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Last updated by author(s): Jul 22, 2021

Reporting Summary

Nature Portfolio 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 Portfolio 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	Ethovision 13 (Noldus Information Technologies, Leesburg, VA) was used to record and quantify locomotion and exploration behaviours.
Data analysis	Ethovision 13, GraphPad Prism 9, and FED3 Viz (Python).

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 Portfolio 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 description of any restrictions on data availability
- For clinical datasets or third party data, please ensure that the statement adheres to our policy

The authors declare that the main data supporting the results in this study are available within the paper and its Supplementary Information. Source data for Fig. 3 and Extended Fig. 1 are provided with this paper. The data collected in the animal studies is available from the corresponding authors on reasonable request.

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

Life sciences study design

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

Sample size	The starting sample sizes selected were determined with G*Power3, on the basis of a power of 0.85, or estimated from published data (or, in some cases, from small pilot studies run for this purpose).
Data exclusions	Animals were excluded if any of these three conditions applied: 1) viral expression was not achieved at the target site; 2) the fibre-optic, µ-ILED device or microfluidic device were not in the targeted brain regions; or 3) there was indication from video or WNBN logs that stimulation did not occur.
Replication	All attempts at replication were successful.
Randomization	All animals were randomly assigned to test groups within a given treatment group.
Blinding	Investigators were blinded to each group during data collection and analysis. An exception was within-subject tests, where the experimenter knew that all animals received all treatments. In all cases, the experimenter was blind to the video analyses.

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	Chicken Anti-Tyrosine hydroxylase, Aves Labs, Cat#TH, AB_10013440 Rabbit anti-ChR2, American Research Products, Cat# 03-651180
Validation	From the supplier: Antibodies were analyzed by immunohistochemistry (at a concentration of 3 µg/mL) using fluorescein-labelled goat anti-chicken IgY (1:500 dilution, Aves Labs Cat.# F-1005) as the secondary reagent. We also validated this antibody in the following published papers: McCall, J. G. et al. CRH Engagement of the Locus Coeruleus Noradrenergic System Mediates Stress-Induced Anxiety. Neuron (2015) doi:10.1016/j.neuron.2015.07.002. Kim, T. et al. Injectable, cellular-scale optoelectronics with applications for wireless optogenetics. Science 340, 211–216 (2013).

Animals and other organisms

Policy information about studies involving animals; ARRIVE guidelines recommended for reporting animal research

Laboratory animals	Mice: C57BL/6J, DAT-IRES-Cre, Thy1-ChR2-YFP, Dbh-IRES-Cre, and AgRP-IRES-Cre crossed with Ai32 mice. Male and female mice, aged 3–6 months, were used for each experiment. Male Wistar rats, 2-months old.
Wild animals	The study did not involve wild animals.
Field-collected samples	The study did not involve samples collected from the field.

Ethics oversight	All mouse procedures were approved by the Animal Care and Use Committee of Washington University, and conformed to U.S. National Institutes of Health (NIH) guidelines. All rat procedures were approved by the University of Missouri Institutional Animal Care and Use Committee guidelines and approved protocols.

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