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Main Figures: 7

Supplementary Figures: 13

Supplementary Tables: 0

Supplementary Videos: 4

Reporting Checklist for Nature Neuroscience

This checklist is used to ensure good reporting standards and to improve the reproducibility of published results. For more information, please read Reporting Life Sciences Research.

Please note that in the event of publication, it is mandatory that authors include all relevant methodological and statistical information in the manuscript.

Statistics reporting, by figure

- Please specify the following information for each panel reporting quantitative data, and where each item is reported (section, e.g. Results, & paragraph number).
- Each figure legend should ideally contain an exact sample size (n) for each experimental group/condition, where n is an exact number and not a range, a clear definition of how n is defined (for example x cells from x slices from x animals from x litters, collected over x days), a description of the statistical test used, the results of the tests, any descriptive statistics and clearly defined error bars if applicable.
- For any experiments using custom statistics, please indicate the test used and stats obtained for each experiment.
- Each figure legend should include a statement of how many times the experiment shown was replicated in the lab; the details of sample collection should be sufficiently clear so that the replicability of the experiment is obvious to the reader.
- For experiments reported in the text but not in the figures, please use the paragraph number instead of the figure number.

Note: Mean and standard deviation are not appropriate on small samples, and plotting independent data points is usually more informative. When technical replicates are reported, error and significance measures reflect the experimental variability and not the variability of the biological process; it is misleading not to state this clearly.

		TEST USED		n			DESCRIPTIVE STATS (AVERAGE, VARIANCE)		P VALUE		DEGREES OF FREEDOM & F/t/z/R/ETC VALUE	
	FIGURE NUMBER	WHICH TEST?	SECTION & PARAGRAPH #	EXACT VALUE	DEFINED?	SECTION & PARAGRAPH #	REPORTED?	SECTION & PARAGRAPH #	EXACT VALUE	SECTION & PARAGRAPH #	VALUE	SECTION & PARAGRAPH #
example	1a	one-way ANOVA	Fig. legend	9, 9, 10, 15	mice from at least 3 litters/group	Methods para 8	error bars are mean +/- SEM	Fig. legend	p = 0.044	Fig. legend	F(3, 36) = 2.97	Fig. legend
example	results, para 6	unpaired t-test	Results para 6	15	slices from 10 mice	Results para 6	error bars are mean +/- SEM	Results para 6	p = 0.0006	Results para 6	t(28) = 2.808	Results para 6
+ -												

