

Reporting Summary

Nature Research wishes to improve the reproducibility of the work that we publish. This form provides structure for consistency and transparency in reporting. For further information on Nature Research policies, see our [Editorial Policies](#) and the [Editorial Policy Checklist](#).

Statistics

For all statistical analyses, confirm that the following items are present in the figure legend, table legend, main text, or Methods section.

n/a Confirmed

- ☐ ☒ The exact sample size (n) for each experimental group/condition, given as a discrete number and unit of measurement
- ☐ ☒ A statement on whether measurements were taken from distinct samples or whether the same sample was measured repeatedly
- ☐ ☒ The statistical test(s) used AND whether they are one- or two-sided
Only common tests should be described solely by name; describe more complex techniques in the Methods section.
- ☐ ☒ A description of all covariates tested
- ☐ ☒ A description of any assumptions or corrections, such as tests of normality and adjustment for multiple comparisons
- ☐ ☒ A full description of the statistical parameters including central tendency (e.g. means) or other basic estimates (e.g. regression coefficient) AND variation (e.g. standard deviation) or associated estimates of uncertainty (e.g. confidence intervals)
- ☐ ☒ For null hypothesis testing, the test statistic (e.g. F , t , r) with confidence intervals, effect sizes, degrees of freedom and P value noted
Give P values as exact values whenever suitable.
- ☒ ☐ For Bayesian analysis, information on the choice of priors and Markov chain Monte Carlo settings
- ☒ ☐ For hierarchical and complex designs, identification of the appropriate level for tests and full reporting of outcomes
- ☐ ☒ Estimates of effect sizes (e.g. Cohen's d , Pearson's r), indicating how they were calculated

Our web collection on [statistics for biologists](#) contains articles on many of the points above.

Software and code

Policy information about [availability of computer code](#)

Data collection	Microendoscopic imaging data was collected using an open source data acquisition software (https://github.com/Aharoni-Lab/Miniscope-DAQ-QT-Software). Fiber photometry data was collected using the Spike2 software (v10.09a).
Data analysis	Statistical analysis was conducted using Prism (v9, GraphPad), MATLAB (R2018a and R2019b, MathWorks), R (v3.4.3), and Python (v3.5.6). Code for behavioral analysis (https://github.com/pdollar/toolbox) and microendoscopic imaging data analysis (https://github.com/etterguillaume/MiniscopeAnalysis , https://github.com/zhoup/CNMF_E , and https://github.com/flatironinstitute/NoRMCorre) is available on GitHub. Animal pose tracking was performed using SLEAP (https://github.com/murthylab/sleap/releases/tag/v1.0.9). The pre-trained Google Inception v3 network is available at https://download.tensorflow.org/models/image/imagenet/inception-2015-12-05.tgz . Deep neural network training was performed using TensorFlow 1.11.

For manuscripts utilizing custom algorithms or software that are central to the research but not yet described in published literature, software must be made available to editors and reviewers. We strongly encourage code deposition in a community repository (e.g. GitHub). See the Nature Research [guidelines for submitting code & software](#) for further information.

Data

Policy information about [availability of data](#)

All manuscripts must include a [data availability statement](#). This statement should provide the following information, where applicable:

- Accession codes, unique identifiers, or web links for publicly available datasets
- A list of figures that have associated raw data
- A description of any restrictions on data availability

Source Data are provided for all figures. Additional data relating to the paper are available upon reasonable request to the corresponding author.

Field-specific reporting

Please select the one below that is the best fit for your research. If you are not sure, read the appropriate sections before making your selection.

☒ Life sciences ☐ Behavioural & social sciences ☐ Ecological, evolutionary & environmental sciences

For a reference copy of the document with all sections, see [nature.com/documents/nr-reporting-summary-flat.pdf](https://www.nature.com/documents/nr-reporting-summary-flat.pdf)

Life sciences study design

All studies must disclose on these points even when the disclosure is negative.

