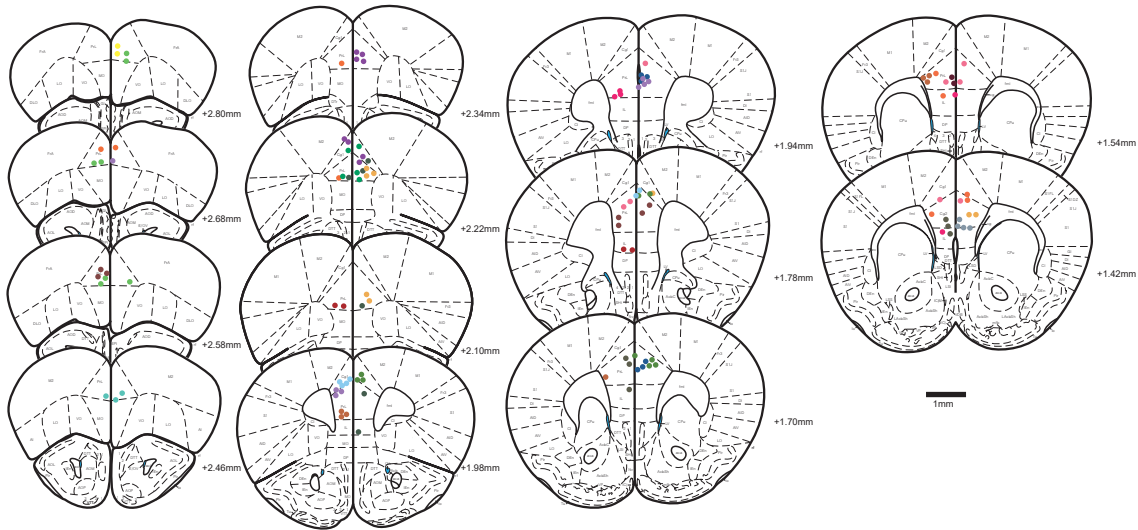
a-d. Trial type comparison of PCC values of theta (a), beta (b), and low gamma (c) for each epoch (n=3 [WT-WT], n=3 [KO-KO], n=6 [WT-KO], WT-WT, N too small to run normality test or any other statistical tests) for control stimulus condition A (a).

e-h. Trial type comparison of PCC values of theta (d), beta (e), and low gamma (f) for each epoch (n=3 [WT-WT], n=3 [KO-KO], n=6 [WT-KO], WT-WT, N too small to run normality test or any other statistical tests) for control stimulus condition B (e).

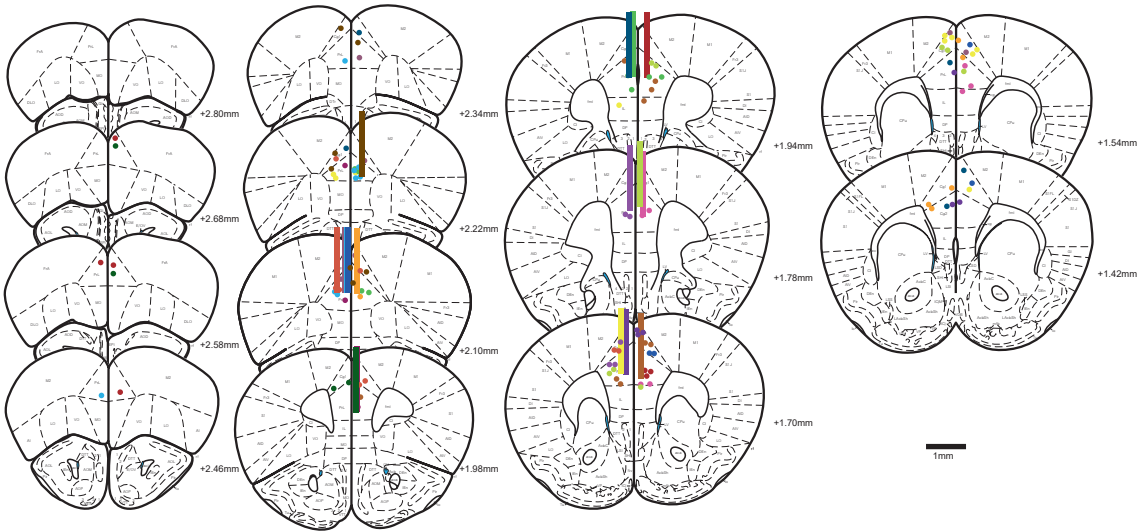
Source data are provided as a Source Data file.

Supplementary figure 11

a



b



Supplementary figure 11. Placement of tetrodes and optic fibers

a. Histology showing tetrode location. Different colors indicate tetrodes location from different animals.

b. Histology showing tetrode location and optic fiber placement. Different colors indicate tetrodes and optic fiber location from different animals.

Supplementary tables				
Supplementary Table 1. Statistical results and details				
Figure 1				
Number	Comparison	N	Parameter	Statistical tests and significance
c	WT vs KO	16,14	distribution of all behaviors	Chi-square; $p=0.0002$
d	WT vs KO	16,14	social interaction time	Mann Whitney; $p<0.0001$
	Trial type (WT-WT, WT-KO, KO-WT, KO-KO)	WT-WT: 70, WT-KO:66, KO-KO:68, KO-WT: 66	social interaction time	Two-way ANOVA; Main effect of self-genotype $p<0.001$; Main effect of the other genotype $p<0.001$; Main effect of self x other $p=0.111$
	WT-WT vs WT-KO	70,66	social interaction time	Mann Whitney; $p=0.0002$
	WT-KO vs KO-WT	66,66	social interaction time	Mann Whitney; $p=0.7058$
	KO-WT vs KO-KO	66,68	social interaction time	Mann Whitney; $p=0.7058$
e	Trial type (WT-WT, WT-KO, KO-KO)	WT-WT: 70, WT-KO:66, KO-KO:68	bi-sniffing time	Kruskal Wallis; $p<0.001$
	WT-WT vs WT-KO	70,66	bi-sniffing time	Dunn's multiple comparisons; $p<0.001$
	WT-KO vs KO-KO	66,68	bi-sniffing time	Dunn's multiple comparisons; $p=0.347$
	WT-WT vs KO-KO	70,68	bi-sniffing time	Dunn's multiple comparisons; $p<0.001$
f	Trial type (WT-WT, WT-KO, KO-WT, KO-KO)	WT-WT: 70, WT-KO:66, KO-KO:80, KO-WT: 66	active social behavior time	Two way ANOVA; Main effect of self-genotype $p<0.001$, Main effect of other-genotype $p=0.005$, Main effect of self x other $p=0.615$
	WT-WT vs KO-WT	70,66	active social behavior time	Uncorrected Fisher's LSD; $p=0.007$
	WT-WT vs KO-KO	35,80	active social behavior time	Uncorrected Fisher's LSD; $p<0.001$
	WT-KO vs KO-KO	66,80	active social behavior time	Uncorrected Fisher's LSD; $p<0.001$
	KO-WT vs KO-KO	66,80	active social behavior time	Uncorrected Fisher's LSD; $p=0.016$
	WT-WT vs WT-KO	70,66	active social behavior time	Uncorrected Fisher's LSD; $p=0.1014$
	WT-KO vs KO-WT	66,66	active social behavior time	Uncorrected Fisher's LSD; $p=0.2816$
Figure 2				
Number	Comparison	N	Parameter	Statistical tests and significance
b.Left	Trial type (WT-WT, WT-KO, KO-KO)	WT-WT: 70, WT-KO:66, KO-KO:68	Theta Pearson correlation coefficient	Kruskal Wallis; $p=0.0061$
	WT-WT vs WT-KO	35, 66	Theta Pearson correlation coefficient	Dunn's multiple comparisons; $p>0.9999$
	WT-WT vs KO-KO	35,34	Theta Pearson correlation coefficient	Dunn's multiple comparisons; $p=0.0072$
	WT-KO vs KO-KO	66,34	Theta Pearson correlation coefficient	Dunn's multiple comparisons; $p=0.031$
b.Middle	Trial type (WT-WT, WT-KO, KO-KO)	WT-WT: 70, WT-KO:66, KO-KO:68	Beta Pearson correlation coefficient	Kruskal Wallis; $p=0.0161$
	WT-WT vs WT-KO	35, 66	Beta Pearson correlation coefficient	Dunn's multiple comparisons; $p=0.4236$
	WT-WT vs KO-KO	35,34	Beta Pearson correlation coefficient	Dunn's multiple comparisons; $p=0.0124$
	WT-KO vs KO-KO	66,34	Beta Pearson correlation coefficient	Dunn's multiple comparisons; $p=0.2092$
b.Right	Trial type (WT-WT, WT-KO, KO-KO)	WT-WT: 70, WT-KO:66, KO-KO:68	Low gamma Pearson correlation coefficient	Kruskal Wallis; $p=0.0432$
	WT-WT vs WT-KO	35, 66	Low gamma Pearson correlation coefficient	Dunn's multiple comparisons; $p=0.4975$
	WT-WT vs KO-KO	35,34	Low gamma Pearson correlation coefficient	Dunn's multiple comparisons; $p=0.0366$
	WT-KO vs KO-KO	66,34	Low gamma Pearson correlation coefficient	Dunn's multiple comparisons; $p=0.4119$
c	WT-WT	35	Social interaction time vs Theta power PCC Pearson correlation coefficient	Simple linear regression; $p=0.0223$, $r^2=0.074$
	WT-KO	66	Social interaction time vs Theta power PCC Pearson correlation coefficient	Simple linear regression; $p=0.0316$, $r^2=0.035$
	KO-KO	68	Social interaction time vs Theta power PCC Pearson correlation coefficient	Simple linear regression; $p=0.3294$, $r^2=0.014$
d	WT-WT Within vs Between	35	Theta Pearson correlation coefficient	Wilcoxon; $p<0.0001$
	WT-KO Within vs Between	66	Theta Pearson correlation coefficient	Wilcoxon; $p<0.0001$
	KO-KO Within vs Between	34	Theta Pearson correlation coefficient	Wilcoxon; $p=0.5965$
e	WT-WT Direct Interaction vs Solitary	24	Theta Pearson correlation coefficient	Wilcoxon; $p=0.002$

