

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	Neurophysiological data were collected using the ATLAS system (Neuralynx Inc., Bozeman, Montana, USA) and hybrid depth electrodes (Ad-Tech company, Oak Creek, Wisconsin, USA). See detailed description in the Methods section.
Data analysis	Data analyses were performed using MATLAB R2019b and Fieldtrip Toolbox 20190527. Spike sorting was done using the open source toolbox OSort v4 (https://rutishauserlab.org/osort). Anatomical data analysis was performed using FreeSurfer version 6 (surfer.nmr.mgh.harvard.edu) and dcm2niix (github.com/rordenlab/dcm2niix). Specific functions used in this study was described in the Methods section.

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](#)

We have made the data and code that supports the findings of this study publicly available on the NIH DANDI archive and Github. The access links are listed in the "Data availability" and "Code availability" section.

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	Our analysis is based on 985 neurons recorded from 20 subjects. This sample size is very large compared to similar studies. No statistical methods were used to pre-determine sample sizes but our sample sizes are similar to those reported in previous publications.
Data exclusions	No data were excluded
Replication	The analyses were performed at single neuron level. The effect reported in the study were consistent and replicated across 20 subjects.
Randomization	Our design is a within-subject analysis: all the subjects were in the same analysis set and had all types of trials. We performed permutation testing where appropriate to ensure statistical validity of our results.
Blinding	Subjects were not aware of the goals of the study. There was no subjective measurement or decision that the investigator needed to make during the experiment. All the data are collected and analyzed off-line. Data collection and analysis were not performed blind to the conditions of the experiments as conditional information is required for further 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

Methods

n/a	Involved in the study	n/a	Involved in the study
<input checked="" type="checkbox"/>	<input type="checkbox"/> Antibodies	<input checked="" type="checkbox"/>	<input type="checkbox"/> ChIP-seq
<input checked="" type="checkbox"/>	<input type="checkbox"/> Eukaryotic cell lines	<input checked="" type="checkbox"/>	<input type="checkbox"/> Flow cytometry
<input checked="" type="checkbox"/>	<input type="checkbox"/> Palaeontology and archaeology	<input checked="" type="checkbox"/>	<input type="checkbox"/> MRI-based neuroimaging
<input checked="" type="checkbox"/>	<input type="checkbox"/> Animals and other organisms		
<input type="checkbox"/>	<input checked="" 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		

Human research participants

Policy information about [studies involving human research participants](#)

Population characteristics	We studied a group of 20 subjects where 12 were female, and the average age was 40.65 years old (range 20-68), and all were diagnosed with pharmacologically-intractable epilepsy. Supplementary table 3 provides information about each subject. 90 Amazon Mechanical Turk Workers (27 females, age range 21 - 43) have participated in our behavioral only tasks.
Recruitment	Subjects undergoing invasive electrophysiological recording for clinical purposes were recruited and consented to participate in this research study. Subjects who was capable of and was willing to participate the task were recruited. All the Amazon Mechanical Turk Workers recruited in this study were under 50 years old. Their behavioral results might not be generalizable to the older age group.
Ethics oversight	The study was approved by the institutional review boards of Toronto Western Hospital, Cedars-Sinai Medical Center and Boston Children's Hospital. Subjects provided informed consent.

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