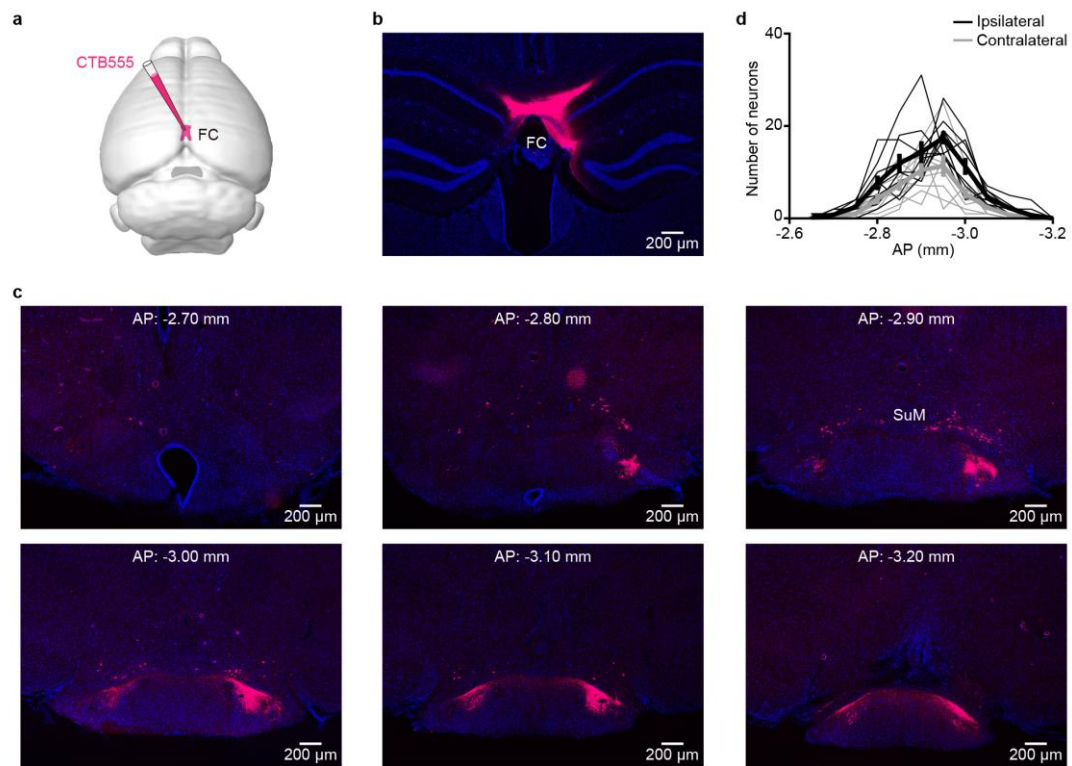
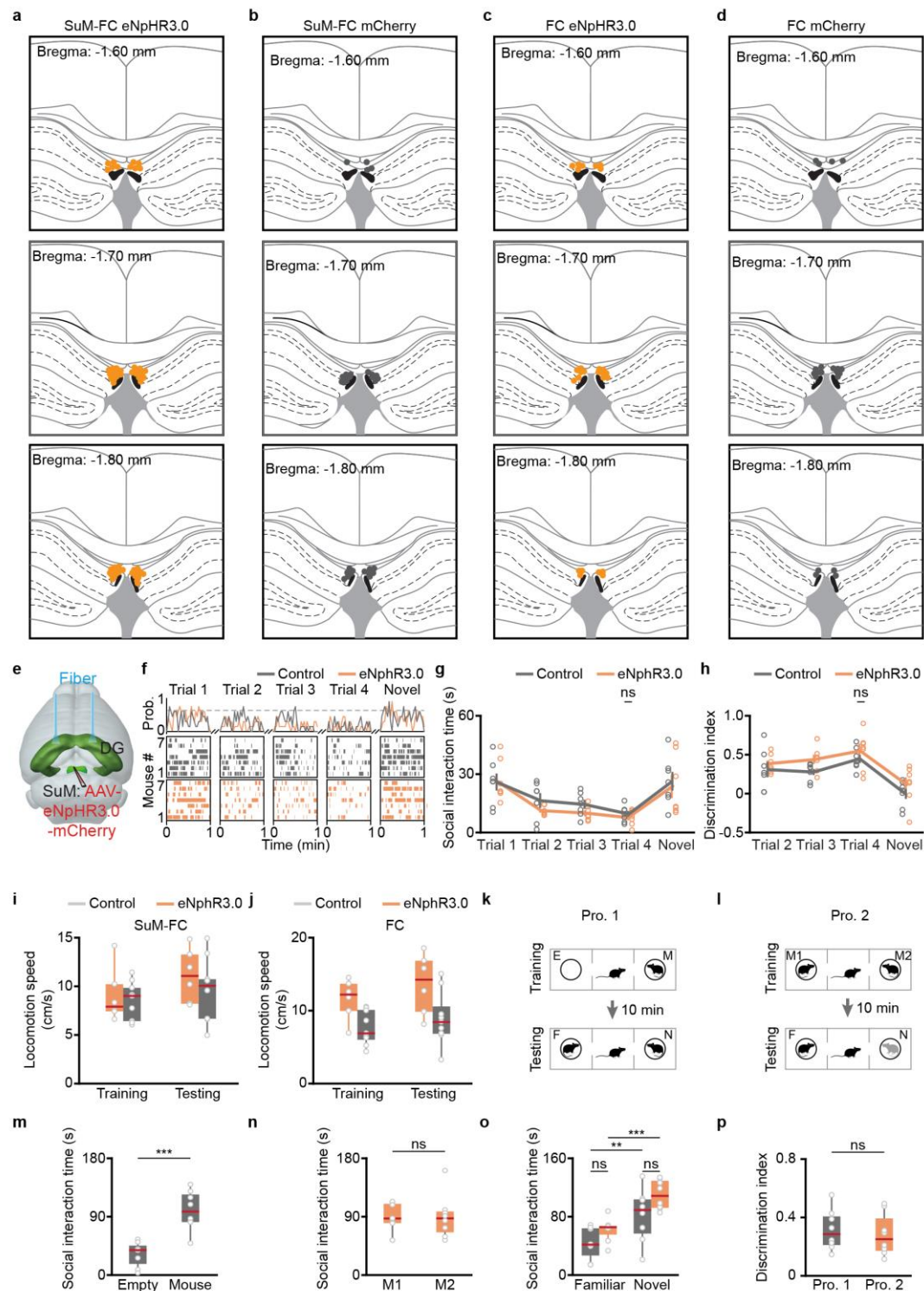


