Supplementary Materials for

Deep brain stimulation of the thalamus restores signatures of consciousness in a nonhuman primate model

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-Extended Materials and Methods

Deep brain stimulation (DBS) methodology

Surgery using neuro-navigation

We implanted a four-lead (0, 1, 2, 3) MRI-compatible clinical DBS electrode (Medtronic 3389, USA) in two macaques (monkey N and T) with the ultimate goal of performing simultaneous DBS-fMRI acquisitions. Electrode leads were 1.5 mm long and spaced by 0.5 mm. The external diameter was 1.27 mm. We targeted the right centro-median thalamus (CM) and performed aseptic stereotaxic surgery under general anesthesia using a neuro-navigation system (BrainSight, Rogue, Canada) guided by anatomical 3T MRI (Prisma Fit, Siemens, Germany) (MPRAGE, T1 weighted, repetition time TR = 2200ms; inversion time TI=900ms, 0.80mm isotropic voxel size, sagittal orientation, mono-channel 1Tx-1Rx circular surface coil of 12.5 cm diameter). The head of the monkey was placed in a stereotaxic frame and maintained with ears and ocular bars. All devices were built in plastic and MR compatible materials. Gadolinium fiducials were placed on the frame, as well as on the macaque skull and the temporary headpost that held additional fiducials. These landmarks, recognized by the neuro-navigation system, were put all around the skull in a non-coplanar manner. Pre-operative MRI images aimed at defining the target and trajectory. We assessed the target location and trajectory according to the MNI macaque brain coordinates (x, y, z) and Paxinos Atlas reference space (L, B, S). We confirmed the contact spot following three other approaches: i) anterior-posterior commissure (AC-PC) system; ii) distance to different anatomical area landmarks such as the right caudate nucleus and iii) Saleem Atlas. Lead placement trajectory was simulated with the neuro-navigation module prior to surgery.

We drilled craniotomy, positioned a plastic cannula to guide the DBS electrode and fixed an anchoring device system (Stim-lock, Medtronic, USA) covering the craniotomy. This element aimed at stabilizing and blocking the lead extremity to avoid lead migration. Per-operative MRI were acquired to control convergence between the theoretical and the practical implantation spot (effective target reached during surgery versus desired planned location). The extracranial part of the lead was
protected with a plastic MR compatible chamber that was home-made by 3D-printing and was fixed to the skull with screws and dental acrylic.

*Verification of the DBS settings and underlying behavioral responses*

To ensure efficiency across experiments, impedances between leads and through electrode to an external reference were first measured outside the MRI environment with the DBS programmer device provided by the manufacturer (8840 N’Vision, Activa Clinician DBS Programmer, Medtronic, USA). Ultimately, we used an oscilloscope (Wave Runner 44XI, LeCroy, USA) to check the electrical current delivered to each lead at the beginning and at the end of each experimental session. The stimulation also generated an artifact on the EEG signal, which provided a final benchmark during the fMRI acquisitions.

Behavioral responses (see behavioral assessment section) to electrical thalamic stimulation were assessed in each animal outside the scanner at least 20 days after the DBS implantation. We empirically explored different voltage amplitudes and pulse widths while keeping a monopolar stimulation at a frequency of 130Hz, applied successively to each of the four DBS contacts. The DBS lead targeted the centro-median thalamus. On the target contact (centered in CM), we determined the voltage level for high central thalamic (CT) DBS as the voltage just above the threshold at which a significant behavioral response was observed. Low CT-DBS corresponded to a lower current delivery below the voltage level that led to an arousal pattern. For comparison and reproducibility purposes, we kept the exact same DBS settings for the control stimulation site (ventro-lateral thalamus (VL) DBS).

*fMRI statistical analysis*

*Block-design fMRI analysis*

We generated plots by extracting the activations responses to high CT-DBS with the hemodynamic function in frontal (area 6V; 9/46; 8A), parietal (ventral intraparietal VIP, parietal area PFG), cingulate (anterior ACC: posterior PCC) and temporal cortex (temporo-parieto-occipital area TPO). Activity profiles were plotted as percentage of signal changes across time.
Resting-state fMRI analysis

For the static resting state, we calculated for each experimental condition and sessions the average of positive and negative Z-values and performed a Student t-test with the null hypothesis of zero correlation to test for statistical significance of connectivity between the different experimental conditions.

We computed the static functional correlations by estimating for each experimental condition (noted e) for the awake state, anesthesia, low CT-DBS, high CT-DBS, low VL-DBS and high VL-DBS and acquired run (noted r) the covariance matrix $C_{e,r}$. This value was obtained by extracting and averaging across all runs r the time series of all voxels included in each selected anatomical ROI. We referred as static functional correlation or stationary functional connectivity the entry matrix $C_{e,r}(i,j)$ where each cell represented the mean strength of the functional correlation between the i-j pair. For each covariance matrix, a Fisher transformation was applied to calculate the Z-score. The Z-score matrices were averaged across runs to obtain one matrix per experimental condition. To assess statistical significance, Student t-test at the threshold p value<0.0001 and a false discovery rate correction were applied on the correlations of all pairs of brain regions.

