

Reporting Summary

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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

Custom C code was used to program the external transceiver microcontroller. LPCOpen (v2014.05) and CMSIS_DSPLIB (v2013) C code libraries from NXP (NXP Semiconductors N.V.) were used to create the code. ARM gcc (arm-none-eabi-gcc GNU Tools for ARM Embedded Processors 6-2017-q2-update 6.3.1 20170620 ARM/embedded-6-branch revision 249437) and MCUXpresso IDE (10.1.1.606, NXP) were used in the development, compiling and deployment of the transceiver code. The external transceiver collected backscatter data and transferred it to a Matlab script (R2017b, R2019a Mathworks, Inc) running on a PC that coordinated experiments and saved data. Some EMG data digitization and collection was coordinated by Signal Express software (v2015, National Instruments).

See also the final paragraph in Methods, 'Design of the external transceiver', and the third paragraph of Methods, 'In vivo extracellular electrophysiological stimulation.'

Data analysis

Data was analysed by using custom scripts in Matlab (R2017b and R2019a, Mathworks, Inc.).

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/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

The main data supporting the results in this study are available within the paper and its Supplementary Information. Raw, pre-processed data for Figs. 4–7 and Supplementary Figs. 3–9 are available at <https://github.com/maharbizgroup/StimDust>.

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	The study was carried out with six animal subjects. Wireless stimulation was confirmed in these six animals via visual observation of the muscle twitch. Detailed quantitative results were collected for three of the animals. Given the high reproducibility of these results, no further animal experiments were deemed necessary. No a priori power analysis was performed. See Methods, 'In vivo extracellular electrophysiological stimulation' for details. Additional subjects were used in pilot studies.
Data exclusions	Data from 878 backscatter recordings in a gel phantom are presented in Fig. 4b, out of 920 taken during that experimental condition. Data from 111 backscatter recordings are presented in Fig. 6e out of 115 taken during that experimental condition. See Methods for details. All in vivo experiments included some sets of stimulation trials that were used for initial setup, calibration and exploration, and whose data is not part of the parameter sweeps presented in the figures. The in vivo data presented in Figs. 6 and 7, and Supplementary Figs. 5 and 6, originate from 18 sets of trials with animal C, 51 sets of trials with animal D, and 21 sets of trials with animal F. An additional 52 sets of trials with animal C, 102 sets of trials with animal D, and 152 sets of trials from animal F were performed. For all in vivo studies, many trials were performed to ensure that the system was set up and operating properly, to generate video data depicted in video S1, and for the final 'exploratory' sets of trials taken after the data shown in the figures. All data for every animal and every trial is available on reasonable request. See Methods, 'In vivo extracellular electrophysiological stimulation' for details. A rare ultrasound downlink decoding error was observed in which the mote watchdog timer incorrectly identified a change of ultrasound state, resulting in a stimulation of different duration than that specified. These stimulation pulses were excluded when analysing the recruitment curve for the EMG amplitude (1 total with animal C, 0 total with animal D, 4 total with animal F). These exclusion criteria were not pre-established. This is detailed in Methods, under 'In vivo extracellular electrophysiological stimulation'. In Supplementary Fig. 8, electrode-material characterization, 26 pulses with stimulation-timing aberrations out of 1076 pulses in the experiment are not shown.
Replication	Specific experimental findings were reproducible in multiple sessions with the same subject (animal D). Wireless stimulation with an implanted device was replicated across six subjects. The findings of sigmoidal stimulation recruitment curves was replicated across three subjects.
Randomization	Randomization was not relevant without comparisons of an effect across populations. The key effect shown was controllable stimulation, evidenced by recruitment curves replicated across three animals.
Blinding	No blinding was used. Data collection and analysis for physiological response quantification, shown in Figs. 6 and 7, and Supplementary Figs. 5 and 6, was automated.

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
☐	☒ Animals and other organisms
☒	☐ Human research participants
☒	☐ Clinical data

Methods

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

Animals and other organisms

Policy information about [studies involving animals](#); [ARRIVE guidelines](#) recommended for reporting animal research

Laboratory animals

Male Long-Evans rats between 9 and 17 weeks of age and between 248 g and 523 g in mass from Charles River Laboratories, Inc (Wilmington, MA, USA) were used. See also in Methods, 'In vivo extracellular electrophysiological stimulation'.

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 in vivo procedures were performed in accordance with the University of California Berkeley Animal Care and Use Committee regulations.

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