Supplementary figures

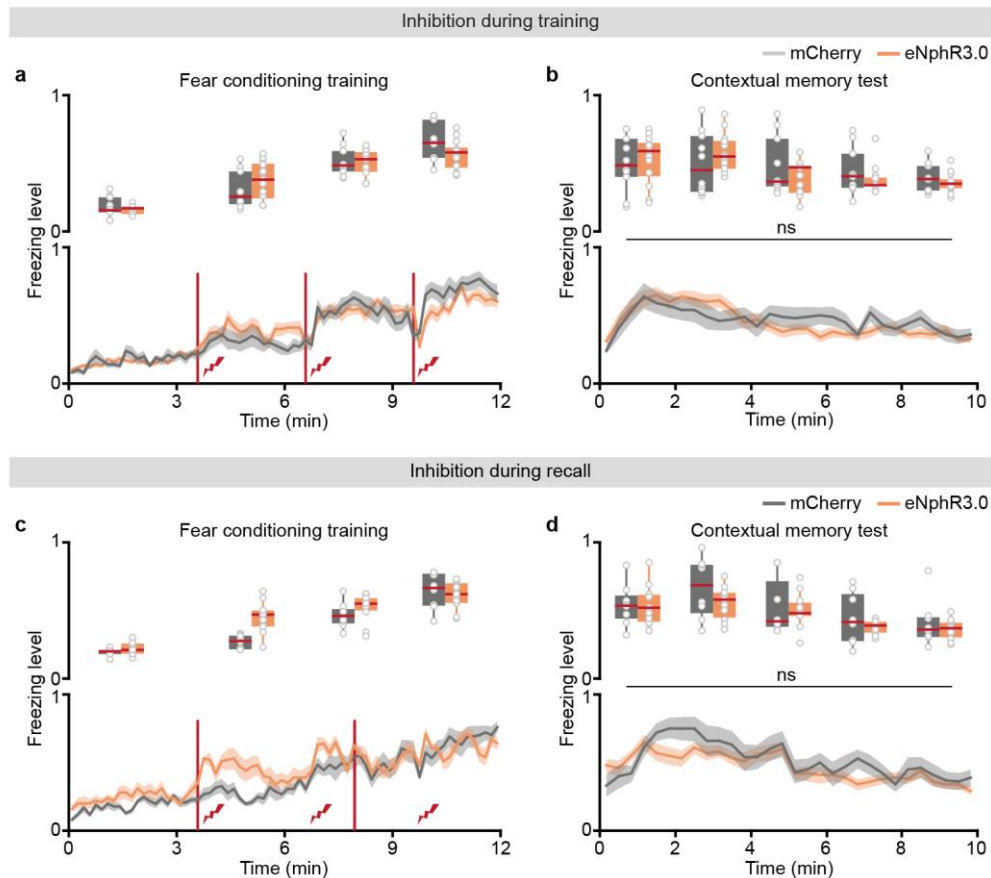


Supplementary figure 1 Retrograde tracing of FC-projecting SuM neurons using cholera toxin subunit B (CTB). **a,b** Diagram (**a**) and image (**b**) showing a CTB555 injection into the FC. **c** Serial coronal sections showing neurons labeled in the SuM. **d** The distribution of SuM^{FC} projecting neurons at different anterior-posterior positions, $n = 9$ mice.