	WT-KO Direct Interaction vs Solitary	24	Theta Pearson correlation coefficient	Paired t-test; $p=0.001$
	KO-KO Direct Interaction vs Solitary	8	Theta Pearson correlation coefficient	Paired t-test; $p=0.712$
f	WT-WT Social vs Non-social vs Rest vs Velocity	33	Theta Pearson correlation coefficient	Repeated measures one-way ANOVA, At the 0.001 level, the population means are significantly different, $p<0.0001$, $F(2.435, 77.91)=25.73$, Tukey posthoc comparisons; Social vs NonSocial $p=0.0099$, Social vs Rest $p=0.0043$, Social vs Velocity $p<0.0001$; NonSocial vs Rest = 0.9996, NonSocial vs Velocity $p<0.0001$, Rest vs Velocity $p<0.0001$
	WT-KO Social vs Non-social vs Rest vs Velocity	61	Theta Pearson correlation coefficient	Friedman; $p<0.0001$, Dunn's multiple comparisons; Social vs NonSocial $p=0.1239$, Social vs Rest $p=0.0302$, Social vs Velocity $p<0.0001$; NonSocial vs Rest $p>0.9999$, NonSocial vs Velocity $p<0.0001$, Rest vs Velocity $p=0.0001$
	KO-KO Social vs Non-social vs Rest vs Velocity	26	Theta Pearson correlation coefficient	Friedman; $p=0.0123$, Dunn's multiple comparisons; Social vs NonSocial $p=0.5140$, Social vs Rest $p>0.999$, Social vs Velocity $p=0.0076$; NonSocial vs Rest $p>0.9999$, NonSocial vs Velocity $p=0.7957$, Rest vs Velocity $p=0.1901$
g	WT bi-sniffing vs uni-sniffing	94	Theta Pearson correlation coefficient	Wilcoxon; $p=0.002$
	KO bi-sniffing vs uni-sniffing	87	Theta Pearson correlation coefficient	Wilcoxon; $p=0.791$
h	WT-WT Switch to NonInteraction vs Switch to Interaction	33	Theta power Pearson correlation coefficient	Welch's t-test; $p=0.0178$
	WT-KO Switch to NonInteraction vs Switch to Interaction	61	Theta power Pearson correlation coefficient	Mann-Whitney; $p=0.0219$
	KO-KO Switch to NonInteraction vs Switch to Interaction	26	Theta power Pearson correlation coefficient	Mann-Whitney; $p=0.0299$
Figure 3				
Number	Comparison	N	Parameter	Statistical tests and significance

b	WT vs KO	16,14	social gaze time	Mann-Whitney; $p=0.085$
	Trial type (WT-WT, WT-KO, KO-KO, KO-WT)	WT-WT:70, WT-KO:66, KO-KO:80, KO-WT: 66	social gaze time	Two-way ANOVA; Main effect of self-genotype $p=0.0091$ Main effect of the other genotype $p=0.0941$; Main effect of self x other $p=0.0479$, Tukey posthoc comparisons; WT>WT vs WT>KO $p=0.9700$, WT>WT vs KO>WT $p=0.9965$, WT>WT vs KO>KO $p=0.0127$, WT>KO vs KO>WT $p=0.9102$, WT>KO vs KO>KO $p=0.0455$, KO>WT vs KO>KO $p=0.0061$
c	WT-WT gaze vs no-gaze during different types of behavior(social,non-social, and rest)	33	Theta Pearson correlation coefficient	Two-way ANOVA; Main effect of behavior $p = 0.002$, Main effect of gaze $p = 0.0007$, Main effect of behavior x gaze $p = 0.0182$. Tukey posthoc comparisons Social-Gaze vs Social-NoGaze $p=0.0024$, Social-Gaze vs NonSocial-Gaze $p=0.0863$, Social-Gaze vs NonSocial-Gaze $p<0.0001$, Social-Gaze vs Rest-Gaze $p=0.0003$, Social-Gaze vs Rest-NoGaze $p=0.0006$, Social-NoGaze vs NonSocial-Gaze $p=0.8681$, Social-NoGaze vs NonSocial-NoGaze $p=0.8444$, Social-NoGaze vs Rest-Gaze $p=0.9933$, Social-NoGaze vs Rest-NoGaze $p=0.9991$, NonSocial-Gaze vs NonSocial-NoGaze $p=0.1906$, NonSocial-Gaze vs Rest-Gaze $p=0.5368$, NonSocial-Gaze vs Rest-NoGaze $p=0.6627$, NonSocial-NoGaze vs Rest-Gaze $p>0.9894$, NonSocial-NoGaze vs Rest-NoGaze $p=0.9652$, Rest-Gaze vs Rest-NoGaze $p>0.9999$
	WT-KO gaze vs no-gaze during different types of behavior(social,non-social, and rest)	61	Theta Pearson correlation coefficient	Two-way ANOVA; Main effect of behavior $p = 0.022$, Main effect of gaze $p < 0.001$, Main effect of behavior x gaze $p = 0.367$.

	KO-KO gaze vs no-gaze during different types of behavior(social,non-social, and rest)	28	Theta Pearson correlation coefficient	Two-way ANOVA; Main effect of behavior $p = 0.260$, Main effect of gaze $p = 0.0040$, Main effect of behavior x gaze $p = 0.003$. Tukey posthoc comparisons Social-Gaze vs Social-NoGaze $p=0.0122$, Social-Gaze vs NonSocial-Gaze $p=0.5684$, Social-Gaze vs NonSocial-Gaze $p=0.0110$, Social-Gaze vs Rest-Gaze $p=0.0065$, Social-Gaze vs Rest-NoGaze $p=0.3192$, Social-NoGaze vs NonSocial-Gaze $p=0.5385$, Social-NoGaze vs NonSocial-NoGaze $p>0.9999$, Social-NoGaze vs Rest-Gaze $p>0.9999$, Social-NoGaze vs Rest-NoGaze $p=0.7892$, NonSocial-Gaze vs NonSocial-NoGaze $p=0.5176$, NonSocial-Gaze vs Rest-Gaze $p=0.4152$, NonSocial-Gaze vs Rest-NoGaze $p=0.9987$, NonSocial-NoGaze vs Rest-Gaze $p>0.9999$, NonSocial-NoGaze vs Rest-NoGaze $p=0.7717$, Rest-Gaze vs Rest-NoGaze $p=0.6755$
d	WT-WT gaze vs no-gaze during different types of behavior(social,non-social, and rest)	33	Beta Pearson correlation coefficient	Two-way ANOVA; Main effect of behavior $p = 0.0596$, Main effect of gaze $p = 0.0005$, Main effect of behavior x gaze $p = 0.0572$
	WT-KO gaze vs no-gaze during different types of behavior(social,non-social, and rest)	61	Beta Pearson correlation coefficient	Two-way ANOVA; Main effect of behavior $p = 0.0398$, Main effect of gaze $p < 0.0001$, Main effect of behavior x gaze $p = 0.0592$. Tukey posthoc comparisons Social-Gaze vs Social-NoGaze $p=0.0297$, Social-Gaze vs NonSocial-Gaze $p=0.7567$, Social-Gaze vs NonSocial-Gaze $p<0.0001$, Social-Gaze vs Rest-Gaze $p=0.0133$, Social-Gaze vs Rest-NoGaze $p=0.0088$, Social-NoGaze vs NonSocial-Gaze $p=0.5405$, Social-NoGaze vs NonSocial-NoGaze $p=0.3867$, Social-NoGaze vs Rest-Gaze $p=0.9999$, Social-NoGaze vs Rest-NoGaze $p=0.9990$, NonSocial-Gaze vs NonSocial-NoGaze $p=0.0044$, NonSocial-Gaze vs Rest-Gaze $p=0.3765$, NonSocial-Gaze vs Rest-NoGaze $p=0.3068$, NonSocial-NoGaze vs Rest-Gaze $p=0.5518$, NonSocial-NoGaze vs Rest-NoGaze $p=0.6328$, Rest-Gaze vs Rest-NoGaze $p>0.9999$
	KO-KO gaze vs no-gaze during different types of behavior(social,non-social, and rest)	28	Beta Pearson correlation coefficient	Two-way ANOVA; Main effect of behavior $p = 0.3671$, Main effect of gaze $p = 0.0002$, Main effect of behavior x gaze $p = 0.3671$
e	WT-WT gaze vs no-gaze during different types of behavior(social,non-social, and rest)	33	Low gamma Pearson correlation coefficient	Two-way ANOVA; Main effect of behavior $p = 0.0608$, Main effect of gaze $p < 0.0001$, Main effect of behavior x gaze $p = 0.0049$. Tukey posthoc comparisons, Social-Gaze vs Social-NoGaze $p=0.0002$, Social-Gaze vs NonSocial-Gaze $p=0.4620$, Social-Gaze vs NonSocial-Gaze $p<0.0001$, Social-Gaze vs Rest-Gaze $p=0.0017$, Social-Gaze vs Rest-NoGaze $p=0.0021$, Social-NoGaze vs NonSocial-Gaze $p=0.0900$, Social-NoGaze vs NonSocial-NoGaze $p=0.09944$, Social-NoGaze vs Rest-Gaze $p=0.9929$, Social-NoGaze vs Rest-NoGaze $p=0.9892$, NonSocial-Gaze vs NonSocial-NoGaze $p=0.0196$, NonSocial-Gaze vs Rest-Gaze $p=0.3045$, NonSocial-Gaze vs Rest-NoGaze $p=0.3342$, NonSocial-NoGaze vs Rest-Gaze $p=0.8763$, NonSocial-NoGaze vs Rest-NoGaze $p=0.8527$, Rest-Gaze vs Rest-NoGaze $p>0.9999$