		TEST USED		n			DESCRIPTIVE STATS (AVERAGE, VARIANCE)		P VALUE		DEGREES OF FREEDOM & F/t/z/R/ETC VALUE	
	FIGURE NUMBER	WHICH TEST?	SECTION & PARAGRAPH #	EXACT VALUE	DEFINED?	SECTION & PARAGRAPH #	REPORTED?	SECTION & PARAGRAPH #	EXACT VALUE	SECTION & PARAGRAPH #	VALUE	SECTION & PARAGRAPH #
+ -	1C	correlation	results para 2	40	binned lick rate and binned spike rate	results para 2	no		1.53e-19	results para 2	r (38)= 0.94	results para 2
+ -	1f	correlation	results para 3	40	binned lick rate and binned spike rate	results para 2	no		8.38e-15	results para 3	r (38) = -0.89	results para 3
+ -	2d	Chi square	results para 4	87 SNR units; 74 SC units	units recorded from 6 mice (SNR) and 4 mice (SC)	Methods para 1 and results para 4	no		1.9e10-5	results para 4	$\chi 2$ (1) = 18.31	results para 4
+ -	2e	Chi square	Results para 5	87 SNR units; 74 SC units	units recorded from 6 mice (SNR) and 4 mice (SC)	Methods para 1 and results para 5	no		9.2e-7	results para 5	$\chi 2$ (1) = 24.08	results para 5
+ -	S4b	one-way ANOVA	Fig. legend	14	14 hemispheres from 7 mice	Fig legend	error bars are mean +/- sem	Fig legend	6.36e-5	fig legend	f (2,26) = 22.24	fig legend
+ -	5h	one-way ANOVA	results para 11	7	mice	fig legend	error bars are mean +/- sem	fig legend	5.42e-10	fig legend and results para 11	f (6, 36) = 19.55	results para 11
+ -	6h	one way anova	results para 16	3	mice	results para 13 and Fig legend	error bars are mean +/- sem	fig legend	0.0035	results para 16	f (6, 12) = 6.29	results para 16
+ -	6i	one way anova	results para 16	135	single units from 3 mice and 7 stimulation conditions	Fig legend	error bars are mean +/- sem	fig legend	7.12e-7	results para 16 and fig legend	f (6, 134) = 7.37	results para 16
+ -	7b	paired t test	results para 16	11	light responsive units from 3 mice. planned comparison pre vs stim and stim vs post	results para 16	error bars are mean +/- sem; individual data points are overlayed	fig legend	2.19e-13 7.93e-7	results para 16 and fig legend	t (10) = 50.62 t (10) = 10.78	results para 16
+ -	7f	t test	fig legend	36	trials from one mouse	fig legend	error bars are mean +/- sem	fig legend	0.0005	fig legend	t (34) = 3.85	fig legend
+ -	7i	t test with welch's correction for unequal variance	fig legend	36	trails from one mouse	fig legend	error bars are mean +/- sem	fig legend	5.31e-7	fig legend	t (31) = 6.27	fig legend
+ -	S1e	Mann-Whitney U	Results para 2	25	testing sessions from 6 mice (SNR) and 4 mice (SC)	Fig legend	error bars are mean +/- sem	fig legend	0.5287	Fig legend	U = 65.00	Fig legend
+ -	S1f	Mann-Whitney U	Results para 2	25	testing sessions from 6 mice (SNR) and 4 mice (SC)	Fig Legend	error bars are mean +/- sem	fig legend	0.3823	Fig Legend	U = 72.50	Fig legend
+ -	S5a	one way anova	fig legend	7	mice	fig legend	error bars are mean +/- sem	fig legend	0.2071	fig legend	f (6,36) = 1.50	fig legend
+ -	S5b	one way anova	fig legend	7	mice	fig legend	error bars are mean +/- sem	fig legend	0.0002	fig legend	f (6,36) = 5.91	fig legend

+ -	S5c	one way anova	fig legend	7	mice	fig legend	error bars are mean +/- sem	fig legend	0.0437	fig legend	f (6,36) = 2.45	fig legend
+ -	S5f	two-way ANOVA	fig legend	7	mice, 7 stimulation conditions per mouse	fig legend	error bars are mean +/- sem	fig legend	6.90e-6; 7.62e-5; 0.0031	fig legend	main effect of Frequency F(6,42) = 8.18; main effect of Motivation F(1,42) = 19.23; interaction between Frequency and Motivation F(6,42) = 3.97	fig legend
+ -	S6b	one way anova	fig legend	6	mice	Fig legend	error bars are mean +/- sem	fig legend	0.18	fig legend	f (6,30) = 1.59	fig legend
+ -	S7c	two way anova	fig legend	11	mice from two groups (7 ChR2, 4 eYFP)	Fig legend	error bars are mean +/- sem	fig legend	0.13; 0.20; 0.59	fig legend	no main effect of Group, F(1,36) = 2.66; no main effect of Frequency, F(4,36) = 1.56; no interaction between Group and Frequency F(4,36) = 0.71	fig legend
+ -	S11b	one way anova	fig legend	18	single units from 3 mice	fig legend	error bars are mean +/- sem	fig legend	5.36e-8	fig legend	F (6,102) = 9.14	fig legend
+ -	S3d	t-test	fig legend	12	mice from two groups (6 sham, 6 lesion)	fig legend	error bars are mean +/- sem	fig legend	0.45	fig legend	t (10) = 0.79	fig legend
+ -	S3e	t-test	fig legend	12	mice from two groups (6 sham, 6 lesion)	fig legend	error bars are mean +/- sem	fig legend	0.02	fig legend	t (10) = 2.77	fig legend
+ -	S5d	one way anova	fig legend	7	mice	fig legend	error bars are mean +/- sem	fig legend	0.36	fig legend	F (6,36) = 1.13	fig legend
+ -	S5e	one way anova	fig legend	7	mice	fig legend	error bars are mean +/- sem	fig legend	0.0045	fig legend	F (6,36) = 3.86	fig legend
+ -	S10b	one way anova	fig legend	6	mice	fig legend	error bars are mean +/- sem	fig legend	0.06	fig legend	F (6,30) = 2.26	fig legend
+ -	S10e	one way anova	fig legend	5	mice	fig legend	error bars are mean +/- sem	fig legend	0.23	fig legend	F (6,24) = 1.46	fig legend
+ -	S13h	Mann-Whitney U	fig legend	72	neurons from 3 mice in 7 conditions (BL=28, 3Hz=8, 10Hz=8, 50Hz=8, 100Hz=8, 1s On =7, 2s On =5)	fig legend	error bars are mean +/- sem	fig legend	BL vs. 3Hz: 0.66; BL vs. 10Hz: 0.09; BL vs. 50Hz: 0.56; BL vs. 100Hz: 0.02; BL vs. 1s On: 0.02; BL vs 2s On: 0.90	fig legend	BL vs. 3Hz: U=100 BL vs. 10Hz: U=67; BL vs. 50Hz: U=96; BL vs. 100Hz: U=52; BL vs. 1s On: U=42; BL vs 2s On: U=67	fig legend
+ -	S13k	Chi square	fig legend	40	neurons from two conditions (BL=20, Stim=20)	fig legend	n/a	n/a	0.03	fig legend	$\chi 2$ (1) = 4.91	fig legend
+ -	3c	one-way ANOVA	Results para. 7	4	Mice, three conditions each	fig legend	error bars are mean +/- sem	fig legend	0.019	Results para. 7	F (2,6) = 8.24	results para. 7
+ -	3d	two way anova (Time x Dose)	fig legend	4	Mice, three conditions each	fig legend	error bars are mean +/- sem	fig legend	0.0007, 1.53e-4, 0.33	fig legend	main effect of Time F(7,48) = 3.75; main effect of Dose, F(2,48) = 12.95; no interaction F(14,48) = 1.16	fig legend
+ -	3e	one way anova	results para 7	3	Mice, three conditions each	results para. 7	error bars are mean +/- sem	fig legend	0.008	results para. 7	f (2,8) = 20.42	results para. 7