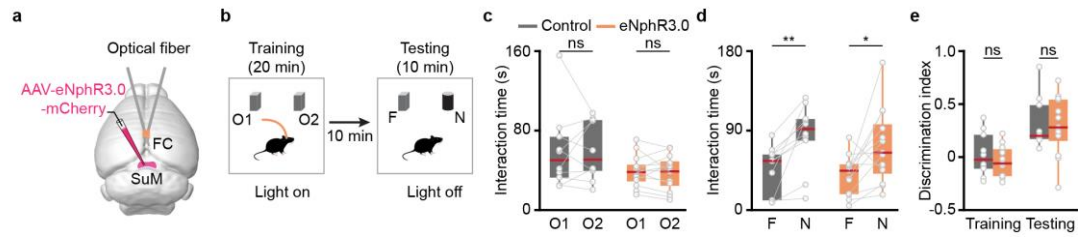


Supplementary figure 2 Optogenetic silencing of SuM-DG terminals does not impair social memory formation, fiber tip placement in FC, locomotion analysis during three-chamber social tasks and three-chamber social task by presenting two initially novel conspecifics. a–d The fiber tip positions of SuM-FC projection (**a**, eNpHR3.0 $n = 30$ mice; **b**, mCherry $n = 15$ mice) and FC^{SuM} recipient neuron silencing experiments (**c**, eNpHR3.0 $n = 13$ mice; **b**, mCherry

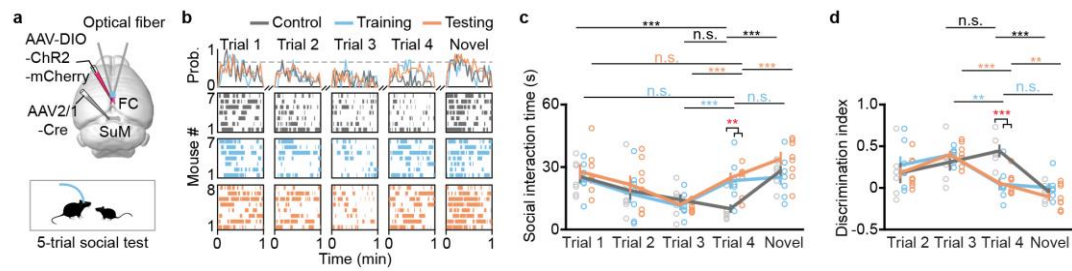
n = 10 mice). **e** Experimental protocol for 5-trial social memory test and optogenetic silencing of SuM-DG projection during training. **f** Social interaction episodes in the SuM-DG eNpHR3.0 group and control group (GFP), and the corresponding social proportion across time (top) in the 5-trial social test. **g,h** Summary of the interaction time (**g**) and discrimination index (**h**) across the 5-trial social test. RMs 1-way ANOVA with LSD post-hoc test, eNpHR3, *n* = 7; control, *n* = 7. **i,j** Silencing of SuM-FC projections (**i**; control, *n* = 10, eNpHR3.0, *n* = 6), Silencing of FC^{SuM} recipient neurons (**j**; control, *n* = 9, eNpHR3.0, *n* = 6) did not alter locomotion speed during the three-chamber social task. **k** Diagram showing three-chamber social task training with a novel conspecific and an empty cup (protocol 1). **l** Diagram showing three-chamber social task training with two initially novel conspecifics (protocol 2). **m,n** Interaction time in the training phase of the task with protocol 1 (**m**) and protocol 2 (**n**), *n* = 8 mice. **o** Interaction time in the testing phase of the task with two protocols, *n* = 8 mice. **p** Discrimination index in the testing phase of the task with two protocols, *n* = 8 mice, pro., protocol.