	WT-KO gaze vs no-gaze during different types of behavior(social,non-social, and rest)	61	Low gamma Pearson correlation coefficient	Two-way ANOVA; Main effect of behavior $p = 0.0131$, Main effect of gaze $p < 0.0001$, Main effect of interaction $p = 0.0004$. Tukey posthoc comparisons Social-Gaze vs Social-NoGaze $p < 0.0001$,Social-Gaze vs NonSocial-Gaze $p = 0.3582$,Social-Gaze vs NonSocial-Gaze $p < 0.0001$,Social-Gaze vs Rest-Gaze $p = 0.0010$,Social-Gaze vs Rest-NoGaze $p = 0.0005$,Social-NoGaze vs NonSocial-NoGaze $p = 0.0266$ Social-NoGaze vs NonSocial-NoGaze $p = 0.3399$,Social-NoGaze vs Rest-Gaze $p = 0.8973$,Social-NoGaze vs Rest-NoGaze $p = 0.9453$,NonSocial-Gaze vs NonSocial-NoGaze $p < 0.0001$,NonSocial-Gaze vs Rest-Gaze $p = 0.3351$,NonSocial-Gaze vs Rest-NoGaze $p = 0.2537$,NonSocial-NoGaze vs Rest-Gaze $p = 0.0273$,NonSocial-NoGaze vs Rest-NoGaze $p = 0.0431$,Rest-Gaze vs Rest-NoGaze $p > 0.9999$
	KO-KO gaze vs no-gaze during different types of behavior(social,non-social, and rest)	28	Low gamma Pearson correlation coefficient	Two-way ANOVA; Main effect of behavior $p = 0.1775$, Main effect of gaze $p < 0.0001$, Main effect of interaction $p = 0.0194$. Tukey posthoc comparisons Social-Gaze vs Social-NoGaze $p < 0.0001$,Social-Gaze vs NonSocial-Gaze $p = 0.9960$,Social-Gaze vs NonSocial-Gaze $p = 0.0001$,Social-Gaze vs Rest-Gaze $p = 0.0265$,Social-Gaze vs Rest-NoGaze $p = 0.0009$,Social-NoGaze vs NonSocial-NoGaze $p = 0.0005$ Social-NoGaze vs NonSocial-NoGaze $p > 0.9999$,Social-NoGaze vs Rest-Gaze $p = 0.5856$,Social-NoGaze vs Rest-NoGaze $p = 0.9862$,NonSocial-Gaze vs NonSocial-NoGaze $p = 0.0010$,NonSocial-Gaze vs Rest-Gaze $p = 0.1035$,NonSocial-Gaze vs Rest-NoGaze $p = 0.0060$,NonSocial-NoGaze vs Rest-Gaze $p = 0.6956$,NonSocial-NoGaze vs Rest-NoGaze $p = 0.9965$,Rest-Gaze vs Rest-NoGaze $p = 0.9295$
Figure 4				
Number	Comparison	N	Parameter	Statistical tests and significance
a	WT-WT	35	Theta Pearson correlation coefficient vs time	Simple linear regression; $p = 0.405$ $r^2 = 0.013$,slope=0.000
	WT-WT	35	Social behavior time vs time	Simple linear regression; $p < 0.001$ $r^2 = 0.657$,slope=-0.005
	WT-WT	35	Social gaze time vs time	Simple linear regression; $p < 0.001$ $r^2 = 0.419$,slope=0.002
	WT-KO	66	Theta Pearson correlation coefficient vs time	Simple linear regression; $p < 0.001$ $r^2 = 0.542$,slope=-0.002
	WT-KO	66	Social behavior time vs time	Simple linear regression; $p < 0.001$ $r^2 = 0.779$, slope=-0.003
	WT-KO	66	Social gaze time vs time	Simple linear regression; $p < 0.001$ $r^2 = 0.445$, slope=0.001
	KO-KO	34	Theta Pearson correlation coefficient vs time	Simple linear regression; $p < 0.001$ $r^2 = 0.410$,slope=-0.001
	KO-KO	34	Social behavior time vs time	Simple linear regression; $p = 0.108$ $r^2 = 0.067$,slope=-0.004
	KO-KO	34	Social gaze time vs time	Simple linear regression; $p = 0.203$ $r^2 = 0.194$,slope=-0.099
b	Trial type (WT-WT, WT-KO, KO-KO,)	WT-WT: 70, WT-KO:73, KO-KO:80	first two minutes of social interaction time	Kruskal Wallis test $p < 0.001$, Dunn's multiple comparisons test WT-WT vs WT-KO $p = 0.004$, WT-WT vs KO-KO $p < 0.0001$, WT-KO vs KO-KO $p < 0.0001$
	Trial type (WT-WT, WT-KO, KO-KO,)	WT-WT: 70, WT-KO:73, KO-KO:80	last two minutes social interaction time	Kruskal Wallis test $p < 0.0001$, Dunn's multiple comparisons test WT-WT vs WT-KO $p = 0.003$, WT-WT vs KO-KO $p < 0.0001$, WT-KO vs KO-KO $p = 0.031$
c	Trial type (WT-WT, WT-KO, KO-KO,)	WT-WT: 70, WT-KO:73, KO-KO:80	first two minutes social gaze time	Kruskal Wallis; $p = 0.0891$

	Trial type (WT-WT, WT-KO, KO-KO)	WT-WT: 70, WT-KO:73, KO-KO:80	last two minutes social gaze time	Kruskal Wallis test $p=0.001$, Dunn's multiple comparisons test WT-WT vs WT-KO $p>0.999$, WT-WT vs KO-KO $p<0.002$, WT-KO vs KO-KO $p=0.002$
d	Trial type (WT-WT, WT-KO, KO-KO)	WT-WT: 70, WT-KO:73, KO-KO:80	first two minutes of Pearson correlation coefficient	Kruskal Wallis; $p=0.5823$
	Trial type (WT-WT, WT-KO, KO-KO)	WT-WT: 70, WT-KO:73, KO-KO:80	last two minutes of Pearson correlation coefficient	Kruskal Wallis; $p=0.0167$, Dunn's multiple comparisons; WT-WT vs WT-KO $p=0.0691$, WT-WT vs KO-KO $p=0.02$, WT-KO vs KO-KO $p>0.999$
e	KO-WT vs KO-KO	14	entire 10 minutes of Pearson correlation coefficient	Wilcoxon; $p=0.5703$
f	KO-WT	14	first two minutes vs last two minutes of Pearson correlation coefficient	Paired t-test; $p=0.0576$
	KO-KO	14	first two minutes vs last two minutes of Pearson correlation coefficient	Wilcoxon; $p=0.0245$
Figure 5				
Number	Comparison	N	Parameter	Statistical tests and significance
a	WT neurons vs KO neurons	WT(,1032 161) KO(929, 47)	Distribution of self social vs self-non-social neuron	Fisher's exact test; $p<0.001$
b	WT neurons vs KO neurons	WT(1114, 44) KO(974, 26)	Distribution of other social vs other-non-social neuron	Fisher's exact test; $p=0.148$
d	WT Theta vs Beta vs Low gamma	Theta=125, Beta=35, LowGamma=54	Unit vector lengths of WT social neurons	Kruskal Wallis; $p<0.001$, Dunn's multiple comparisons,Theta vs Beta $p=0.004$, Theta vs Gamma $p<0.001$, Beta vs Gamma $p=0.725$
	KO Theta vs Beta vs Low gamma	Theta=42, Beta=14, LowGamma=18	Unit vector lengths of KO social neurons	Kruskal Wallis; $p<0.001$, Dunn's multiple comparisons Theta vs Beta $p<0.001$, Theta vs Gamma $p=0.203$, Beta vs Gamma $p>0.999$
f	WT Theta vs Beta vs Low gamma	Theta=83, Beta=25, LowGamma=6	Unit vector lengths of WT social neurons	Kruskal Wallis; $p=0.001$, Dunn's multiple comparisons Theta vs Beta $p=0.002$, Theta vs Gamma $p=0.028$, Beta vs Gamma $p>0.999$
	KO Theta vs Beta vs Low gamma	Theta=35, Beta=11,LowGamma=5	Unit vector lengths of KO social neurons	Kruskal Wallis; $p=0.169$, Dunn's multiple comparisons
g	WT vs KO	WT(self=69, other=28 overlap=56), KO(self=13, other=6,overlap= 29)	Distribution of self vs other phase locked neuron	Chi square; $p=0.0330$
h	WT-WT Regress out	26	Pearson correlation coefficient	WT-WT Repeated measure ANOVA; $p=0.006$, Tukey posthoc comparisons Social vs NonSocial $p=0.095$, Social vs Random $p=0.0701$, Social vs Original $p=0.034$, NonSocial vs Random $p=0.994$, NonSocial vs Original $p=0.104$, Random vs Original $p=0.126$