Dynamic resting state fMRI analysis

Covariance values between all ROIs were included ($[82\times(82-1)]/2=3,321$ features per matrix). $Z_{e,s,w}$ matrices were subsampled along the time dimension (w) before clustering. The resulting centroids or median clusters (BS$_n$ with n=1–7; each BS$_n$ is sized 82×82) were then used to initialize a clustering of all data, obtaining a matrix of brain states $B_{e,s,w}$, which, for a given arousal condition e and session s, is a vector of length 464, valued 1–7, because each matrix in $Z_{e,s,p,w}$ is assigned a BS$_n$.

The similarity score was computed from the correlation coefficient between the vectorized structural matrix and each vectorized brain state from the clustering analysis. All brain states were ordered in ascending order of similarity to the structure using the similarity score. To quantify the relation between the probability of occurrence of a BS and the similarity score, for each arousal condition, a regression analysis was done, to quantify the beta value ($\beta$), the $R^2$ and a P value. The differences in BS composition across arousal states was evaluated through a fixed-effects ANOVA, with mean rank similarity, that is, the result of averaging each BS time series, valued from 1 to 7, as a dependent
variable and the vigilance condition as the in-dependent variable. A fixed-effects ANOVA was run to quantify the effect of sedation on the probability of brain state 7. For this, we followed the same procedure, but the mean rank similarity was calculated considering only BS 7 (window w valued at 1; any other state window w valued at 0).

To explore specifically the fluctuations of intervoxel correlation within nodes of the “macaque global neuronal workspace” and sensori-motor areas (anterior cingulate cortex, ACC; dorsolateral prefrontal cortex, PFCdl; frontal eye fields, FEF; dorsolateral premotor cortex, PMCdl; primary somatosensory cortex, S1; primary motor cortex, M1; intraparietal cortex, Peip; primary auditory cortex, A1; inferior temporal cortex, TCi; visual area 1, V1 and posterior cingulate cortex, PCC), we extracted the values from the whole brain matrices and applied a one-way analysis of variance (ANOVA). FC across the brain states were highlighted by displaying Z-score in inter-region matrices.

**Event-related task fMRI analysis**

We generated plots by obtaining the β-weight of SPM regressions of individual macaque data with the hemodynamic functions of the appropriate stimulus categories and then plotted the mean and SE of these β-weights. These values estimate, in percentages of the whole-brain fMRI signal, the size of the fMRI activation relative to the implicit rest baseline that divides trials.

The first level analyses consisted in the convolution of the stimulus categories with the MION canonical hemodynamic response function (HRF) and its time derivative. We also added motion regressors and heart rate as variables of non-interest to the event-related regressors. Activation time series of all the fMRI voxels were computed for each fMRI run and signal change expressed in T-score maps for the different stimulus categories relative to rest periods. Global standard trials that immediately followed a global deviant trial were excluded.

**-Extended Results**

**Thalamic DBS effects on resting-state networks in anesthetized macaques**

**Static Functional Correlations (Figure 4, S6)**

To test for statistical significance of connectivity between brain regions in different experimental
conditions, Student t-tests were performed with the null hypothesis of zero correlation. We calculated for each experimental condition c and sessions the average of positive and negative Z values of Z_{c,s}.

The average positive Z-value was 0.43+/-2.9e-4 in the awake state, 0.22+/-2.6e-4 under anesthesia, 0.27+/-2.5e-4 during low CT-DBS, 0.39+/-2.8e-4 during high CT-DBS, 0.28+/-3.1e-4 during low VL-DBS and 0.19+/-2.4e-4 during high VL-DBS (Figure 4A). Positive Z-values were significantly different under anesthesia and high CT-DBS (p < 0.001, FDR corrected) (Figure 4A). The average negative Z-value was 0.24+/-4.2e-4 in the awake state, 0.09+/-1.7e-4 under anesthesia, 0.12+/-2.7-4 during low CT-DBS, 0.11+/-3.2e-4 during high CT-DBS, 0.08+/-2.7e-4 during low VL-DBS and 0.08+/-2.2e-4 during high VL-DBS (Figure 4A). Negative Z-values were significantly different under anesthesia and high CT-DBS (p < 0.001, FDR corrected) (Figure 4A). In the awake state, the frontal cortex (areas 9/46, 8A, 6V and M1), parietal cortex (parietal area PFG and ventral intraparietal area), anterior and posterior cingulate cortices, temporal cortex (area A1) and occipital cortex (area V1) were strongly correlated to each other (left column, Figure 4B).

**Dynamic Functional Correlations (Figure 5, S7-S8, Table S4)**

We applied k-means to the whole acquired dataset (including all experimental conditions) to cluster brain states (Figure S7). We also applied k-means to two data subsets, subset CT and subset VL, to specifically characterize the effects of CT-DBS and VL-DBS respectively. Subset CT included data from awake, anesthesia and anesthesia + high CT-DBS conditions (Figure 5A-C). Subset VL included data from awake, anesthesia and anesthesia + high VL-DBS conditions (Figure 5D-E).