Sample size	Sample sizes were not predetermined using statistical methods. Sample sizes were chosen to reliably measure experimental effects while minimizing the number of animals used in accordance with ethical guidelines. Our sample sizes are similar to those used in previous publications in the field (e.g. Burkett et al. 2016, Science; Allsop et al. 2018, Cell; Hu et al. 2021, Nat Neurosci), and are deemed appropriate based on the size and statistical significance of the effects and consistency across animals.
Data exclusions	In fiber photometry experiments, calcium signal was examined prior to behavioral procedures and animals showing very few calcium transients and a low signal-to-noise ratio were not used. Post hoc histological examination showed that viral injection and/or fiber-optic implantation missed the target region in these animals. Exclusion criteria were pre-established.
Replication	All behavioral, imaging, and optogenetics experiments were replicated in multiple animals with similar results (see Supplementary Table 1 for exact numbers of animals and/or trials for each experiment). Example micrographs were based on at least three independent biological samples (animals or independently injected brain hemispheres) showing similar results.
Randomization	Animals of appropriate genotype, sex, age, and weight were randomly assigned to experimental or control group.
Blinding	Experimenters were not blind to group allocation during data acquisition or analysis. We ensured that control and experimental groups were tested using the same experimental conditions (except for the experimental treatments or manipulations) whenever necessary, and that data from control and experimental groups were analyzed using the same criteria and methods.

Reporting for specific materials, systems and methods

We require information from authors about some types of materials, experimental systems and methods used in many studies. Here, indicate whether each material, system or method listed is relevant to your study. If you are not sure if a list item applies to your research, read the appropriate section before selecting a response.

Materials & experimental systems

n/a	Involved in the study
☐	☒ Antibodies
☒	☐ Eukaryotic cell lines
☒	☐ Palaeontology and archaeology
☐	☒ Animals and other organisms
☒	☐ Human research participants
☒	☐ Clinical data
☒	☐ Dual use research of concern

Methods

n/a	Involved in the study
☒	☐ ChIP-seq
☒	☐ Flow cytometry
☒	☐ MRI-based neuroimaging

Antibodies

Antibodies used	1. Rabbit anti-GFP antibody (Invitrogen, Catalog # A-11122) 2. Donkey anti-rabbit IgG secondary antibody (Invitrogen, Catalog # A-21206)
Validation	1. Rabbit anti-GFP antibody – Validation statement from vendor: "Antibody specificity was demonstrated by detection of different targets fused to GFP tag in transiently transfected lysates tested. Relative detection of GFP tag was observed across different proteins fused with GFP in H3-GFP (Lane 3-5) and p65-GFP (Lane 6). GFP-variant, YFP is also being detected in His-p65-YFP lysate (Lane 7)." This antibody has been cited in at least 527 publications for immunohistochemistry according to the vendor's website. 2. Donkey anti-rabbit IgG secondary antibody – This antibody has been cited in at least 74 publications for immunohistochemistry according to the vendor's website.

Animals and other organisms

Policy information about [studies involving animals](#); [ARRIVE guidelines](#) recommended for reporting animal research

Laboratory animals	Mice strains used in this study include C57BL/6J, BALB/cJ, Vgat-Cre, Vgat-Flp, Tac1-Cre, Sst-Cre, and Cck-Cre. All strains were purchased from Jackson Laboratories (stock No: 000664, 000651, 028862, 029591, 021877, 013044, and 012706). Animals were
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housed in 12 h light-dark cycle (10 p.m. – 10 a.m. light), with food and water available ad libitum. The housing facility had a temperature of 21–23°C and a humidity of 30–70%. Both males and females were used for experiments. 12–16-week-old animals were used for characterization of prosocial interaction in wild-type animals. 10–12-week-old animals were used for stereotaxic surgeries and were tested in behavioral experiments after >4 weeks following surgeries.

Wild animals

No wild animals were used in this study.

Field-collected samples

No field-collected samples were used in this study.

Ethics oversight

Care and experimental manipulations of all animals were carried out in accordance with the NIH Guide for Care and Use of Laboratory Animals and approved by UCLA IACUC.

Note that full information on the approval of the study protocol must also be provided in the manuscript.