	WT-KO Regress out	32	Pearson correlation coefficient	WT-KO Friedman; $p=0.001$ Dunn's multiple comparisons Social vs NonSocial $p>0.999$, Social vs Random $p>0.999$, Social vs Original $p=0.008$, NonSocial vs Random $p>0.999$, NonSocial vs Original $p=0.008$, Random vs Original $p=0.006$
	KO-KO Regress out	9	Pearson correlation coefficient	KO-KO Repeated measures ANOVA $p=0.464$
i	WT neurons vs KO neurons	WT(717, 185) KO(644, 96)	Distribution of self-social vs other-social neuron	Fisher's exact test; $p<0.001$
j	WT neurons vs KO neurons	WT(1174, 46) KO(1003, 4)	Distribution of self- and other- social vs non-social neuron	Fisher's exact test; $p<0.001$
Figure 6				
Number	Comparison	N	Parameter	Statistical tests and significance
c	WT	9	Behavior distribution across epochs	Fisher's exact test; $p=0.290$
	KO	8	Behavior distribution across epochs	Fisher's exact test; $p=0.0386$
d	Epoch condition, Genotype	WT 87, KO 87	Social interaction time	WT: Wilcoxon test, No Stim vs Sync $p<0.0001$, KO: Wilcoxon test, No Stim vs Sync $p<0.0001$
e	WT-WT NoStim vs Sync	56	social interaction time	WT-WT: Wilcoxon test $p=0.004$
	WT-KO NoStim vs Sync	62	social interaction time	WT-KO: Wilcoxon test $p=0.007$
	KO-KO NoStim vs Sync	56	social interaction time	KO-KO: Wilcoxon test $p<0.001$
f	WT-WT NoStim vs Sync	56	Pearson correlation coefficient	WT-WT: Wilcoxon test $p=0.010$
	WT-KO NoStim vs Sync	62	Pearson correlation coefficient	WT-KO: Wilcoxon test $p=0.860$
	KO-KO NoStim vs Sync	56	Pearson correlation coefficient	KO-KO: Wilcoxon test $p<0.001$
g	WT-WT Nostim	56	Theta Pearson correlation coefficient vs time	Simple linear regression; $p=0.53$ $r^2=0.01$, slope=0.003
	WT-WT Sync	56	Theta Pearson correlation coefficient vs time	Simple linear regression; $p=0.018$ $r^2=0.10$, slope=0.008
	WT-KO Nostim	62	Theta Pearson correlation coefficient vs time	Simple linear regression; $p=0.003$ $r^2=0.16$, slope=-0.015
	WT-KO Sync	62	Theta Pearson correlation coefficient vs time	Simple linear regression; $p<0.001$ $r^2=0.44$, slope=0.027
	KO-KO Nostim	56	Theta Pearson correlation coefficient vs time	Simple linear regression; $p=0.035$ $r^2=0.02$, slope=-0.004

	KO-KO Sync	56	Theta Pearson correlation coefficient vs time	Simple linear regression; $p<0.001$ $r^2=0.25$, slope=0.021
h	WT-WT Nostim	56	Social behavior time vs time	Simple linear regression; $p=0.31$ $r^2=0.104$, slope=0.04
	WT-WT Sync	56	Social behavior time vs time	Simple linear regression; $p=0.25$ $r^2=0.05$, slope=0.04
	WT-KO Nostim	62	Social behavior time vs time	Simple linear regression; $p=0.001$ $r^2=0.31$, slope=-0.06
	WT-KO Sync	62	Social behavior time vs time	Simple linear regression; $p<0.001$ $r^2=0.37$, slope=-0.12
	KO-KO Nostim	56	Social behavior time vs time	Simple linear regression; $p=0.001$ $r^2=0.32$, slope=-0.11
	KO-KO Sync	56	Social behavior time vs time	Simple linear regression; $p=0.7668$ $r^2=0.00$, slope=-0.01
i-j	Nostim WT neurons vs KO neurons	WT(465, 56) KO(456, 24)	Distribution of self-social vs self-non-social neuron	chi-square; $p=0.204$
	Sync WT neurons vs KO neurons	WT(530, 36) KO(610, 29)	Distribution of self-social vs self-non-social neuron	chi-square; $p=0.023$
	WT No Stim vs Sync neurons	No Stim (456,56) Sync (530, 36)	Distribution of self-social vs self-non-social neuron	chi-square; $p=0.012$
	KO No Stim vs Sync neurons	No Stim (456,24) Sync (610, 29)	Distribution of self-social vs self-non-social neuron	chi-square; $p=0.023$
Figure 7				
Number	Comparison	N	Parameter	Statistical tests and significance
b	WT-WT stimulus condition A	24	social interaction time	No Stim vs Sync Wilcoxon test $p=0.0457$
	WT-KO stimulus condition A	36	social interaction time	No Stim vs Sync Wilcoxon test $p=0.005$
	KO-KO stimulus condition A	22	social interaction time	No Stim vs Sync Wilcoxon test $p<0.001$
c	WT-WT stimulus condition B	24	social interaction time	No Stim vs Sync Wilcoxon test $p=0.3464$
	WT-KO stimulus condition B	36	social interaction time	No Stim vs Sync Wilcoxon test $p<0.001$
	KO-KO stimulus condition B	22	social interaction time	No Stim vs Sync Wilcoxon test $p=0.0332$
f	WT vs HT	WT 58, HT 62	social interaction time	Welch's t; $p<0.0001$
g	WT	58	social interaction time	NoStim vs Sync paired t-test $p=0.0062$

	HT	62	social interaction time	NoStim vs Sync paired t-test $p<0.001$
h	WT-WT	24	social interaction time	Wilcoxon test NoStim vs Sync $p=0.7683$
	WT-HT	28	social interaction time	Wilcoxon test NoStim vs Sync $p<0.001$
	HT-HT	34	social interaction time	Wilcoxon test NoStim vs Sync $p=0.7683$
Supplementary Figure 1				
Number	Comparison	N	Parameter	Statistical tests and significance
b	WT Direct Interaction vs solitary	69	Total Rest time	Wilcoxon; $p<0.0001$
	KO Direct Interaction vs solitary	56	Total Rest time	Wilcoxon; $p<0.0001$
	WT Direct Interaction vs solitary	69	Total Thigmotaxis time	Wilcoxon; $p=0.635$
	KO Direct Interaction vs solitary	56	Total Thigmotaxis time	Wilcoxon; $p=0.401$
	WT Direct Interaction vs solitary	69	Total Moving time	Wilcoxon; $p<0.0001$
	KO Direct Interaction vs solitary	56	Total Moving time	Wilcoxon; $p=0.276$
	WT Direct Interaction vs solitary	69	Total Grooming time	Wilcoxon; $p=0.0004$
	KO Direct Interaction vs solitary	56	Total Grooming time	Wilcoxon; $p=0.755$
	WT Direct Interaction vs solitary	69	Total Rearing time	Wilcoxon; $p<0.0001$
	KO Direct Interaction vs solitary	56	Total Rearing time	Wilcoxon; $p<0.0001$
	WT Direct Interaction vs solitary	69	Total Jumping time	Wilcoxon; $p=0.273$
	KO Direct Interaction vs solitary	56	Total Jumping time	Wilcoxon; $p=0.787$
c	Trial type (WT-WT, WT-KO, KO-WT, KO-KO)	WT-WT: 35, WT-KO:73, KO-KO:40, KO-WT: 73	Total circling time	Kruskal-Wallis; $p<0.001$, Dunn's multiple comparisons test