+ -	3f	one way anova	results para. 7	3	Mice, three conditions each	results para. 7	error bars are mean +/- sem	fig legend	0.41	results para. 7	f (2,8) = 1.12	results para. 7
+ -	S8b	two way anova (group x frequency	fig legend	8	mice from two groups (n=5 chr2, n=3 control)	fig legend	error bars are mean +/- sem	fig legend	0.0013; 0.0256; 0.1726.	fig legend	main effect of Group, F (1, 30) = 32.42, p = 0.0013; main effect of Stimulation Frequency, F (5, 30) = 3.01, p = 0.0256; no interaction between Group and Stimulation Frequency, F (5, 30) = 1.669, p = 0.1726.	fig legend
+ -	S8c	two way anova (group x frequency	fig legend	8	mice from two groups (n=5 chr2, n=3 control)	fig legend	error bars are mean +/- sem	fig legend	0.4203; 0.065; 0.2542	fig legend	no main effect of Group, F (1, 30) = 0.7483, p = 0.4203; no main effect of Stimulation Frequency, F (5, 30) = 2.35, p = 0.065; no interaction between Group and Stimulation Frequency, F (5, 30) = 1.395, p = 0.2542.	fig legend
+ -	S8d	two way anova (group x frequency	fig legend	8	mice from two groups (n=5 chr2, n=3 control)	fig legend	error bars are mean +/- sem	fig legend	0.5594; 0.9175; 0.7694	fig legend	no main effect of Group, F (1, 30) = 0.3818, p = 0.5594; no main effect of Stimulation Frequency, F (5, 30) = 0.2852, p = 0.9175; no interaction between Group and Stimulation Frequency, F (5, 30) = 0.5059, p = 0.7694.	fig legend

Representative figures

1. Are any representative images shown (including Western blots and immunohistochemistry/staining) in the paper?

   If so, what figure(s)?

   yes
   Fig. 4; 6b,d-g; S1a,b; S3a; S9a

2. For each representative image, is there a clear statement of how many times this experiment was successfully repeated and a discussion of any limitations in repeatability?