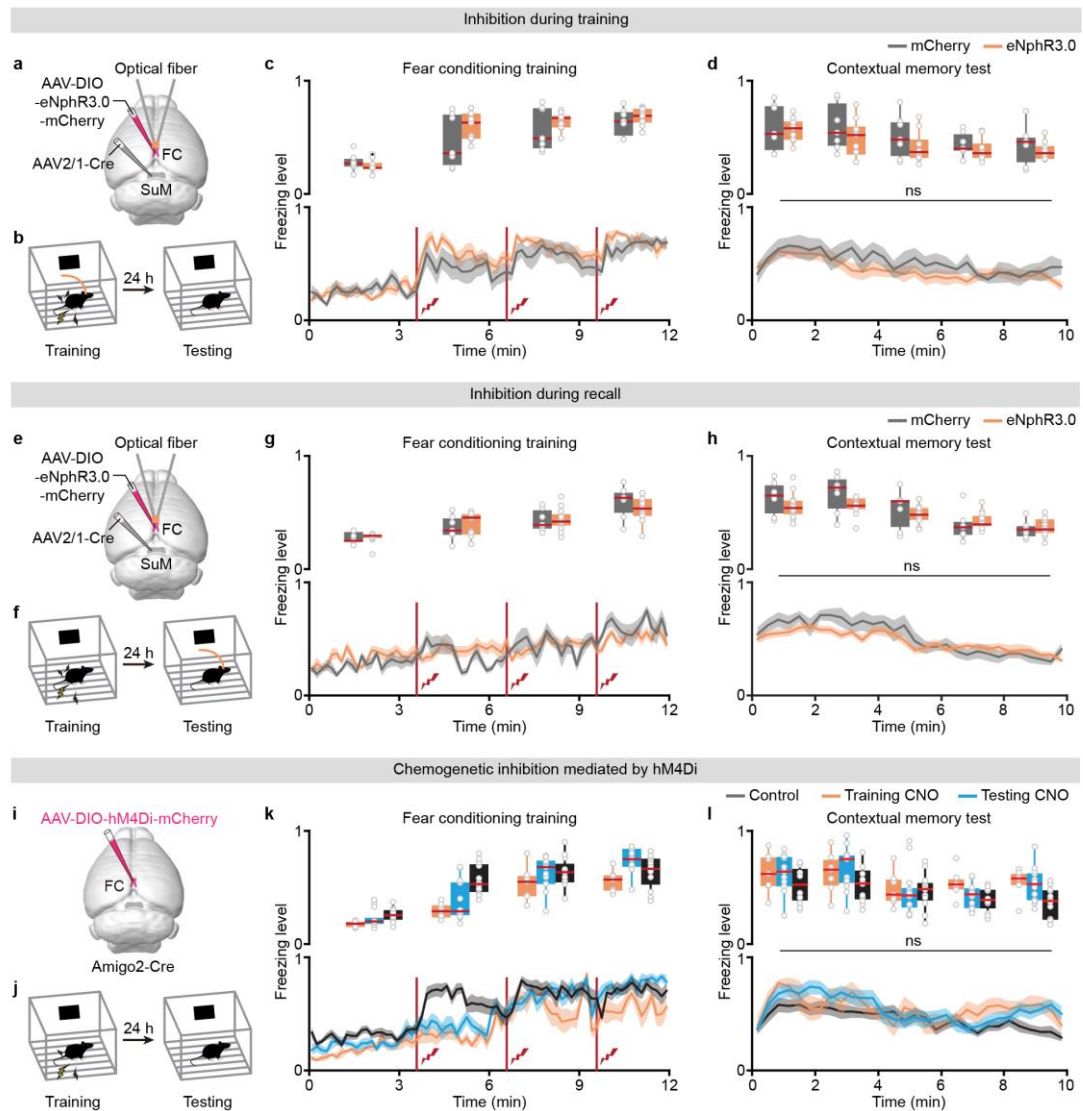
Supplementary figure 3 Contextual fear memory was not affected by silencing of SuM-FC projections during either training or recall. a,b Freezing levels during training (**a**) and testing (**b**) phases when SuM-FC projections were silenced during the training phase. RMs 2-way ANOVA test; mCherry, $n = 10$, eNphR3.0, $n = 13$. **c,d** Freezing levels during training (**c**) and testing (**d**) phases when SuM-FC projections were silenced during the recall phase. RMs 2-way ANOVA test; mCherry, $n = 8$, eNphR3.0, $n = 11$.



Supplementary figure 4 Object recognition memory was not affected by silencing of SuM-FC axonal projections. **a,b** Diagram of virus injection in SuM and fiber implantation in FC, and the protocol for object recognition memory task and optogenetic silencing during training. **c,d** Summary of the interaction time in eNphR3.0 and mCherry groups during training (**c**) and testing (**d**) phases of the object recognition task. Paired *t* test, mCherry group, *n* = 10, eNpHR3.0, *n* = 13. **e** Summary of the discrimination index in training and testing phases of the object recognition task. Unpaired *t* test, mCherry group, *n* = 10, eNpHR3.0 group, *n* = 13.

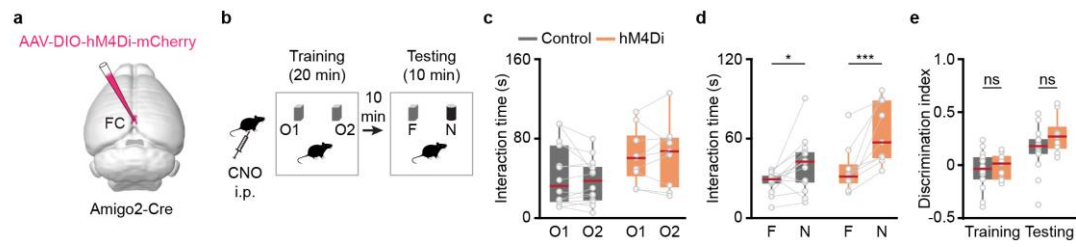


Supplementary figure 5 Social memory recall was impaired by activation of FC^{SuM} recipient neurons. **a** Diagram illustrating labeling of FC^{SuM} recipient neurons with ChR2 and fiber implantation in FC. **b** Social interaction episodes in the control (black), training activation group (blue), and testing activation group (yellow); the corresponding social proportion over time is shown above. **c,d** Summary of the interaction time (**c**) and discrimination index (**d**) across the task. RMs 2-way ANOVA with LSD post-hoc test, control group, $n = 7$ mice; training activation group, $n = 7$ mice; testing activation group, $n = 8$ mice.