d	WT	108	Total circling time vs social interaction time	Simple linear regression; $p=0.102$ $r^2=0.019$
	KO	113	Total circling time vs social interaction time	Simple linear regression; $p=0.042$ $r^2=0.027$
e	Trial type (WT-WT, WT-KO, KO-KO)	WT-WT: 35, WT-KO:73, KO-KO:34	distance during rest	Kruskal-Wallis; $p=0.620$
f	WT vs KO	WT:6, KO:6	Total social interaction time	Mann-Whitney; $p=0.931$
Supplementary Figure 2				
Number	Comparison	N	Parameter	Statistical tests and significance
b.Left	Trial type (WT-WT, WT-KO, KO-KO)	WT-WT: 33, WT-KO:61, KO-KO:26)	Theta Pearson correlation coefficient	Kruskal Wallis; $p=0.0422$; Dunn's multiple comparisons; WT-WT vs WT-KO $p=0.5024$, WT-WT vs KO-KO $p=0.0356$, WT-KO vs KO-KO $p=0.3717$
b.Middle	Trial type (WT-WT, WT-KO, KO-KO)	WT-WT: 33, WT-KO:61, KO-KO:26)	Beta Pearson correlation coefficient	Kruskal Wallis; $p=0.0302$; Dunn's multiple comparisons; WT-WT vs WT-KO $p>0.9999$, WT-WT vs KO-KO $p=0.0606$, WT-KO vs KO-KO $p=0.0606$
b.Right	Trial type (WT-WT, WT-KO, KO-KO)	WT-WT: 33, WT-KO:61, KO-KO:26)	Low gamma Pearson correlation coefficient	Brown-Forsythe; $p=0.0746$, $F(2,119) = 0.7893$, Ordinary one way ANOVA; $p=0.0696$, $F(2,61.75) = 2.725$,
c	Trial type (WT-WT, WT-KO, KO-KO)	WT-WT: 66, WT-KO:61, KO-KO:52)	Theta Pearson correlation coefficient	Kruskal-Wallis; $p=0.015$, Dunn's multiple comparisons;WT-WT vs WT-KO $p>0.999$, WT-WT vs KO-KO $p=0.067$, WT-KO vs KO-KO $p=0.015$, Mann-Whitney; WT-WT vs KO-KO $p=0.025$).
d	WT first vs KO first	WT;69, KO;56	Theta pearson correlation coefficient	Mann-Whitney; $p=0.2421$
g	WT-WT Within vs Between	35	Beta Pearson correlation coefficient	Wilcoxon; $p<0.0001$
	WT-KO Within vs Between	66	Beta Pearson correlation coefficient	Wilcoxon; $p<0.0001$
	KO-KO Within vs Between	34	Beta Pearson correlation coefficient	Wilcoxon; $p=0.3765$
h	WT-WT Within vs Between	35	Low gamma Pearson correlation coefficient	Wilcoxon; $p<0.0001$
	WT-KO Within vs Between	66	Low gamma Pearson correlation coefficient	Wilcoxon; $p<0.0001$
	KO-KO Within vs Between	34	Low gamma Pearson correlation coefficient	Wilcoxon; $p=0.1716$
i	WT-WT Direct Interaction vs Solitary	24	Beta Pearson correlation coefficient	Wilcoxon; $p=0.3305$
	WT-KO Direct Interaction vs Solitary	24	Beta Pearson correlation coefficient	Wilcoxon; $p=0.16$
	KO-KO Direct Interaction vs Solitary	8	Beta Pearson correlation coefficient	Wilcoxon; $p=0.8438$
j	WT-WT Direct Interaction vs Solitary	24	Low gamma Pearson correlation coefficient	Wilcoxon; $p=0.2643$
	WT-KO Direct Interaction vs Solitary	24	Low gamma Pearson correlation coefficient	Wilcoxon; $p=0.128$
	KO-KO Direct Interaction vs Solitary	8	Low gamma Pearson correlation coefficient	Wilcoxon; $p=0.1484$
Supplementary Figure 3				
Number	Comparison	N	Parameter	Statistical tests and significance

c	Within vs Between	11	Theta Pearson correlation coefficient	paired t-test; $p=0.644$
	Within vs Solitary	11	Theta Pearson correlation coefficient	Wilcoxon test; $p=0.3203$
d	Within vs Between	11	Beta Pearson correlation coefficient	paired t-test; $p=0.2183$
	Within vs Solitary	11	Beta Pearson correlation coefficient	Wilcoxon test; $p=0.5771$
e	Within vs Between	11	Low Gamma Pearson correlation coefficient	paired t-test; $p=0.2522$
	Within vs Solitary	11	Low Gamma Pearson correlation coefficient	Wilcoxon test; $p=0.2061$
f	Within vs Between	11	4-100 Pearson correlation coefficient	paired t-test; $p=0.8666$
	Within vs Solitary	11	4-100 Pearson correlation coefficient	Wilcoxon test; $p=0.6377$
Supplementary Figure 4				
Number	Comparison	N	Parameter	Statistical tests and significance
a	WT-WT Social vs Non-social vs Rest vs Velocity	33	Beta Pearson correlation coefficient	Friedman; $p<0.0001$, Dunn's multiple comparisons; Social vs NonSocial $p>0.9999$, Social vs Rest $p>0.9999$, Social vs Velocity $p<0.0001$; NonSocial vs Rest $p>0.9999$, NonSocial vs Velocity $p<0.0001$, Rest vs Velocity $p<0.0001$
	WT-KO Social vs Non-social vs Rest vs Velocity	61	Beta Pearson correlation coefficient	Friedman; $p<0.0001$, Dunn's multiple comparisons; Social vs NonSocial $p=0.4095$, Social vs Rest $p=0.1489$, Social vs Velocity $p<0.0001$; NonSocial vs Rest $p>0.9999$, NonSocial vs Velocity $p<0.0001$, Rest vs Velocity $p=0.0001$
	KO-KO Social vs Non-social vs Rest vs Velocity	26	Beta Pearson correlation coefficient	Friedman; $p<0.0001$, Dunn's multiple comparisons; Social vs NonSocial $p>0.9999$, Social vs Rest $p>0.9999$, Social vs Velocity $p<0.0001$; NonSocial vs Rest $p>0.9999$, NonSocial vs Velocity $p=0.0114$, Rest vs Velocity $p=0.0012$
b	WT-WT Social vs Non-social vs Rest vs Velocity	33	Low gamma Pearson correlation coefficient	Friedman; $p<0.0001$, Dunn's multiple comparisons; Social vs NonSocial $p=0.916$, Social vs Rest $p>0.9999$, Social vs Velocity $p<0.0001$; NonSocial vs Rest $p>0.9999$, NonSocial vs Velocity $p<0.0001$, Rest vs Velocity $p<0.0001$
	WT-KO Social vs Non-social vs Rest vs Velocity	61	Low gamma Pearson correlation coefficient	Friedman; $p<0.0001$, Dunn's multiple comparisons; Social vs NonSocial $p>0.9999$, Social vs Rest $p=0.1489$, Social vs Velocity $p<0.0001$; NonSocial vs Rest $p=0.845$, NonSocial vs Velocity $p<0.0001$, Rest vs Velocity $p<0.0001$
	KO-KO Social vs Non-social vs Rest vs Velocity	26	Low gamma Pearson correlation coefficient	Friedman; $p<0.0001$, Dunn's multiple comparisons; Social vs NonSocial $p>0.9999$, Social vs Rest $p>0.9999$, Social vs Velocity $p=0.0008$; NonSocial vs Rest $p>0.9999$, NonSocial vs Velocity $p=0.0114$, Rest vs Velocity $p=0.0008$
c	WT-WT	70	Bi-sniffing time vs Theta Pearson correlation coefficient	Simple linear regression; $p=0.040$, $r^2=0.06$
	WT-KO	132	Bi-sniffing time vs Theta Pearson correlation coefficient	Simple linear regression; $p=0.615$, $r^2=0.06$
	KO-KO	68	Bi-sniffing time vs Theta Pearson correlation coefficient	Simple linear regression; $p<0.001$, $r^2=0.22$
d	WT bi-sniffing vs uni-sniffing	94	Beta Pearson correlation coefficient	Wilcoxon; $p=0.091$
	KO bi-sniffing vs uni-sniffing	87	Beta Pearson correlation coefficient	Wilcoxon; $p=0.044$
	WT bi-sniffing vs uni-sniffing	94	Low gamma Pearson correlation coefficient	Wilcoxon; $p=0.356$
	KO bi-sniffing vs uni-sniffing	87	Low gamma Pearson correlation coefficient	Wilcoxon; $p=0.685$
e	WT-WT	33	Theta Pearson correlation coefficient	Two-way ANOVA; Main effect of behavior $p=0.003$, Main effect of comparison $p<0.001$, Main effect of behavior x comparison $p=0.125$. Tukey posthoc comparisons, Social vs NonSocial $p=0.003$, Social vs Rest $p=0.027$ NonSocial vs. Rest $p=0.7156$

