

## 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 [Authors & Referees](#) 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                                                                                                                                                                                                                                                                                      |
| <input type="checkbox"/>            | <input checked="" type="checkbox"/> The exact sample size ( $n$ ) for each experimental group/condition, given as a discrete number and unit of measurement                                                                                                                                    |
| <input type="checkbox"/>            | <input checked="" type="checkbox"/> A statement on whether measurements were taken from distinct samples or whether the same sample was measured repeatedly                                                                                                                                    |
| <input type="checkbox"/>            | <input checked="" type="checkbox"/> The statistical test(s) used AND whether they are one- or two-sided<br><i>Only common tests should be described solely by name; describe more complex techniques in the Methods section.</i>                                                               |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> A description of all covariates tested                                                                                                                                                                                                                                |
| <input type="checkbox"/>            | <input checked="" type="checkbox"/> A description of any assumptions or corrections, such as tests of normality and adjustment for multiple comparisons                                                                                                                                        |
| <input type="checkbox"/>            | <input checked="" type="checkbox"/> 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) |
| <input type="checkbox"/>            | <input checked="" type="checkbox"/> For null hypothesis testing, the test statistic (e.g. $F$ , $t$ , $r$ ) with confidence intervals, effect sizes, degrees of freedom and $P$ value noted<br><i>Give <math>P</math> values as exact values whenever suitable.</i>                            |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> For Bayesian analysis, information on the choice of priors and Markov chain Monte Carlo settings                                                                                                                                                                      |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> For hierarchical and complex designs, identification of the appropriate level for tests and full reporting of outcomes                                                                                                                                                |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> 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

Custom C & C++ (gcc 5.4.0) code (using OpenCV 3.1) was used for animal tracking and all the closed-loop control. Real-time visualization of 3D trajectories was done using gnuplot (5.2). Real-time behavior analysis was done using a custom programmed (Python 3) real-time version of DeepLabCut (1.0) software (Mathis et al. 2018). Electrophysiology recordings was acquired using Trodes software (1.8.1, SpikeGadgets). Custom Arduino (1.8.5) code was used to program the RECO-boxes.

#### Data analysis

All the analysis of tracking data, statistics and plots were done using R (3.4.4) software. Spike sorting was done using SpykingCircus (only one version exists). Analysis of tetrode position in the mouse lemur brain was done using Amira software (6.0.0).

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/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

All figure data is provided in the Supplementary Data section. The original raw data (videos, electrophysiological recordings, 3D trajectories) is available upon request. The MRI Atlas for mouse lemur is available at: <https://www.nitrc.org/projects/mouselemuratlans>.

## 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 size was not predetermined in this study for both mice and mouse lemurs. We used 4 mice in 3D arena and 6 mice for open-field arena for closed-loop experiments and 5 mice for optogenetics experiments to be able to perform statistical analysis on their performance. For the mouse lemur closed-loop experiments we only used one mouse lemur as a proof of principle that our system can produce same results with primates. For the social behavior analysis of mouse lemurs we used 3 mouse lemurs (2 male and 1 female) and run experiments with male-male and female-male mouse lemurs to be able to compare their social interaction. For the electrophysiology experiments we only recorded neuronal activity from two mouse lemurs.                                                                                                                                                                                                                                 |
| Data exclusions | We did not exclude any data.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| Replication     | We repeated experiments with multiple mice for place conditioning (N=4 for 3D arena, N=6 for 2D arena), behavior conditioning (N=4 for 3D arena, N=3 for open field), operant conditioning via wireless optogenetic stimulation (N=2) and tethered optogenetic stimulation (N=2 for place conditioning and N=3 for behavior conditioning) to demonstrate system's ability to reproduce the same data in different experimental conditions (multiple conditioned locations in both the 3D and open-field arena). The replication was successful as reported in Extended Data Figures 2-8 in addition to Figures 3-5. Additionally we performed the same conditioning experiments for one mouse lemur (2 different location for place conditioning and rearing for behavior conditioning) as a proof of principle that we can reproduce the same data with primates. The replication for place conditioning experiment in mouse lemur was successful as reported in Extended Data Fig 4. |
| Randomization   | We did not divide animals into different experimental groups.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| Blinding        | We did not perform any blinding since all the data acquisition and the pipeline for the analysis was automatically done.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |