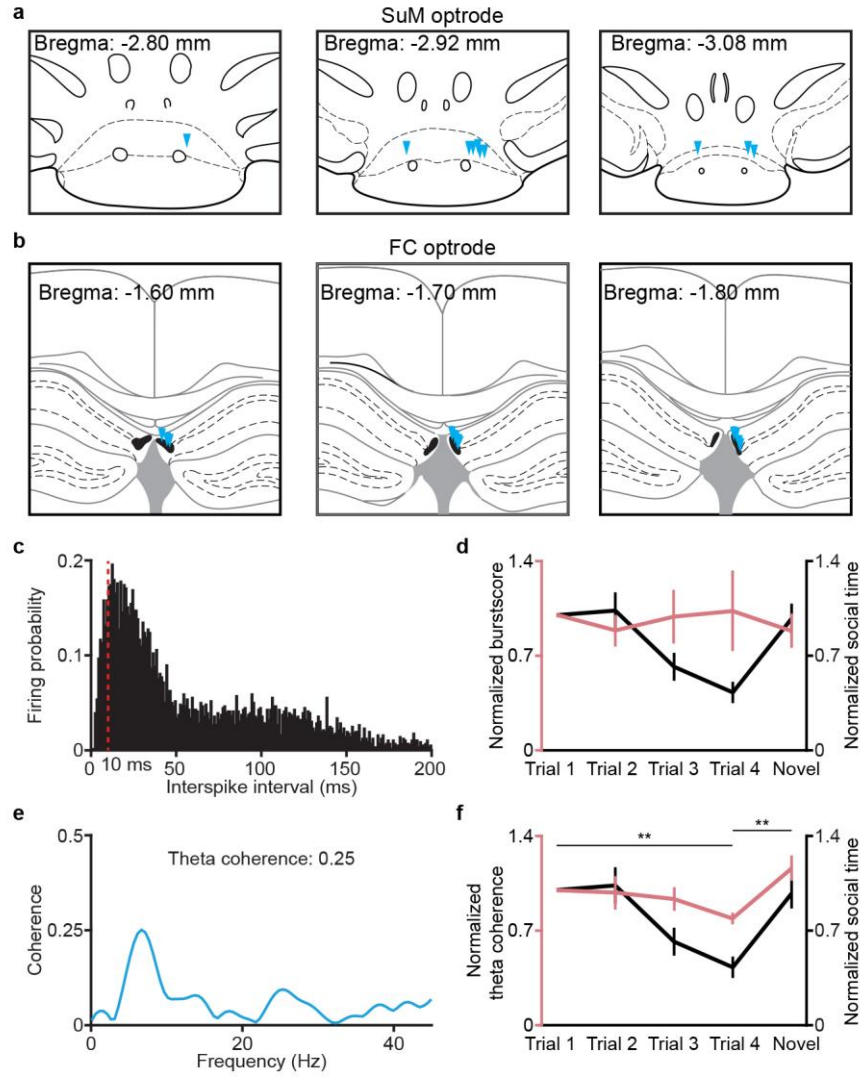


Supplementary figure 6 Contextual fear memory was not affected by silencing of FC^{SuM} recipient and FC^{Amigo2} neurons during either training or recall. **a,b** Diagram showing labeling of FC^{SuM} recipient neurons and fiber implantation in FC, and protocol for contextual fear conditioning and optogenetic inhibition during training. **c,d** Freezing levels during training (**c**) and testing (**d**) phases when FC^{SuM} recipient neurons were silenced during the training phase. RMs 2-way ANOVA test; mCherry, $n = 7$, eNphR3.0, $n = 9$. **e,f** Diagram showing labeling of FC^{SuM} recipient neurons and fiber implantation in FC, and protocol for contextual fear conditioning and optogenetic inhibition during testing. **g,h** Freezing levels during training (**g**) and testing (**h**) phases when FC^{SuM} recipient neurons were silenced during the recall phase. RMs 2-way ANOVA test; mCherry, $n = 7$, eNphR3.0, $n = 12$. **i,j** Diagram showing labeling of FC^{Amigo2} neurons with hM4Di, and protocol for contextual fear conditioning. **k,l** Freezing levels during training (**k**) and testing (**l**) phases when FC^{Amigo2} neurons were silenced by CNO i.p. injection during the training

