nature portfolio

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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	BrainVision Recoder (BrainProducts, GMBH, Germany)
Data analysis	EEGLAB (UC San Diego, La Jolla California, USA), FieldTrip toolbox (Radboud University, Netherlands), MATLAB (The MathWorks Inc., Natick, MA, USA). Custom MATLAB code employed for data analyses will be made available at the following Github repository: https://github.com/XavierCorominas/Neural-signatures-of-weak-magnetic-stimulation.

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 datasets produced and/or analyzed during the current study are not publicly accessible due to institutional regulations. However, they can be obtained from

the corresponding and/or first author upon reasonable request. The codes for data analysis are accessible at the permanent link: https://github.com/XavierCorominas/Neural-signatures-of-weak-magnetic-stimulation.

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	Sex and gender was reported in the main manuscript. The following information was reported in the main manuscript: Participants Eighteen healthy volunteers (n=18, mean age ±SD = 26.1 ± 5.8 years; 10 females / 8 males), all right-handed according to a standard handedness inventory test[24], free of neurological, or psychiatric symptoms and with normal or corrected-to-normal vision, were recruited for this study. All participants satisfied international TMS and magnetic resonance imaging (MRI) safety criteria[25,26] and provided informed consent prior to the study. The research protocol respected the Declaration of Helsinki, French legislation regulating good clinical practices (ICH-E6, R2) and received the approval of a local ethical committee (Comité de Protection des Personnes, Ile de France I).
Reporting on race, ethnicity, or other socially relevant groupings	Our experimental human cohort did not exclude participants based on race, gender, or socioeconomic status. Participant inclusion was fully blinded and involved no exclusion criteria related to these factors, resulting in a cohort that is broadly representative of a diverse population.
Population characteristics	See above: reporting on sex and gender.
Recruitment	Participants were recruited via The RISC platform (Relais d'information en Sciences de la Cognition) a CNRS entity dedicated to the recruitment of participants in France. Also from a list of healthy participants provided by the Centre d'Investigation Clinique (CIC) from te Paris Brain Institute, France.
Ethics oversight	Comité de Protection des Personnes, Ile de France I, France

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	Our final sample comprised 18 participants, each contributing 80 artifact-clean trials for time–frequency (oscillatory) analyses. This sample size is consistent with prior concurrent TMS-EEG studies quantifying oscillatory responses, including work in 15 healthy participants examining induced oscillatory power changes (Shibata, S., et al., Sci Rep 14, 22394 (2024) and pharmaco–TMS–EEG studies in 16 healthy adults explicitly analyzing TMS-induced oscillations in the time–frequency domain (Belardinelli, P. et al. Sci Rep 11, 8159 (2021)). Overall, N = 18 with 80 trials/participant provides a data volume comparable to published TMS-EEG oscillation studies while accounting for the known susceptibility of TMS-EEG recordings to trial loss from stimulation-related artifacts and quality control procedures.
Data exclusions	No data were excluded from the analyses. However, EEG trials containing continuous muscular activity or heavily contaminated by noise (of either physiological or non-physiological origin) were discarded during the TMS-EEG data-cleaning procedures.
Replication	To enhance the replication and reproducibility of the findings, open-access, automated code for data processing and analysis was developed and will be made publicly available through the project's GitHub repository. Moreover, this study builds upon previously published work investigating TMS-EEG signatures of very weak magnetic fields. Although the present study focuses on different aspects of the neuronal effects of weak magnetic fields, it reproduces key findings from earlier studies and further expands current knowledge in this area.
Randomization	In the present study, all participants were exposed to multiple experimental conditions. The order of the experimental conditions was randomized across participants. Additionally, within each condition, active TMS pulses and sham pulses were randomized in time until the predefined total number of pulses per participant was recorded.
Blinding	Participants were blinded to the TMS-EEG experimental conditions to the greatest extent practically possible. All efforts were made to minimize participants' awareness of the specific condition being administered, including the use of sham stimulation. However, because the same experimental personnel were responsible for both data acquisition and data analysis, blinding at the analysis stage was not feasible. This limitation should be considered when interpreting the results, although the use of automated and standardized data-processing pipelines was considered to reduce potential experimenter bias.

Behavioural & social sciences study design

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

Study description	*Briefly describe the study type including whether data are quantitative, qualitative, or mixed-methods (e.g. qualitative cross-sectional, quantitative experimental, mixed-methods case study).*
Research sample	*State the research sample (e.g. Harvard university undergraduates, villagers in rural India) and provide relevant demographic information (e.g. age, sex) and indicate whether the sample is representative. Provide a rationale for the study sample chosen. For studies involving existing datasets, please describe the dataset and source.*
Sampling strategy	*Describe the sampling procedure (e.g. random, snowball, stratified, convenience). Describe the statistical methods that were used to predetermine sample size OR if no sample-size calculation was performed, describe how sample sizes were chosen and provide a rationale for why these sample sizes are sufficient. For qualitative data, please indicate whether data saturation was considered, and what criteria were used to decide that no further sampling was needed.*
Data collection	*Provide details about the data collection procedure, including the instruments or devices used to record the data (e.g. pen and paper, computer, eye tracker, video or audio equipment) whether anyone was present besides the participant(s) and the researcher, and whether the researcher was blind to experimental condition and/or the study hypothesis during data collection.*
Timing	*Indicate the start and stop dates of data collection. If there is a gap between collection periods, state the dates for each sample cohort.*
Data exclusions	*If no data were excluded from the analyses, state so OR if data were excluded, provide the exact number of exclusions and the rationale behind them, indicating whether exclusion criteria were pre-established.*
Non-participation	*State how many participants dropped out/declined participation and the reason(s) given OR provide response rate OR state that no participants dropped out/declined participation.*
Randomization	*If participants were not allocated into experimental groups, state so OR describe how participants were allocated to groups, and if allocation was not random, describe how covariates were controlled.*

