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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 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	[1] Intracranial EEG (iEEG) data: Neurofax 1100A Digital System (Nihon Kohden America Inc., Foothill Ranch, CA, USA). [2] T1-weighted MRI imaging and diffusion-weighted imaging: GE Signa 3T scanner (GE Healthcare, Milwaukee, WI, USA).
Data analysis	[1] EEGLAB Toolbox winPACT (https://sccn.ucsd.edu/wiki/WinPACT) for computing the modulation index. [2] RIPPLELAB software (https://github.com/BSP-Uniandes/RIPPLELAB/) for computing the rate of high-frequency oscillations. [3] FreeSurfer version 6.0.0 (https://surfer.nmr.mgh.harvard.edu/) for processing and analyzing MRI. [4] DSI studio (http://dsi-studio.labsolver.org/) for dynamic tractography analysis. [5] Statistics implemented in the MATLAB version R2020a.

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 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

We stated: "The iEEG data are available at https://openneuro.org/ (doi:10.18112/openneuro.ds004551.v1.0.2) and https://nemar.org/. The analysis codes are available at https://github.com/kaz1126/flatten_map_and_tractography."

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	iEEG signals recorded from 8,251 nonepileptic cortical sites (114 patients; aged: 1.0-41.5 years). We studied a consecutive series of 114 patients with focal epilepsy (ages 1.0 to 41.5 years) who met the following eligibility criteria (Table 1; Figure S1). Inclusion criteria consisted of: [a] simultaneous video-iEEG recording between January 2007 and November 2020, as part of presurgical assessment at Children's Hospital of Michigan or Harper University Hospital, Detroit Medical Center, [b] iEEG sampling rate of 1,000 Hz (Davis et al., 2018), [c] iEEG contained an artifact-free 20-minute slow-wave sleep epoch at least two hours apart from clinical seizure events (Bagshaw et al., 2009; Nagasawa et al., 2012), and [d] International League Against Epilepsy (ILAE) class 1 outcome in the last follow-up after focal resection (Kuroda et al., 2021).
Data exclusions	Exclusion criteria included [a] a history of previous resective epilepsy surgery, [b] undergoing hemispherotomy or hemispherectomy, and [c] lacking artifact-free, nonepileptic electrode sites (defined as those outside the SOZ [Asano et al., 2009], interictal spike zone [Kural et al., 2020], and MRI-visible lesions [van Klink et al., 2021]).
Replication	Our group validated the use of open-source DWI data by demonstrating that the inferred velocity of neural propagations induced by single-pulse electrical stimulation was similar whether using open-source or individual patient DWI data (Sonoda et al., 2021). We previously validated our group-level analysis of iEEG across generations from infancy to adulthood (Sakakura et al., 2022).
Randomization	Randomization is not applicable to our observational study. All data were derived from the standard treatment of drug-resistant focal epilepsy, with no deviation from clinical protocols.
Blinding	Blinding is not applicable to our observational study. All data were derived from the standard treatment of drug-resistant focal epilepsy, with no deviation from clinical protocols.

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

Human research participants

Policy information about studies involving human research participants

Population characteristics	We studied a consecutive series of 114 patients with focal epilepsy (ages 1.0 to 41.5 years) who met the following eligibility criteria (Table 1; Figure S1). Inclusion criteria consisted of: [a] simultaneous video-iEEG recording between January 2007 and November 2020, as part of presurgical assessment at Children's Hospital of Michigan or Harper University Hospital, Detroit Medical Center, [b] iEEG sampling rate of 1,000 Hz (Davis et al., 2018), [c] iEEG contained an artifact-free 20-minute slow-wave sleep epoch at least two hours apart from clinical seizure events (Bagshaw et al., 2009; Nagasawa et al., 2012), and [d] International League Against Epilepsy (ILAE) class 1 outcome in the last follow-up after focal resection (Kuroda et al., 2021).
Recruitment	All patients were recruited at the Neurology/Neurosurgery Clinics at Children's Hospital of Michigan in Detroit, USA. Prior to the surgical procedure, written informed consent was obtained from each patient's parents or legal guardians, and assent was obtained from patients older than 13 years.
Ethics oversight	This study has been approved by the Wayne State University Institutional Review Board (048404MP2E).

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