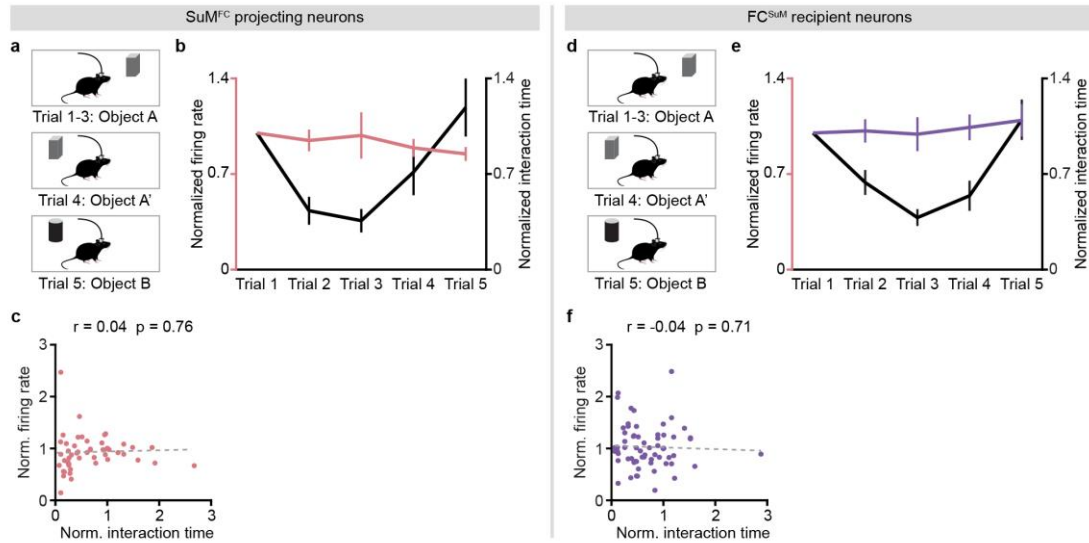
(orange traces) or recall phase (blue traces). RMs 2-way ANOVA test; control, $n = 12$, training CNO, $n = 7$, testing CNO, $n = 13$.



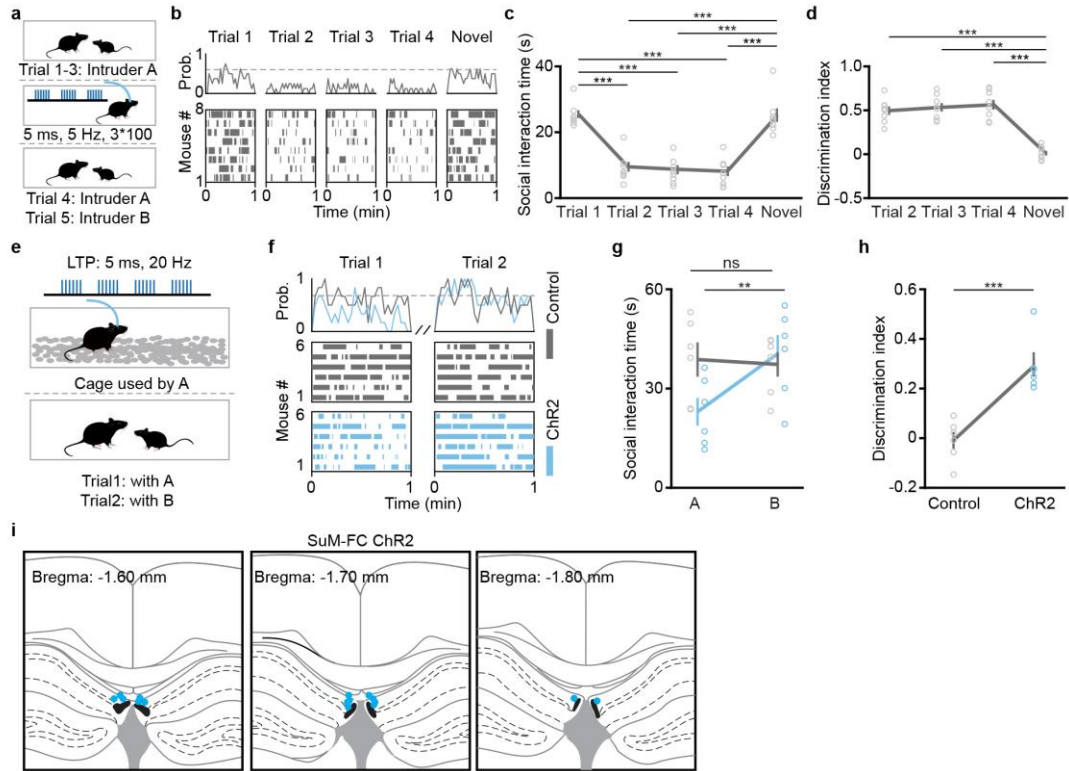
Supplementary figure 7 Object recognition memory was not affected by silencing of FC^{Amigo} neurons. **a,b** Diagram of virus injection in FC of Amigo2-Cre mice, and the protocol for object recognition memory task and chemogenetic silencing. **c,d** Summary of the interaction time in hM4Di and mCherry groups during training (**c**) and testing (**d**) phases of the object recognition task. Paired *t* test, mCherry group, *n* = 14, hM4Di, *n* = 9. **e** Summary of the discrimination index in training and testing phases of the object recognition task. Unpaired *t* test, mCherry group, *n* = 14, hM4Di group, *n* = 9.



