

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 (<i>n</i>) 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 <i>Only common tests should be described solely by name; describe more complex techniques in the Methods section.</i>
☒	☐ 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. <i>F</i> , <i>t</i> , <i>r</i>) with confidence intervals, effect sizes, degrees of freedom and <i>P</i> value noted <i>Give P values as exact values whenever suitable.</i>
☒	☐ 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 <i>d</i> , Pearson's <i>r</i>), 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	Local field potentials were collected using the Medtronic percept device. Behavioral data were collected using Matlab Pyschtoolbox. Structural MRI scans were acquired using a Siemens 3T scanner.
Data analysis	All data analysis was done using Matlab. Acoustic simulations and modelling were done using BabelBrain (https://proteusmrighifu.github.io/BabelBrain/).

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](#)

All behavioral data from healthy participants and the acoustic simulation data are publicly available at Figshare (<https://figshare.com/s/359031a0ea6613016a8b>). Upon request, the de-identified local field potential data from individual patients will be made available to investigators by the corresponding authors via private online cloud storage. Source data are provided with this paper.

Research involving human participants, their data, or biological material

Policy information about studies with [human participants or human data](#). See also policy information about [sex, gender \(identity/presentation\), and sexual orientation](#) and [race, ethnicity and racism](#).

Reporting on sex and gender	No sex/based or gender based analysis was performed as the measured parameters are not known to be influenced by sex/gender.
Reporting on race, ethnicity, or other socially relevant groupings	Social variables are not known to influence local field potentials and acoustic parameters. Thus, we did not perform any extra analysis to account for these social variables.
Population characteristics	Ten patients (nine with Parkinson's disease and one with dystonia), all implanted with GPi-DBS devices (ClinicalTrials.gov identifier NCT06232629), participated in this experiment; their average age was 66 ± 8.6 years (nine males and one female).
Recruitment	Patients were recruited from our Toronto Western Hospital, where they had received their DBS implants and routinely visited the DBS clinic. All patients were on stable dopaminergic medications and had bilateral GPi-DBS with a commercial IPG capable of both stimulation and recording (Percept PC; Medtronic Inc.). Patients were included regardless of age, sex, or disease severity, covering both new DBS implants and older systems upgraded with the Percept PC battery. Exclusion criteria included any neurological condition other than Parkinson's disease, significant psychiatric disorders, a MoCA score below 22, cardiac or other neurological implants, a history of intracranial lesioning or implantation of more than two leads, serious illness, infection, pregnancy, or damaged lead contacts.
Ethics oversight	All experiments were approved by the Research Ethics Board (REB) of University Health Network (UHN) and conformed to the latest version of the Declaration of Helsinki.

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

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	This study is the first to investigate the effects of transcranial ultrasound stimulation (TUS) on local field potentials recorded from the basal ganglia in patients with movement disorders, and there are no prior studies using this specific methodology. Given the exploratory nature of our research, we selected a sample size of 10 patients, which aligns with the standard range typically used in studies involving intracranial recording approaches in patients with movement disorders. This sample size was chosen to balance the need for robust data collection with the feasibility of recruiting participants who had an invasive procedure.
Data exclusions	No data were excluded from the analyses.
Replication	Not applicable
Randomization	The order of TUS protocols was randomized across participants.
Blinding	All participants and data analysts were blind to the experimental conditions. The experimenters were not blind to the experimental conditions.

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
☐	☒ Clinical data
☒	☐ Dual use research of concern
☒	☐ Plants

Methods

n/a	Involved in the study
☒	☐ ChIP-seq
☒	☐ Flow cytometry
☐	☒ MRI-based neuroimaging

Clinical data

Policy information about [clinical studies](#)

All manuscripts must comply with the ICMJE [guidelines for publication of clinical research](#) and a completed [CONSORT checklist](#) must be included with all submissions.

Clinical trial registration	NCT06232629
Study protocol	Study protocols are available from clinicaltrials.gov website and the corresponding author by request.
Data collection	MRI data was acquired at Toronto Western Hospital (Toronto, Ontario, Canada) from June 2022 to Dec 2023. The associated clinical data was acquired at the Movement Disorder Clinic at Toronto Western Hospital (Toronto, Ontario, Canada) during the same time period.
Outcomes	The primary outcome was changes in the power of local field potentials in the basal ganglia output nucleus (GPI) during and after transcranial ultrasound stimulation.