## 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                                           |
|-------------------------------------|-----------------------------------------------------------------|
| <input type="checkbox"/>            | <input checked="" type="checkbox"/> Antibodies                  |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> Eukaryotic cell lines                  |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> Palaeontology                          |
| <input type="checkbox"/>            | <input checked="" type="checkbox"/> Animals and other organisms |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> Human research participants            |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> Clinical data                          |

### Methods

| n/a                                 | Involved in the study                           |
|-------------------------------------|-------------------------------------------------|
| <input checked="" type="checkbox"/> | <input type="checkbox"/> ChIP-seq               |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> Flow cytometry         |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> MRI-based neuroimaging |

## Antibodies

|                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Antibodies used | In this study, the following primary antibodies was used: rabbit polyclonal anti-Tyrosine Hydroxylase (1/500 dilution, abcam, ab6211). The following secondary antibodies was used: donkey polyclonal anti-rabbit 555 (Alexa Fluor - 1/500 dilution, abcam-ab150062).                                                                                                                                                                                                                                                                                          |
| Validation      | The antibodies used in the study were commercially available antibodies validated for IHC and WB experiments in rodents. For references of the primary antibody: <a href="https://www.abcam.com/tyrosine-hydroxylase-antibody-ab6211.html">https://www.abcam.com/tyrosine-hydroxylase-antibody-ab6211.html</a> and the secondary antibody: <a href="https://www.abcam.com/donkey-rabbit-igg-hl-alex-fluor-555-preadsorbed-ab150062.html">https://www.abcam.com/donkey-rabbit-igg-hl-alex-fluor-555-preadsorbed-ab150062.html</a> under the References section. |

## Animals and other organisms

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

|                    |                                                                                                                             |
|--------------------|-----------------------------------------------------------------------------------------------------------------------------|
| Laboratory animals | Mice used for all experiments in 3D arena were adult C57Bl/6J (N=4 mice; 2 males and 2 females; mice were 18, 18, 12 and 12 |
|--------------------|-----------------------------------------------------------------------------------------------------------------------------|

## Laboratory animals

weeks old during the experiment).

Mice used in the operant conditioning using optogenetic stimulation were adult DAT-iresCre mice (Slc6a3tm1.1(cre)Bkmn/J; tethered optogenetics; N=3 mice; 2 females and 1 male; mice were 13, 13 and 48 weeks old during experiment; wireless optogenetics; N=2 mice; both female; mice were 17 and 27 weeks old during experiment).

Mice used for experiments in open-field arena were adult C57Bl/6J (N=6 mice; 5 females and 1 male; mice were 29, 34, 34, 11, 11 and 26 weeks old during experiment).

4 adult grey mouse lemurs (*Microcebus murinus*) were used for this study. All mouse lemurs were born and raised in the "Mouse Lemur Platform" of the Museum of Natural History in Brunoy, France (N=4 mouse lemurs; 3 males and 1 female; mouse lemurs were 1.5, 3, 2.5 and 3 years old during experiment).

## Wild animals

No wild animals were used for this study.

## Field-collected samples

No field-collected samples were used for this study.

## Ethics oversight

The procedures with mouse lemurs are in accordance with European animal welfare regulations and were reviewed by the local ethics committee ("Comité d'éthique en expérimentation animale No. 68") in Brunoy, France, by the ethics committee of the University of Geneva, Switzerland, and authorized by the French "Ministère de l'éducation nationale de l'enseignement supérieur et de la recherche".

All experiments with mice were carried out in Geneva, Switzerland, and reviewed by the local ethics committee and authorities of the Geneva canton ("Institutional Animal Care and Use Committee of the University of Geneva and Geneva veterinary offices. ").

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