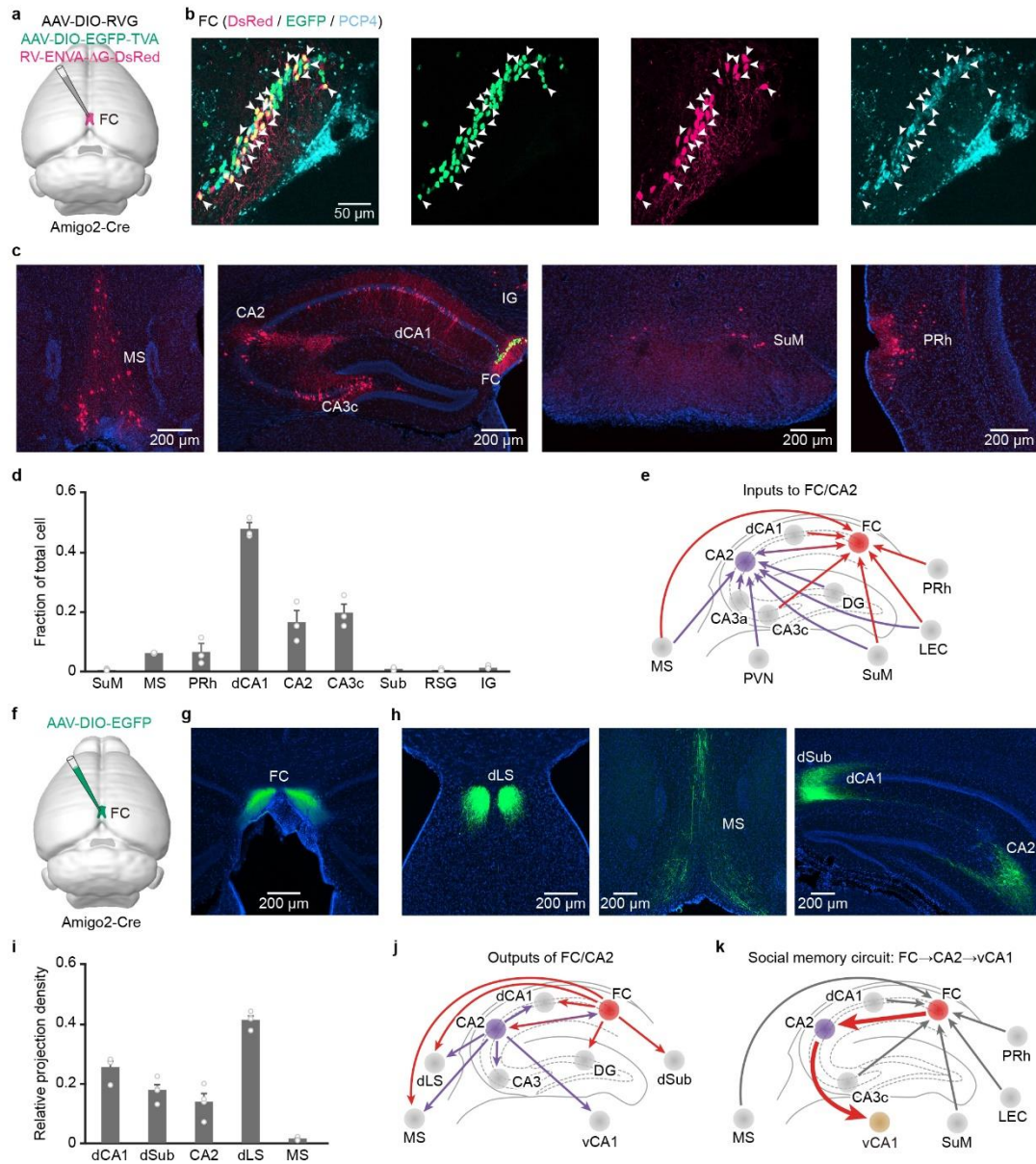
Supplementary figure 8 Tetrode locations, and theta phase-locking and burst score of SuM^{FC} projecting neurons during increasing familiarity with a conspecific. a,b Tetrode locations for recordings of SuM^{FC} projecting (a, n = 10 mice) FC^{SuM} recipient (b, n = 10 mice) neurons. **c** Distribution of interspike intervals of a SuM^{FC} projecting neuron during social test, the red dashed line representing the time point of 10 ms. **d** Summary of the normalized burstscore of SuM^{FC} projecting (orange trace; n = 11, RMs 1-way ANOVA) neurons, and the corresponding normalized social interaction time (black). **e** Quantification of the theta related firing for a SuM^{FC} projecting neuron by spike-field coherence. **f** Summary of the normalized theta coherence of SuM^{FC} projecting (orange trace; n = 11, RMs 1-way ANOVA) neurons, and the corresponding normalized social interaction time (black).



Supplementary figure 9 The firing rates of SuM^{FC} projecting and FC^{SuM} recipient neurons remained unchanged in object recognition task. **a,d** Behavioral paradigm for neural recordings during the object recognition task. **b,e** Summary of the normalized firing rate of SuM^{FC} projecting (**b**, orange trace; $n = 16$, RMs 1-way ANOVA) and FC^{SuM} recipient (**e**, purple trace; $n = 12$, RMs 1-way ANOVA) neurons, and the corresponding normalized object interaction time (black, RMs 1-way ANOVA with LSD post hoc comparison; B, $n = 12$ trials; E, $n = 11$ trials). **c,f** Correlational analysis between normalized firing rate and normalized object interaction time for SuM^{FC} projecting (**c**, Pearson correlation test, $r = 0.04$, $P = 0.76$, $n = 16$ neurons from 9 mice) and FC^{SuM} recipient (**f**, Pearson correlation test, $r = -0.04$, $P = 0.71$, $n = 12$ neurons from 9 mice) neurons.

