Reported 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.

- 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: matlab (2018b), imageJ (1.52j), and NIS-Elements (2018)

Data analysis: matlab (2018b), imageJ (1.52j), Prism 7, Origin 2016

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 DNA and protein sequences described have been deposited at Addgene (https://www.addgene.org/browse/article/28203791/). Source data from experiments in this study are available from the 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
Life sciences study design

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

| Sample size | No specific sample size calculations were performed. Generally, sample size was the maximum possible within reasonable time and resource allocation limits. |
|-------------|----------------------------------------------------------------------------------------------------------------------------------|
| Data exclusion | No data were excluded. |
| Replication | Multiple experimental replicates were performed for each type of measurement as described in the manuscript. All attempts to replicate the data were successful. |
| Randomization | Data collection for different samples was interleaved to avoid systematic biases over time. |
| Blinding | No blinding was performed. The study does not contain experiments whose outcome is susceptible to human suggestion. |

Reporting for specific materials, systems and methods

We require information from authors on 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 an item applies to your research, read the appropriate section before selecting a response.

**Materials & experimental systems**

| Materials & experimental systems | Methods |
|---------------------------------|---------|
| n/a | Involved in the study |
| • Antibodies | | □-ChIP-seq |
| • Eukaryotic cell lines | | □-Flow cytometry |
| • Palaeontology | | □-MRI-based neuroimaging |
| • Animals and other organisms | | |
| • Human research participants | | |
| □ Clinical data | | |

**Eukaryotic cell lines**

Policy information about cell lines

| Cell line source(s) | Spiking HEK 293 cells from Adam Cohen lab (Harvard) |
|---------------------|---------------------------------------------------|
| Authentication | No authentication was performed. |
| Mycoplasma contamination | Cell cultures were tested and determined to be negative for mycoplasma contamination. |
| Commonly misidentified lines | No commonly misidentified cell lines were used in the study. |

**Animals and other organisms**

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

| Laboratory animals | Rattus norvegicus (rat), Sprague-Dawley, 0 days, both males and females |
|---------------------|---------------------------------------------------------------------|
| Wild animals | None |
| Field-collected samples | None |
| Ethics oversight | All procedures involving animals were conducted in accordance with protocols approved by the Howard Hughes Medical Institute (HHMI) Janelia Research Campus Institutional Animal Care and Use Committee and Institutional Biosafety Committee. |

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