	WT-KO	61	Theta Pearson correlation coefficient	Two-way ANOVA; Main effect of behavior $p < 0.001$, Main effect of comparison $p < 0.001$, Main effect of behavior x comparison $p < 0.001$. Tukey posthoc comparisons, Social-Within vs Social-Between $p < 0.0001$, Social-Within vs Nonsocial-Within $p < 0.0001$, Social-Within vs Nonsocial-Between $p < 0.0001$, Social-Within vs Rest-Within $p = 0.1555$, Social-Within vs Rest-Between $p < 0.0001$, Social-Between vs Nonsocial-Within $p < 0.09826$, Social-Between vs Rest-Within $p < 0.0001$, Social-Between vs Rest-Between $p = 0.9974$, Nonsocial-Within vs Nonsocial-Between $p = 0.2561$, Nonsocial-Within vs Rest-Within $p = 0.0006$, Nonsocial-Within vs Rest-Between $p = 0.9618$, Nonsocial-Between vs Rest-Within $p < 0.0001$, Nonsocial-Between vs Rest-Between $p = 0.8084$, Rest-Within vs Rest-Between $p < 0.0001$
	KO-KO	26	Theta Pearson correlation coefficient	Two-way ANOVA; Main effect of behavior $p = 0.081$, Main effect of comparison $p = 0.007$, Main effect of behavior x comparison $p = 0.395$. Tukey posthoc comparisons, Social vs NonSocial $p = 0.0797$ Social vs Rest $p = 0.8835$ NonSocial vs. Rest $p = 0.3262$
f	WT-WT	33	Beta Pearson correlation coefficient	Two-way ANOVA; Main effect of behavior $p < 0.001$, Main effect of comparison $p = 0.002$, Main effect of behavior x comparison $p = 0.444$. Tukey posthoc comparisons, Social vs NonSocial $p = 0.0007$ Social vs Rest $p = 0.5326$ NonSocial vs. Rest $p = 0.0171$
	WT-KO	61	Beta Pearson correlation coefficient	Two-way ANOVA; Main effect of behavior $p < 0.001$, Main effect of comparison $p < 0.001$, Main effect of behavior x comparison $p = 0.065$. Tukey posthoc comparisons, Social vs NonSocial $p < 0.0001$ Social vs Rest $p = 0.1574$ NonSocial vs. Rest $p < 0.0001$
	KO-KO	26	Beta Pearson correlation coefficient	Two-way ANOVA; Main effect of behavior $p = 0.002$, Main effect of comparison $p = 0.092$, Main effect of behavior x comparison $p = 0.222$. Tukey posthoc comparisons, Social vs NonSocial $p = 0.0012$ Social vs Rest $p = 0.2754$ NonSocial vs. Rest $p = 0.2516$
g	WT-WT	33	Low gamma Pearson correlation coefficient	Two-way ANOVA; Main effect of behavior $p = 0.981$, Main effect of comparison $p = 0.001$, Main effect of behavior x comparison $p = 0.0010$. Tukey posthoc comparisons, Social vs NonSocial $p = 0.4529$ Social vs Rest $p = 0.2754$ NonSocial vs. Rest $p = 0.0317$
	WT-KO	61	Low gamma Pearson correlation coefficient	Two-way ANOVA; Main effect of behavior $p < 0.001$, Main effect of comparison $p = 0.003$, Main effect of behavior x comparison $p = 0.936$. Tukey posthoc comparisons, Social vs NonSocial $p < 0.0001$ Social vs Rest $p = 0.9964$, NonSocial vs. Rest $p < 0.0001$
	KO-KO	26	Low gamma Pearson correlation coefficient	Two-way ANOVA; Main effect of behavior $p < 0.001$, Main effect of comparison $p = 0.091$, Main effect of behavior x comparison $p = 0.1145$. Tukey posthoc comparisons, Social vs NonSocial $p < 0.0001$ Social vs Rest $p = 0.9959$ NonSocial vs. Rest $p < 0.0001$
h	WT-WT	35	Theta Pearson correlation coefficient	Friedman; $p = 0.148$
	WT-KO	66	Theta Pearson correlation coefficient	Friedman; $p = 0.121$
	KO-KO	34	Theta Pearson correlation coefficient	Friedman; $p = 0.421$
Supplementary Figure 5				
Number	Comparison	N	Parameter	Statistical tests and significance

a	WT-WT	70	Social interaction time vs Social gaze time	Simple linear regression; $p=0.0368$, $r^2=0.0644$
	WT-KO	132	Social interaction time vs Social gaze time	Simple linear regression; $p=0.07$, $r^2=0.0266$
	KO-KO	68	Social interaction time vs Social gaze time	Simple linear regression; $p=0.9803$, $r^2<0.0001$
b	WT-WT Gaze vs NoGaze vs Angle	66	Theta Pearson correlation coefficient	Friedman; $p<0.0001$, Dunn's multiple comparisons; Gaze vs NoGaze $p<0.0001$, Gaze vs Angle $p=0.058$, NoGaze vs Angle $p=0.1467$
	WT-KO Gaze vs NoGaze vs Angle	61	Theta Pearson correlation coefficient	Friedman; $p<0.0001$, Dunn's multiple comparisons; Gaze vs NoGaze $p<0.0001$, Gaze vs Angle $p=0.1718$, NoGaze vs Angle $p=0.0198$
	KO-KO Gaze vs NoGaze vs Angle	56	Theta Pearson correlation coefficient	Friedman; $p=0.0052$, Dunn's multiple comparisons; Gaze vs NoGaze $p=0.004$, Gaze vs Angle $p=0.6873$, NoGaze vs Angle $p=0.1351$
c	WT-WT Gaze vs NoGaze vs Angle	66	Beta Pearson correlation coefficient	Friedman; $p<0.0001$, Dunn's multiple comparisons; Gaze vs NoGaze $p<0.0001$, Gaze vs Angle $p<0.0001$, NoGaze vs Angle $p>0.9999$
	WT-KO Gaze vs NoGaze vs Angle	61	Beta Pearson correlation coefficient	Friedman; $p<0.0001$, Dunn's multiple comparisons; Gaze vs NoGaze $p<0.0001$, Gaze vs Angle $p=0.0557$, NoGaze vs Angle $p=0.0002$
	KO-KO Gaze vs NoGaze vs Angle	56	Beta Pearson correlation coefficient	Friedman; $p<0.0001$, Dunn's multiple comparisons; Gaze vs NoGaze $p<0.0001$, Gaze vs Angle $p=0.0063$, NoGaze vs Angle $p=0.4247$
d	WT-WT Gaze vs NoGaze vs Angle	66	Low gamma Pearson correlation coefficient	Friedman; $p<0.0001$, Dunn's multiple comparisons; Gaze vs NoGaze $p=0.0007$, Gaze vs Angle $p<0.0001$, NoGaze vs Angle $p>0.9999$
	WT-KO Gaze vs NoGaze vs Angle	61	Low gamma Pearson correlation coefficient	Friedman; $p<0.0001$, Dunn's multiple comparisons; Gaze vs NoGaze $p<0.0001$, Gaze vs Angle $p=0.0017$, NoGaze vs Angle $p=0.0017$
	KO-KO Gaze vs NoGaze vs Angle	56	Low gamma Pearson correlation coefficient	Friedman; $p<0.0001$, Dunn's multiple comparisons; Gaze vs NoGaze $p<0.0001$, Gaze vs Angle $p=0.015$, NoGaze vs Angle $p=0.1351$
f	Theta trial type,trial	10	Theta Pearson correlation coefficient	Two-way ANOVA; Main effect of trial type $p=0.002$, Main effect of trial $p=0.74$, Main effect of trial type x trial $p=0.82$, .Tukey posthoc comparisons, WT-WT vs KO-KO $p=0.110$, WT-WT vs WT-KO $p=0.110$, KO-KO vs WT-KO: $p=0.001$
	Beta trial type,trial	9	Beta Pearson correlation coefficient	Two-way ANOVA; Main effect of trial type $p=0.010$, Main effect of trial $p=0.020$, Main effect of trial type x trial $p<0.001$.Tukey posthoc comparisons WT-WT vs KO-KO $p=0.040$, WT-WT vs WT-KO $p=0.910$, KO-KO vs WT-KO: $p=0.020$
	Low Gamma trial type,trial	8	Low gamma Pearson correlation coefficient	Two-way ANOVA; Main effect of trial type $p=0.009$, Main effect of trial $p=0.220$, Main effect of trial type x trial $p=0.006$.Tukey posthoc comparisons WT-WT vs KO-KO $p=0.007$, WT-WT vs WT-KO $p=0.150$, KO-KO vs WT-KO: $p=0.650$
Supplementary Figure 6				
Number	Comparison	N	Parameter	Statistical tests and significance
a	WT-WT	35	Beta Pearson correlation coefficient vs time	Simple linear regression; $p<0.001$ $r^2=0.203$, slope=-0.0001
	WT-KO	66	Beta Pearson correlation coefficient vs time	Simple linear regression; $p<0.001$ $r^2=0.473$, slope=-0.0001