   If so, where is this reported (section, paragraph #)?

   yes, in corresponding figure legends

Statistics and general methods

1. Is there a justification of the sample size? If so, how was it justified? Where (section, paragraph #)? Even if no sample size calculation was performed, authors should report why the sample size is adequate to measure their effect size.	no
2. Are statistical tests justified as appropriate for every figure? Where (section, paragraph #)?	yes, Results paragraphs 1-17 and figure legends
a. If there is a section summarizing the statistical methods in the methods, is the statistical test for each experiment clearly defined?	yes, para 27
b. Do the data meet the assumptions of the specific statistical test you chose (e.g. normality for a parametric test)? Where is this described (section, paragraph #)?	Data were assumed to be normal but this was not formally tested. Methods para 27
c. Is there any estimate of variance within each group of data? Is the variance similar between groups that are being statistically compared? Where is this described (section, paragraph #)?	Yes, results para 2 and methods para 27
d. Are tests specified as one- or two-sided?	yes, all tests are two-sided
e. Are there adjustments for multiple comparisons?	yes
3. Are criteria for excluding data points reported? Was this criterion established prior to data collection? Where is this described (section, paragraph #)?	no, all data were included
4. Define the method of randomization used to assign subjects (or samples) to the experimental groups and to collect and process data. If no randomization was used, state so. Where does this appear (section, paragraph #)?	Mice were randomly assigned to either ChR2 or eYFP groups for optogenetics experiments. Methods paragraph 2. Mice were randomly assigned to either Lesion or Sham groups for SC lesion experiment. Methods paragraph 7. Drug order was randomized for Fig 3. Methods para 15. Optogenetic stimulation was randomized between mice. methods para. 19

5. Is a statement of the extent to which investigator knew the group allocation during the experiment and in assessing outcome included? If no blinding was done, state so. Where (section, paragraph #)?	motion tracking experiments, and headfix behavior scoring were performed by researchers blinded to group identity. All other data collection and analysis were not performed blind to the conditions of the experiments. methods para 23
6. For experiments in live vertebrates, is a statement of compliance with ethical guidelines/regulations included? Where (section, paragraph #)?	yes, methods para 1
7. Is the species of the animals used reported? Where (section, paragraph #)?	yes, methods para 1
8. Is the strain of the animals (including background strains of KO/ transgenic animals used) reported? Where (section, paragraph #)?	yes, methods para 1
9. Is the sex of the animals/subjects used reported? Where (section, paragraph #)?	yes, methods para 1
10. Is the age of the animals/subjects reported? Where (section, paragraph #)?	yes, methods para 1
11. For animals housed in a vivarium, is the light/dark cycle reported? Where (section, paragraph #)?	yes, methods para 1
12. For animals housed in a vivarium, is the housing group (i.e. number of animals per cage) reported? Where (section, paragraph #)?	yes, methods para 3-7
13. For behavioral experiments, is the time of day reported (e.g. light or dark cycle)? Where (section, paragraph #)?	yes, methods para 1
14. Is the previous history of the animals/subjects (e.g. prior drug administration, surgery, behavioral testing) reported? Where (section, paragraph #)?	yes, methods para 1
a. If multiple behavioral tests were conducted in the same group of animals, is this reported? Where (section, paragraph #)?	yes, methods para 12,16
15. If any animals/subjects were excluded from analysis, is this reported? Where (section, paragraph #)?	none were excluded

a. How were the criteria for exclusion defined?

Where is this described (section, paragraph #)?

n/a

b. Specify reasons for any discrepancy between the number of animals at the beginning and end of the study.

Where is this described (section, paragraph #)?

n/a

Reagents

1. Have antibodies been validated for use in the system under study (assay and species)?

yes

a. Is antibody catalog number given?

Where does this appear (section, paragraph #)?

yes, methods para 16

b. Where were the validation data reported (citation, supplementary information, Antibodypedia)?

Where does this appear (section, paragraph #)?

antibodies were validated in the manuscript

2. If cell lines were used to reflect the properties of a particular tissue or disease state, is their source identified?

Where (section, paragraph #)?

n/a

a. Were they recently authenticated?

Where is this information reported (section, paragraph #)?

n/a

Data deposition

Data deposition in a public repository is mandatory for:

a. Protein, DNA and RNA sequences
b. Macromolecular structures
c. Crystallographic data for small molecules
d. Microarray data

Deposition is strongly recommended for many other datasets for which structured public repositories exist; more details on our data policy are available here. We encourage the provision of other source data in supplementary information or in unstructured repositories such as Figshare and Dryad.

We encourage publication of Data Descriptors (see Scientific Data) to maximize data reuse.

