

## 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** Two-photon imaging was performed using Nikon-A1R (Nikon, Tokyo, Japan) and data were saved using NIC-Elements-AR software (Nikon, Tokyo, Japan). Widefield imaging was performed using MVX-10 (Olympus, Tokyo, Japan) equipped with Zyla4.2 sCMOS camera (Andor) and data were saved using NIC-Elements-AR software (Nikon, Tokyo, Japan).

**Data analysis** Data analysis were conducted using custom-written Matlab codes (MathWorks, Nattick, MA). A code used for the simulation is available on GitHub ([https://github.com/teppeimatsui/NN\\_Simulation](https://github.com/teppeimatsui/NN_Simulation)). Other codes are available from the corresponding authors upon reasonable requests.

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 datasets from this study are available from the corresponding authors upon 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](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	No statistics are used to predetermine the sample size, but the sample sizes are comparable to those of other reports in the field.
Data exclusions	Only field of views containing sufficiently large number of neurons with detectable calcium responses (both evoked and spontaneous) could be used in the present analyses. Therefore, data from field of views containing only small number of neurons (typically less than 100) were excluded.
Replication	Findings were replicated across multiple animals, imaged field of views and experiments.
Randomization	Our study did not involve experimental groups and no randomization was required.
Blinding	Our study did not involve experimental groups and no blinding was required.

## 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

### Methods

n/a	Involved in the study
<input checked="" type="checkbox"/>	<input type="checkbox"/> Antibodies
<input type="checkbox"/>	<input checked="" type="checkbox"/> Eukaryotic cell lines
<input checked="" type="checkbox"/>	<input type="checkbox"/> Palaeontology and archaeology
<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
<input checked="" type="checkbox"/>	<input type="checkbox"/> Dual use research of concern

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

## Eukaryotic cell lines

Policy information about [cell lines](#)

Cell line source(s)	HEK293T
Authentication	None of cell lines used were authenticated.
Mycoplasma contamination	Cell lines were not tested for mycoplasma contamination.
Commonly misidentified lines (See <a href="#">ICLAC</a> register)	No commonly misidentified cell lines were used.

## Animals and other organisms

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

Laboratory animals	A total of 12 adult common marmosets ( <i>Callithrix jacchus</i> ; 7 males and 5 females; body weight, 280-350 g; age, 1-2 years) obtained from Nihon Clea and three Thy1-GCaMP6 mice (4 males; GP 4.3, JAX#024275; body weight, 28-35 g; age, P50-60) obtained from Jackson Laboratory were used.
Wild animals	No wild animals were used.
Field-collected samples	No field collected samples were used.

## Ethics oversight

All animal experiments were carried out in accordance with the institutional welfare guidelines laid down by the Animal Care and Use Committee of the University of Tokyo, and approved by the Ethical Committee of the University of Tokyo.

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