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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	Blackrock Research Central Software Suite 7.04 was used to acquire electrophysiology data, available at https://blackrockneurotech.com/research/support/software/. Leica Application Suite X software platform 3.5.5 was used to acquire fluorescence images. Psychtoolbox 3 for visual stimulation administration, available at http://psychtoolbox.org.
Data analysis	All data analysis and visualization in this study are implemented based on Python 3.7, MATLAB 2021a, Origin 2020, and Image J 1.53k. The following packages and software were used: R 4.1.0, Rstudio 1.4, Jupyter 1.0.0, Anaconda 4.10.3, WaveClus3 (https://github.com/csn-le/wave_clus), Leiden 0.8.2 (https://github.com/vtraag/leidenalg), UMAP 0.5.2 (https://github.com/lmcinnes/umap), AllenSDK 2.10.1 (https://github.com/AllenInstitute/AllenSDK), tensorflow 2.5 (https://www.tensorflow.org) Monocle 3 (https://cole-trapnell-lab.github.io/monocle3), Mountainsort 4 (https://github.com/flatironinstitute/mountainsort), Spikeinterface 0.93.0 (https://github.com/SpikeInterface), scikit-learn 0.24.2, matplotlib 3.5.1, seaborn 0.11.2, numpy 1.21.5, scipy 1.7.3, pandas 1.3.5, cmasher 1.6.3, isosplit5 0.1.3, pickle5 0.0.12. Custom code used in this study has been deposited on GitHub (https://github.com/LiuLab-Bioelectronics-Harvard/SpikeStability) and Zenodo (https://doi.org/10.5281/zenodo.7504820).

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 data analyzed during the current study are available at https://github.com/LiuLab-Bioelectronics-Harvard/SpikeStability. Source data are provided with this paper. Raw data generated during the current study are available from the corresponding author 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	Sample sizes were estimated based on previous studies. [Yang, X. et al. Bioinspired neuron-like electronics. Nat. Mater. 18, 510-517 (2019).]
Data exclusions	Animals with surgical complications and that displayed health concerns during the post-surgery monitoring period were excluded. Exclusion criteria of units were pre-established: i) units with large spatial extent of the waveform; ii) units whose fraction of refractory period violations was >10%; iii) units with firing rates less than 0.1 Hz. Animals with surgical complications and that displayed health concerns during the post-surgery monitoring period were excluded.
Replication	The number of repetitions for each experiment has been indicated in the manuscript. Attempts at replication were successful and the conclusion were drawn from the analysis of multiple experiments. Specifically, nearly all experiments were replicated with 5 or more independent animals/devices unless noted in figure legends (see Extended Data Fig. 2g-h, n = 3 independent researchers, each researcher with 5 repeated insertion/extractions)
Randomization	Mice were randomized into different experimental group.
Blinding	Investigators were blinded to data collection and analyses of fluorescence images. Blinding was not relevant to this long-term electrophysiological recording because the animals were not divided into control and experimental groups.

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	Primary antibodies: Chicken anti-glial fibrillary protein GFAP (Abcam, Catalog #ab4674, Lot #GR3281175-3) Goat anti-ionized calcium binding adaptor molecule 1 (Iba1) (Abcam, Catalog #ab5076, Lot #GR63420-3) Rabbit anti-neuronal nuclear NeuN (Abcam, Catalog #ab177487, Lot #GR3250076-7)

All primary antibodies were diluted 1:100-1:200

Secondary antibodies:
Alexa Fluor 647 donkey anti-chicken (Jackson Immunoresearch, Catalog #a703605133, Lot #GR144948)
Alexa Fluor 594 donkey anti-goat (Invitrogen,Catalog #A32758, Lot #TI271731)
Alexa Fluor 488 donkey anti-rabbit (Invitrogen,Catalog #A21206, Lot #2045215)
All secondary antibodies were diluted 1:500

Validation

Validation statement on the manufacturer's website and citations: https://www.abcam.com/gfap-antibody-ab4674.html
https://www.abcam.com/neun-antibody-epr12763-neuronal-marker-ab177487.html
Yang, X. et al. Bioinspired neuron-like electronics. Nat. Mater. 18, 510-517 (2019).

Animals and other organisms

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

Laboratory animals	Mature adult male C57BL/6, 16 weeks of age (Charles River Laboratories, USA) were used throughout this study. Mice were housed at a temperature is 22 ± 1 degree Celsius and humidity is 30-70%.
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 procedures were approved by the Animal Care and Use Committee of Harvard University under protocols 19-03-348 and 20-05-368 .

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