1. Are accession codes for deposit dates provided?

Where (section, paragraph #)?

n/a

Computer code/software

Any custom algorithm/software that is central to the methods must be supplied by the authors in a usable and readable form for readers at the time of publication. However, referees may ask for this information at any time during the review process.

1. Identify all custom software or scripts that were required to conduct the study and where in the procedures each was used.

Custom matlab and labview codes were used to control the laser and trigger stimulation when mice contacted the lick spout (Figs. 5-7).

2. If computer code was used to generate results that are central to the paper's conclusions, include a statement in the Methods section under "**Code availability**" to indicate whether and how the code can be accessed. Include version information as necessary and any restrictions on availability.

Matlab and Labview codes for controlling laser and triggering stimulation when mice contact lick spout are available upon request.

Human subjects

1. Which IRB approved the protocol?

   Where is this stated (section, paragraph #)?

n/a

2. Is demographic information on all subjects provided?

   Where (section, paragraph #)?

n/a

3. Is the number of human subjects, their age and sex clearly defined?

   Where (section, paragraph #)?

n/a

4. Are the inclusion and exclusion criteria (if any) clearly specified?

   Where (section, paragraph #)?

n/a

5. How well were the groups matched?

   Where is this information described (section, paragraph #)?

n/a

6. Is a statement included confirming that informed consent was obtained from all subjects?

   Where (section, paragraph #)?

n/a

7. For publication of patient photos, is a statement included confirming that consent to publish was obtained?

   Where (section, paragraph #)?

n/a

fMRI studies

For papers reporting functional imaging (fMRI) results please ensure that these minimal reporting guidelines are met and that all this information is clearly provided in the methods:

1. Were any subjects scanned but then rejected for the analysis after the data was collected? — n/a

    a. If yes, is the number rejected and reasons for rejection described? — n/a

    Where (section, paragraph #)?

2. Is the number of blocks, trials or experimental units per session and/or subjects specified? — n/a

    Where (section, paragraph #)?

3. Is the length of each trial and interval between trials specified? — n/a

4. Is a blocked, event-related, or mixed design being used? If applicable, please specify the block length or how the event-related or mixed design was optimized. — n/a

5. Is the task design clearly described? — n/a

    Where (section, paragraph #)?

6. How was behavioral performance measured? — n/a

7. Is an ANOVA or factorial design being used? — n/a

8. For data acquisition, is a whole brain scan used? — n/a

    If not, state area of acquisition.

    a. How was this region determined? — n/a

9. Is the field strength (in Tesla) of the MRI system stated? — n/a

    a. Is the pulse sequence type (gradient/spin echo, EPI/spiral) stated? — n/a

    b. Are the field-of-view, matrix size, slice thickness, and TE/TR/flip angle clearly stated? — n/a

10. Are the software and specific parameters (model/functions, smoothing kernel size if applicable, etc.) used for data processing and pre-processing clearly stated? — n/a

11. Is the coordinate space for the anatomical/functional imaging data clearly defined as subject/native space or standardized stereotaxic space, e.g., original Talairach, MNI305, ICBM152, etc? Where (section, paragraph #)?	n/a
12. If there was data normalization/standardization to a specific space template, are the type of transformation (linear vs. nonlinear) used and image types being transformed clearly described? Where (section, paragraph #)?	n/a
13. How were anatomical locations determined, e.g., via an automated labeling algorithm (AAL), standardized coordinate database (Talairach daemon), probabilistic atlases, etc.?	n/a
14. Were any additional regressors (behavioral covariates, motion etc) used?	n/a
15. Is the contrast construction clearly defined?	n/a
16. Is a mixed/random effects or fixed inference used?	n/a
a. If fixed effects inference used, is this justified?	n/a
17. Were repeated measures used (multiple measurements per subject)?	n/a
a. If so, are the method to account for within subject correlation and the assumptions made about variance clearly stated?	n/a
18. If the threshold used for inference and visualization in figures varies, is this clearly stated?	n/a
19. Are statistical inferences corrected for multiple comparisons?	n/a
a. If not, is this labeled as uncorrected?	n/a
20. Are the results based on an ROI (region of interest) analysis?	n/a
a. If so, is the rationale clearly described?	n/a
b. How were the ROI's defined (functional vs anatomical localization)?	n/a
21. Is there correction for multiple comparisons within each voxel?	n/a
22. For cluster-wise significance, is the cluster-defining threshold and the corrected significance level defined?	n/a

Additional comments

Additional Comments