Ecological, evolutionary & environmental sciences study design

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

Study description	*Briefly describe the study. For quantitative data include treatment factors and interactions, design structure (e.g. factorial, nested, hierarchical), nature and number of experimental units and replicates.*
Research sample	*Describe the research sample (e.g. a group of tagged Passer domesticus, all Stenocereus thurberi within Organ Pipe Cactus National Monument), and provide a rationale for the sample choice. When relevant, describe the organism taxa, source, sex, age range and any manipulations. State what population the sample is meant to represent when applicable. For studies involving existing datasets, describe the data and its source.*
Sampling strategy	*Note the sampling procedure. Describe the statistical methods that were used to predetermine sample size OR if no sample-size calculation was performed, describe how sample sizes were chosen and provide a rationale for why these sample sizes are sufficient.*
Data collection	*Describe the data collection procedure, including who recorded the data and how.*
Timing and spatial scale	*Indicate the start and stop dates of data collection, noting the frequency and periodicity of sampling and providing a rationale for these choices. If there is a gap between collection periods, state the dates for each sample cohort. Specify the spatial scale from which the data are taken*
Data exclusions	*If no data were excluded from the analyses, state so OR if data were excluded, describe the exclusions and the rationale behind them, indicating whether exclusion criteria were pre-established.*
Reproducibility	*Describe the measures taken to verify the reproducibility of experimental findings. For each experiment, note whether any attempts to repeat the experiment failed OR state that all attempts to repeat the experiment were successful.*
Randomization	*Describe how samples/organisms/participants were allocated into groups. If allocation was not random, describe how covariates were controlled. If this is not relevant to your study, explain why.*
Blinding	*Describe the extent of blinding used during data acquisition and analysis. If blinding was not possible, describe why OR explain why blinding was not relevant to your study.*

Did the study involve field work? ☐ Yes ☐ No

Field work, collection and transport

Field conditions	The experiment was conducted in a neuropsychology laboratory consisting of a closed, dimly illuminated room.
Location	The experiment was conducted at the Paris Brain Institute, ICM, France
Access & import/export	Not applicable
Disturbance	Not applicable

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

Plants

Seed stocks	*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.*
Novel plant genotypes	*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.*
Authentication	*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, mosiacism, off-target gene editing) were examined.*

Magnetic resonance imaging

Experimental design

Design type	T1w structural scans were acquired for Neuronavigation guidance during TMS procedures
Design specifications	Not applicable. Only structural anatomical scans were acquired
Behavioral performance measures	Not applicable. Only structural anatomical scans were acquired

Acquisition

Imaging type(s)	structural t1w
Field strength	3T
Sequence & imaging parameters	3 T Siemens MP2RAGE, flip angle=9, TR=2300 ms, TE=4.18 ms, slice thickness=1 mm
Area of acquisition	Whole Brain

Diffusion MRI ☐ Used ☒ Not used

Preprocessing

Preprocessing software	Not applicable. Structural scans were directly transfered to Neuronavigation BrainSight TMS system.
Normalization	Not applicable. Structural scans were directly transfered to Neuronavigation BrainSight TMS system.
Normalization template	Not applicable. Structural scans were directly transfered to Neuronavigation BrainSight TMS system.
Noise and artifact removal	Not applicable. Structural scans were directly transfered to Neuronavigation BrainSight TMS system.
Volume censoring	Not applicable. Structural scans were directly transfered to Neuronavigation BrainSight TMS system.

Statistical modeling & inference

Model type and settings	Not applicable. Structural scans were directly transfered to Neuronavigation BrainSight TMS system.
Effect(s) tested	Not applicable. Structural scans were directly transfered to Neuronavigation BrainSight TMS system.

Specify type of analysis: ☒ Whole brain ☐ ROI-based ☐ Both

Statistic type for inference (See Eklund et al. 2016)	Not applicable. Structural scans were directly transfered to Neuronavigation BrainSight TMS system.
Correction	Not applicable. Structural scans were directly transfered to Neuronavigation BrainSight TMS system.

Models & analysis

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

Functional and/or effective connectivity	Not applicable. Structural scans were directly transfered to Neuronavigation BrainSight TMS system.
Graph analysis	Not applicable. Structural scans were directly transfered to Neuronavigation BrainSight TMS system.
Multivariate modeling and predictive analysis	Not applicable. Structural scans were directly transfered to Neuronavigation BrainSight TMS system.