Plants

Seed stocks	<i>Report on the source of all seed stocks or other plant material used. If applicable, state the seed stock centre and catalogue number. If plant specimens were collected from the field, describe the collection location, date and sampling procedures.</i>
Novel plant genotypes	<i>Describe the methods by which all novel plant genotypes were produced. This includes those generated by transgenic approaches, gene editing, chemical/radiation-based mutagenesis and hybridization. For transgenic lines, describe the transformation method, the number of independent lines analyzed and the generation upon which experiments were performed. For gene-edited lines, describe the editor used, the endogenous sequence targeted for editing, the targeting guide RNA sequence (if applicable) and how the editor was applied.</i>
Authentication	<i>Describe any authentication procedures for each seed stock used or novel genotype generated. Describe any experiments used to assess the effect of a mutation and, where applicable, how potential secondary effects (e.g. second site T-DNA insertions, mosaicism, off-target gene editing) were examined.</i>

Magnetic resonance imaging

Experimental design

Design type	Only structural MRI scans were collected for ultrasound simulation and modeling, during which the participants did not perform any task.
Design specifications	Each participant had one session of structural MRI, which lasted a maximum of 30 minutes.
Behavioral performance measures	There was no task during the MRI scans.

Acquisition

Imaging type(s)	Structural MRI
Field strength	3T
Sequence & imaging parameters	For patients: High-resolution pre- and postoperative T1-weighted 3-dimensional spoiled gradient echo (3D-SPGR) MRI scans were acquired for each patient. Other acquisition parameters include voxel size = 1×1×1 mm ³ , repetition time (TR) = 9.0/11.9 ms, echo time (TE) = 3.7/5.0 ms, flip angle = 12°/20°. For healthy participants: The parameters for the T1-weighted images were as follows: repetition time (TR) = 2400.0 ms, echo time (TE) = 3.69 ms, inversion time (TI) = 962 ms, flip angle = 8 degrees, field of view (FOV) = 256 mm, slice thickness = 1.0 mm isotropic, number of slices = 176 and acquisition time = 10 mins 16 s. For the T2-weighted image, the parameters were: TR = 7000 ms, TE = 428 ms, an echo train length of 248 ms, FOV = 256 mm, slice thickness = 1.0 mm, and an acceleration factor of 2 using CAIPI, and acquisition time = 8 mins 40 s.
Area of acquisition	whole brain
Diffusion MRI	☐ Used ☒ Not used

Preprocessing

Preprocessing software	Lead DBS V3
Normalization	Pre- and postoperative images were linearly registered using SPM12 (https://www.fil-ion-ucl-ac-uk/spm/software/spm12/) and non-linearly normalized to a Montreal Neurological Institute (MNI) template brain (ICBM 2009b NLIN asymmetric) using ANTs SyN and subcortical refinement (http://stnava.github.io/ANTs/). DBS electrode trajectory was estimated using a semiautomated trajectory reconstruction and manually refined by an experienced user as necessary. Since the directionality of the leads was not utilized during the recording sessions, all leads were recreated as omnidirectional.
Normalization template	ICBM 2009b NLIN asymmetric
Noise and artifact removal	<i>Describe your procedure(s) for artifact and structured noise removal, specifying motion parameters, tissue signals and physiological signals (heart rate, respiration).</i>
Volume censoring	<i>Define your software and/or method and criteria for volume censoring, and state the extent of such censoring.</i>

Statistical modeling & inference

Model type and settings	<i>Specify type (mass univariate, multivariate, RSA, predictive, etc.) and describe essential details of the model at the first and second levels (e.g. fixed, random or mixed effects; drift or auto-correlation).</i>
Effect(s) tested	<i>Define precise effect in terms of the task or stimulus conditions instead of psychological concepts and indicate whether ANOVA or factorial designs were used.</i>
Specify type of analysis:	☐ Whole brain ☐ ROI-based ☐ Both
Statistic type for inference	<i>Specify voxel-wise or cluster-wise and report all relevant parameters for cluster-wise methods.</i>
(See Eklund et al. 2016)	
Correction	<i>Describe the type of correction and how it is obtained for multiple comparisons (e.g. FWE, FDR, permutation or Monte Carlo).</i>

Models & analysis

n/a	Involved in the study
☒	☐ Functional and/or effective connectivity
☒	☐ Graph analysis
☒	☐ Multivariate modeling or predictive analysis