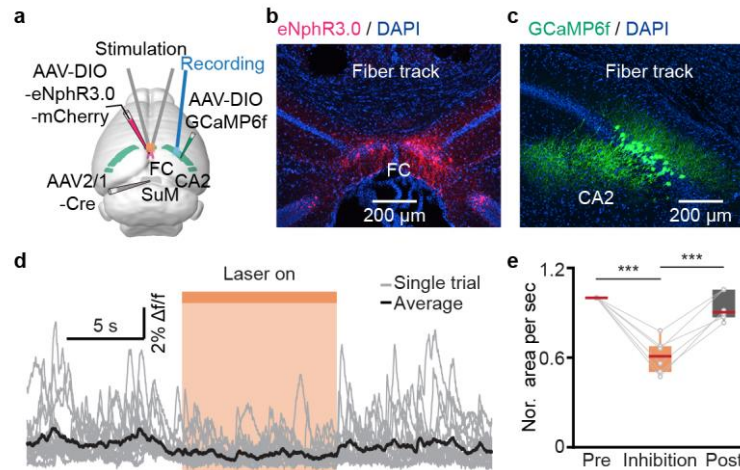


Supplementary figure 10 Synaptic potentiation at SuM-FC synapses promotes social memory formation. **a** Protocol for the 5-Hz stimulation control group in 5-trial social memory test: 5 Hz with 20-s intervals; 100 trains per session for 3 sessions. **b** Social interaction episodes in the 5-Hz stimulation control group, and the corresponding social proportion across time (top). **c,d** Summary of the interaction time (**c**) and discrimination index (**d**) across the task. RMs 1-way ANOVA with LSD post-hoc test, $n = 8$ mice. **e** Schematic of the social memory testing protocol following optogenetic LTP induction. **f** Social interaction episodes in the control (black, middle; social interaction time for each mouse) or LTP group (blue, bottom; social interaction time for each mouse), and summary of social interaction time for each group (top). **g,h** Summary of the interaction time (**g**) and discrimination index (**h**) across the task. Paired t -test, control group, $n = 6$ mice; LTP group, $n = 6$ mice. ** $P < 0.01$, *** $P < 0.001$. **i** The fiber tip positions in the LTD experiments, $n = 8$ mice.



Supplementary figure 11 Inputs and outputs of the FC and CA2. **a** Schematic of retrograde tracing strategy for labeling FC inputs using rabies virus. AAV helper viruses encoding the rabies G protein and TVA receptor were injected into the FC of Amigo2-Cre mice. Three weeks later, RV-DIO-ENVA-ΔG expressing DsRed was injected into the FC region. These experiments were performed in three mice. **b** Coronal section showing starter cells in FC co-labeled with PCP4 immunofluorescence. **c** Representative images of coronal sections illustrating trans-synaptically labeled upstream input neurons. **d** Summary of inputs to FC Amigo2⁺ neurons, n = 3 mice. **e** Summary schematics outlining the major inputs of the FC/CA2 regions. **f** Schematic of resulting FC neuron labeling following AAV-DIO-EGFP injection into the FC of Amigo2-Cre mice. These experiments were performed in four mice. **g** Image showing EGFP expression in FC neurons. **h** Representative brain sections depicting axonal projections of FC neurons. **i** Summary of projections from FC Amigo2⁺ neurons, n = 4 mice. **j** Summary schematics outlining the major outputs of the FC/CA2 regions. **k** Summary schematic of the hippocampal circuits implicated in social memory, with red arrows denoting the flow of social information. DG,

dentate gyrus; MS, medial septum; PRh, perirhinal cortex; LEC, lateral entorhinal cortex; dLS, dorsal lateral septum; dSub, dorsal subiculum.



Supplementary figure 12 Inhibition of FC^{SuM} recipient neurons reduces Ca²⁺ activity in CA2 neurons. **a** Experimental design for anterograde labelling of FC^{SuM} recipient neurons by eNphR3.0-mCherry, anterograde labelling of CA2^{SuM} recipient neurons by GCaMP6f, fiber implantation above FC, and Ca²⁺ recording in CA2. **b** Representative image of mCherry-labeled FC^{SuM} recipient neurons and fiber tracks in FC. **c** Representative image of GCaMP-labeled CA2^{SuM} recipient neurons and fiber track in CA2. **d** Example traces of Ca²⁺ signals in CA2 with or without 594-nm light stimulation in FC from one mouse; gray lines represent individual trials, and the black line indicates the average. **e** Summary of Ca²⁺ signals before (pre), during, and after (post) photoinhibition. The area under the Ca²⁺ signal curve per second was normalized to that before light inhibition; RMs 1-way ANOVA with LSD post-hoc test, *n* = 6 mice.