	KO-KO	34	Beta Pearson correlation coefficient vs time	Simple linear regression; $p<0.001$ $r^2=0.419$, slope=-0.0001
b	WT-WT	35	Low Gamma Pearson correlation coefficient vs time	Simple linear regression; $p=0.57$ $r^2=0.006$, slope=0.000
	WT-KO	66	Low Gamma Pearson correlation coefficient vs time	Simple linear regression; $p=0.009$ $r^2=0.123$, slope=-0.001
	KO-KO	34	Low Gamma Pearson correlation coefficient vs time	Simple linear regression; $p=0.0246$ $r^2=0.488$, slope=-0.0065
c	WT-WT 1st 2min vs last 2min	70	social interaction time	Wilcoxon; $p<0.0001$
	WT-KO 1st 2min vs last 2min	74	social interaction time	Wilcoxon; $p<0.0001$
	KO-KO 1st 2min vs last 2min	80	social interaction time	Wilcoxon; $p<0.0001$
	KO-WT 1st 2min vs last 2min	74	social interaction time	Wilcoxon; $p<0.0001$
d	WT-WT 1st 2min vs last 2min	70	social gaze time	Wilcoxon; $p=0.001$
	WT-KO 1st 2min vs last 2min	74	social gaze time	Wilcoxon; $p=0.001$
	KO-KO 1st 2min vs last 2min	80	social gaze time	Wilcoxon; $p<0.641$
	KO-WT 1st 2min vs last 2min	74	social gaze time	Wilcoxon; $p=0.437$
Supplementary Figure 7				
Number	Comparison	N	Parameter	Statistical tests and significance
b	WT Baseline vs Solitary vs Direct Interaction	835	Putative excitatory neuron firing rates	Friedman; $p<0.0001$, Dunn's multiple comparisons; Baseline vs Solitary $p<0.0001$, Baseline vs Direct Interaction $p<0.0001$, Solitary vs Direct Interaction $p=0.0017$
	KO Baseline vs Solitary vs Direct Interaction	555	Putative excitatory neuron firing rates	Friedman; $p=0.0267$, Dunn's multiple comparisons; Baseline vs Solitary $p>0.9999$, Baseline vs Direct Interaction $p=0.0248$, Solitary vs Direct Interaction $p=0.2297$
	WT Baseline vs Solitary vs Direct Interaction	87	Putative inhibitory neuron firing rates	Friedman; $p=0.0029$, Dunn's multiple comparisons; Baseline vs Solitary $p=0.0073$, Baseline vs Direct Interaction $p=0.0119$, Solitary vs Direct Interaction $p>0.9999$
	KO Baseline vs Solitary vs Direct Interaction	37	Putative inhibitory neuron firing rates	Friedman; $p=0.0002$, Dunn's multiple comparisons; Baseline vs Solitary $p=0.7351$, Baseline vs Direct Interaction $p=0.0001$, Solitary vs Direct Interaction $p=0.011$
c	WT Social vs NonSocial vs Rest	835	Putative excitatory neuron burst proportion	Friedman; $p<0.0001$, Dunn's multiple comparisons; Social vs NonSocial $p<0.0001$, Social vs Rest $p<0.0001$, NonSocial vs Rest $p>0.9999$
	KO Social vs NonSocial vs Rest	555	Putative excitatory neuron burst proportion	Friedman; $p<0.0001$, Dunn's multiple comparisons; Social vs NonSocial $p<0.0001$, Social vs Rest $p=0.5082$, NonSocial vs Rest $p<0.0001$
	WT Social vs NonSocial vs Rest	87	Putative inhibitory neuron burst proportion	Friedman; $p=0.0024$, Dunn's multiple comparisons; Social vs NonSocial $p=0.6392$, Social vs Rest $p=0.088$, NonSocial vs Rest $p=0.0019$
	KO Social vs NonSocial vs Rest	37	Putative inhibitory neuron burst proportion	Friedman; $p=0.0014$, Dunn's multiple comparisons; Social vs NonSocial $p>0.9999$, Social vs Rest $p=0.0056$, NonSocial vs Rest $p=0.0056$
f	WT DI vs solitary	161	Average firing rate	Wilcoxon; $p=0.014$

	KO DI vs solitary	47	Average firing rate	Wilcoxon; $p=0.090$
g	WT DI vs solitary	44	Average firing rate	Wilcoxon; $p=0.004$
	KO DI vs solitary	26	Average firing rate	Wilcoxon; $p=0.047$
h	WT DI vs solitary	185	Average firing rate	Wilcoxon; $p=0.037$
	KO DI vs solitary	96	Average firing rate	Wilcoxon; $p=0.309$
i	WT social neuron vs else	social:185,else: 717	auROC-0.5	Mann-Whitney; $p<0.001$
	WT social neuron vs else	social:96,else:6 44	auROC-0.5	Mann-Whitney; $p<0.001$
j	WT-WT	23	regressed out PCC	Repeated measures ANOVA; $p=0.020$, Tukey's multiple comparisons test, Social vs NonSocial $p=0.208$, Social vs Random $p=0.142$, Social vs Original $p=0.081$, NonSocial vs Random $p=0.986$, NonSocial vs Original $p=0.242$, Random vs Original $p=0.371$
	WT-KO	29	regressed out PCC	Friedman; $p=0.004$, Dunn's multiple comparisons test; Social vs NonSocial $p>0.999$, Social vs Random $p>0.999$, Social vs Original $p=0.049$, NonSocial vs Random $p>0.999$, NonSocial vs Original $p=0.005$, Random vs Original $p=0.036$
	KO-KO	6	regressed out PCC	Repeated measures ANOVA; $p=0.519$
k	WT-WT	14	regressed out PCC	Repeated measures ANOVA; $p=0.024$, Tukey's multiple comparisons; Social vs NonSocial $p=0.202$, Social vs Random $p=0.141$, Social vs Original $p=0.097$, NonSocial vs Random $p=0.995$, NonSocial vs Original $p=0.072$, Random vs Original $p=0.133$
	WT-KO	20	regressed out PCC	Repeated measures ANOVA; $p=0.042$, Tukey's multiple comparisons test; Social vs NonSocial $p=0.709$, Social vs Random $p=0.921$, Social vs Original $p=0.180$, NonSocial vs Random $p=0.139$, NonSocial vs Original $p=0.145$, Random vs Original $p=0.089$
	KO-KO	6	regressed out PCC	Repeated measures ANOVA; $p=0.251$
l	WT-WT	22	regressed out PCC	Repeated measures ANOVA; $p=0.185$
	WT-KO	36	regressed out PCC	Friedman; $p=0.007$, Dunn's multiple comparisons; Social vs NonSocial $p>0.999$, Social vs Random $p>0.999$, Social vs Original $p=0.002$, NonSocial vs Random $p>0.999$, NonSocial vs Original $p=0.004$, Random vs Original $p=0.028$
	KO-KO	12	regressed out PCC	Friedman; $p=0.321$
Supplementary Figure 8				
Number	Comparison	N	Parameter	Statistical tests and significance

b	WT Ipsi/Contral across stimulation types	32 session	Theta power	Two-way ANOVA; Main effect of Ipsi/Contral $p<0.001$ Main effect of the stimulation $p<0.001$; Main effect of Ipsi/Contral x stimulation $p=0.0642$,Dunnett's multiple comparisons test,Contralateral Baseline vs 10Hz $p=0.157$, Baseline vs 5Hz $p=0.7381$, Ipsilateral Baseline vs 10Hz $p=0.0565$, Baseline vs 5Hz $p=0.0892$
	WT Ipsi/Contral across stimulation types	32 session	Beta power	Two-way ANOVA; Main effect of Ipsi/Contral $p<0.001$ Main effect of the stimulation $p<0.001$; Main effect of Ipsi/Contral x stimulation $p<0.001$,Dunnett's multiple comparisons test,Contralateral Baseline vs 10Hz $p<0.001$, Baseline vs 5Hz $p<0.001$, Ipsilateral Baseline vs 10Hz $p=0.0373$, Baseline vs 5Hz $p=0.0696$
	WT Ipsi/Contral across stimulation types	32 session	Low gamma power	Two-way ANOVA; Main effect of Ipsi/Contral $p<0.001$ Main effect of the stimulation $p<0.001$; Main effect of Ipsi/Contral x stimulation $p<0.001$,Dunnett's multiple comparisons test,Contralateral Baseline vs 10Hz $p=0.0521$, Baseline vs 5Hz $p=0.7423$, Ipsilateral Baseline vs 10Hz $p=0.8994$, Baseline vs 5Hz $p=0.0017$
e	WT-WT	56	Bi-sniffing time	Wilcoxon test $p=0.115$
	WT-KO	62	Bi-sniffing time	Wilcoxon test $p=0.001$
	KO-KO	56	Bi-sniffing time	Wilcoxon test $p<0.001$
f	WT-WT	56	Uni-sniffing time	Wilcoxon test $p=0.006$
	WT-KO	62	Uni-sniffing time	Wilcoxon test $p<0.001$
	KO-KO	56	Uni-sniffing time	Wilcoxon test $p<0.001$
g	WT-WT	56	Chasing time	Wilcoxon test $p=0.967$
	WT-KO	62	Chasing time	Wilcoxon test $p=0.004$
	KO-KO	56	Chasing time	Wilcoxon test $p<0.001$
h	WT-WT	56	Approach time	Wilcoxon test $p=0.006$
	WT-KO	62	Approach time	Wilcoxon test $p<0.001$
	KO-KO	56	Approach time	Wilcoxon test $p<0.001$
i	WT-WT	56	Beta Pearson correlation coefficient	Wilcoxon test $p=0.059$
	WT-KO	62	Beta Pearson correlation coefficient	Wilcoxon test $p=0.817$
	KO-KO	56	Beta Pearson correlation coefficient	Wilcoxon test $p=0.937$
j	WT-WT	56	Low gamma Pearson correlation coefficient	Wilcoxon test $p=0.035$
	WT-KO	62	Low gamma Pearson correlation coefficient	Wilcoxon test $p=0.790$
	KO-KO	56	Low gamma Pearson correlation coefficient	Wilcoxon test $p=0.705$
k	WT-WT Nostim	56	Beta Pearson correlation coefficient vs time	Simple linear regression; $p=0.17$, $r^2=0.04$, $slope=-0.007$
	WT-WT Sync	56	Beta Pearson correlation coefficient vs time	Simple linear regression; $p=0.034$ $r^2=0.24$, $slope=0.026$
	WT-KO Nostim	62	Beta Pearson correlation coefficient vs time	Simple linear regression; $p=0.125$ $r^2=0.04$, $slope=0.008$
	WT-KO Sync	62	Beta Pearson correlation coefficient vs time	Simple linear regression; $p=0.990$ $r^2=0.00$, $slope=-0.000$
	KO-KO Nostim	56	Beta Pearson correlation coefficient vs time	Simple linear regression; $p=0.019$ $r^2=0.36$, $slope=-0.013$
	KO-KO Sync	56	Beta Pearson correlation coefficient vs time	Simple linear regression; $p=0.969$ $r^2=0.30$, $slope=0.000$
l	WT-WT Nostim	56	Low gamma Pearson correlation coefficient vs time	Simple linear regression; $p=0.456$, $r^2=0.01$, $slope=-0.004$
	WT-WT Sync	56	Low gamma Pearson correlation coefficient vs time	Simple linear regression; $p=0.057$ $r^2=0.40$, $slope=0.034$
	WT-KO Nostim	62	Low gamma Pearson correlation coefficient vs time	Simple linear regression; $p=0.500$ $r^2=0.01$, $slope=-0.003$

	WT-KO Sync	62	Low gamma Pearson correlation coefficient vs time	Simple linear regression; $p=0.029$ $r^2=0.09$, $slope=0.011$
	KO-KO Nostim	56	Low gamma Pearson correlation coefficient vs time	Simple linear regression; $p<0.001$ $r^2=0.36$, $slope=-0.024$
	KO-KO Sync	56	Low gamma Pearson correlation coefficient vs time	Simple linear regression; $p<0.001$ $r^2=0.32$, $slope=-0.019$
m	WT-WT No Stim Switch to NonInteraction vs Switch to Interaction	56	Theta power Pearson correlation coefficient	Welch's t-test; $p=0.0019$
	WT-WT Sync Switch to NonInteraction vs Switch to Interaction	56	Theta power Pearson correlation coefficient	Welch's t-test; $p=0.0108$
n	WT-KO No Stim Switch to NonInteraction vs Switch to Interaction	62	Theta power Pearson correlation coefficient	Mann-Whitney; $p=0.0285$
	WT-KO Sync Switch to NonInteraction vs Switch to Interaction	62	Theta power Pearson correlation coefficient	Welch's t-test; $p=0.0371$
o	KO-KO No Stim Switch to NonInteraction vs Switch to Interaction	56	Theta power Pearson correlation coefficient	Mann-Whitney; $p=0.0218$
	KO-KO Sync Switch to NonInteraction vs Switch to Interaction	56	Theta power Pearson correlation coefficient	Welch's t-test; $p=0.0272$
p	Nostim WT neurons vs KO neurons	WT(459, 31) KO(485, 33)	Distribution of other-social vs other-non-social neuron	chi-square; $p>0.999$
q	Sync WT neurons vs KO neurons	WT(542, 24) KO(621, 24)	Distribution of other-social vs other-non-social neuron	chi-square; $p=0.753$
p-q	WT No Stim vs Sync	No Stim (459,31) Sync (542,24)	Distribution of other-social vs other-non-social neuron	chi-square; $p=0.164$
	KO No Stim vs Sync	No Stim (485,33) Sync (621,24)	Distribution of other-social vs other-non-social neuron	chi-square; $p=0.041$
Supplementary Figure 9				
Number	Comparison	N	Parameter	Statistical tests and significance
a	WT tetrode vs optrode nostim vs optrode sync	WT optrode 87, KO tetrode 68	Theta Pearson correlation coefficient	Kruskal Wallis test; $p=0.082$, No Stim vs Sync Mann Whitney test $p=0.033$
	KO tetrode vs optrode nostim vs optrode sync	KO optrode 87, KO tetrode 67	Theta Pearson correlation coefficient	Kruskal Wallis test; $p<0.001$, Dunn's multiple comparisons test NoStim vs Sync $p<0.001$, NoStim vs Tetrode $p>0.999$, Sync vs Tetrode $p<0.001$
b	nostim WT Social vs Non-social vs Rest	75	Theta Pearson correlation coefficient	Friedman; $p=0.014$, Dunn's multiple comparisons test, Social vs NonSocial $p=0.0337$, Social vs Rest $p=0.0337$, NonSocial vs Rest $p=0.0337$
	nostim KO Social vs Non-social vs Rest	76	Theta Pearson correlation coefficient	Friedman; $p=0.829$
c	WT across stimuluts conditions	87	Theta oscilation power in a.u.	Mann Whitney test; $p=0.937$
	KO across stimuluts conditions	87	Theta oscilation power in a.u.	Mann Whitney test; $p=0.669$
d	WT vs KO	WT 7, KO 7	Average Velocity	Two-way ANOVA, Main effect of Stimulation $p=0.89$, Genotype $p=0.02$, Interaction $p=0.61$, Sidak's multiple comparisons test 5Hz: WT vs KO $p=0.03$. No Stim WT vs
e	Sync WT vs KO	WT 87, KO 87	Social interaction time	Mann-Whitney; $p=0.234$

	NoStim WT vs KO	WT 87, KO 87	Social interaction time	Mann-Whitney; $p=0.002$
f	Epoch condition, Genotype	WT 87, KO 87	Gaze to,e	WT: Wilcoxon test, No Stim vs Sync $p=0.085$, KO: Wilcoxon test, No Stim vs Sync $p=0.983$
g	WT-WT NoStim vs Sync	56	social interaction time	WT-WT: Wilcoxon test $p=0.085$
	WT-KO NoStim vs Sync	62	social interaction time	WT-KO: Wilcoxon test $p=0.360$
	KO-KO NoStim vs Sync	56	social interaction time	KO-KO: Wilcoxon test $p=0.454$
h	WT-WT Nostim	7	gaze time vs time	Simple linear regression; $p=0.73$ $r^2=0.015$, $slope=0.0003$
	WT-WT Sync	8	gaze time vs time	Simple linear regression; $p=0.096$ $r^2=0.307$, $slope=0.002$
	WT-KO Nostim	16	gaze time vs time	Simple linear regression; $p=0.787$ $r^2=0.010$, $slope=-0.0003$
	WT-KO Sync	12	gaze time vs time	Simple linear regression; $p=0.144$ $r^2=0.0247$, $slope=-0.0019$
	KO-KO Nostim	11	gaze time vs time	Simple linear regression; $p=0.479$ $r^2=0.065$, $slope=0.0007$
	KO-KO Sync	6	gaze time vs time	Simple linear regression; $p=0.619$ $r^2=0.032$, $slope=0.0003$
i	Nostim WT vs KO	WT 9, KO 8	Social interaction time	WT $p=0.307$, $r^2=0.116$, KO $p=0.209$, $r^2=0.153$
	Sync WT vs KO	WT 9, KO 8	Social interaction time	WT $p=0.227$, $r^2=0.456$, KO $p=0.159$, $r^2=0.188$
j	Nostim WT vs KO	WT 9, KO 8	Theta Pearson correlation coefficient	WT $p=0.074$, $r^2=0.008$, KO $p=0.616$, $r^2=0.026$
	Sync WT vs KO	WT 9, KO 8	Theta Pearson correlation coefficient	WT $p=0.958$, $r^2=0.000$ KO $p=0.040$, $r^2=0.361$
Supplementary Figure 10				
Number	Comparison	N	Parameter	Statistical tests and significance
b	Trial type (WT-WT, WT-KO, KO-KO)	WT-WT 3, WT-KO 3, WT-KO 6	Theta Pearson correlation coefficient	N too small to run normality test or any other statistical tests
c	Trial type (WT-WT, WT-KO, KO-KO)	WT-WT 3, WT-KO 3, WT-KO 6	Beta Pearson correlation coefficient	N too small to run normality test or any other statistical tests
d	Trial type (WT-WT, WT-KO, KO-KO)	WT-WT 3, WT-KO 3, WT-KO 6	Low gamma Pearson correlation coefficient	N too small to run normality test or any other statistical tests
f	Trial type (WT-WT, WT-KO, KO-KO)	WT-WT 3, WT-KO 3, WT-KO 6	Theta Pearson correlation coefficient	N too small to run normality test or any other statistical tests
g	Trial type (WT-WT, WT-KO, KO-KO)	WT-WT 3, WT-KO 3, WT-KO 6	Beta Pearson correlation coefficient	N too small to run normality test or any other statistical tests
h	Trial type (WT-WT, WT-KO, KO-KO)	WT-WT 3, WT-KO 3, WT-KO 6	Low gamma Pearson correlation coefficient	N too small to run normality test or any other statistical tests