- **Clustering subset CT (data from awake, anesthesia and anesthesia + high CT-DBS conditions) (Figure 5A-C)**

In the awake state, all 7 brain states were represented with a similar probability of occurrence (β=0.45; R^2=0.22; p=0.28). During anesthesia, state 7 (with the highest function-structure similarity) was dominant and state 1 (with the lowest function-structure similarity) never occurred (β=1.91; R^2=0.67; p=0.02). Under high CT-DBS, consistent with partial recovery of consciousness, the probability of occurrence of state 7 decreased in favor of all the other brain states, especially state 2 and 3 (β=0.64; R^2=0.28; p=0.22). We computed the slope of the linear relation between structural and functional
correlations for each recording session and compared the slope distributions in the awake, anesthesia and DBS conditions. Awake and high CT-DBS slopes were significantly lower than the anesthesia slopes, indicating that a greater diversity of states were explored in the wake state (awake versus anesthesia: t-test, p=6e-5 and BF10=338, high CT-DBS versus anesthesia: t-test, p=0.001 and BF10=23). Importantly no differences were observed between awake and high CT-DBS slopes (t-test, p=0.42, BF01=3.28) (Figure 5A-B, Table S6). In the awake state, the mean rank of brain states was 4 (4.38±1.28), for anesthesia, the mean rank was 6 (5.70±1.40) and during high CT-DBS, the mean rank was 5 (4.55±1.17). This brain state distribution was significantly different (ANOVA; F(2;120)=12.52; p=1.15e-7). Also, the frequency of brain state 7 was moderate in the awake experiments (probability=0.24), high during anesthesia (probability=0.58) and low again during high CT-DBS (probability=0.26; p<0.0001) (Figure 5B). The probability of brain state 7 was higher in anesthesia compared to the awake state (t-test, p=1e-6, BF10=9063) and to high CT-DBS (t-test, p=1e-5, BF10=1017) which did not differ significantly (t-test, p=0.74, BF01=4.18). The mean similarity with the anatomical connectivity was also significantly different with 0.24 (±0.06) for the awake state, 0.31 (±0.07) for anesthesia and 0.25 (±0.06) for high CT-DBS (ANOVA; F(2;120)=14.75; p=1.87e-6).

Anatomically, the functional brain states 1, 2 and 3, that were most characteristic of the awake, presented strong correlations within the “macaque GNW” prefrontal (dorsolateral prefrontal cortex, PFCdl; dorsolateral premotor cortex, PMCdl), parietal (intraparietal cortex, PCip) and cingulate nodes (anterior cingulate cortex, ACC; posterior cingulate cortex, PCCr), whereas state 7 displayed low or null Z-score values across the same entire cortical network (Figure 5C). During high CT-DBS, the average duration of brain state 7 decreased compared to anesthesia (high CT-DBS versus anesthesia, p=2.48e-3; bootstrap analysis) and was similar to the awake state (Figure S8).

- Clustering subset VL (data from awake, anesthesia and anesthesia + high VL-DBS conditions) (Figure 5D-E)

In the awake state, all seven brain states were present (β=0.16; R²=0.02; p=0.74). Under anesthesia, brain state 7 was dominant (β=1.21; R²=0.33; p=0.18), as under high VL-DBS (β=1.69; R²=0.43; p=0.11) (Figure 5F-G). We also computed the slope corresponding to each recording session and
compared the slope distributions in the awake, anesthesia and high VL-DBS conditions. Awake slopes were significantly lower compared to anesthesia and high VL-DBS slopes (awake versus anesthesia: t-test, p=0.0007 and BF10=39, awake versus high CT-DBS: t-test, p=1e-8 and BF10=636824). The slopes under anesthesia were smaller than the high VL-DBS slopes (t-test, p=0.01, BF10=3.81).

For the awake state, the mean rank of brain states was 4 (4.41±0.93), under anesthesia, the mean rank was 6 (5.81±1.39) and under high VL-DBS, the mean rank was 6 (6.41±0.38). The brain state distribution was significantly different (ANOVA; F(2;102)=32.03; p=1.61e-11). Brain state 7 was balanced in the awake state (awake brain state 7 probability=0.19), dominant under anesthesia (anesthesia brain state 7 probability=0.60) and high VL-DBS (high VL-DBS brain state 7 probability=0.72; p<0.0001) (Figure 5F). The probability of state 7 was smaller in the awake state compared to anesthesia (t-test, p=10e-9, BF10=2e7) and compared to high VL-DBS (t-test, p=10e-17, BF10=1e15). However, we found no evidence for a difference nor a similarity between anesthesia and high VL-DBS (t-test, p=0.15, BF10=0.64, BF01=1.54).

Brain state 1 highlighted strong correlations to all the tested cortical areas. Brain state 7 presented weak Z-score values with prefrontal (PFCdl; PMCdl), parietal (PCip) and cingulate cortex (ACC; PCC) (Figure 5C).

With high VL-DBS, the average duration of brain state 7 increased compared to the awake state (high VL-DBS v/s awake, p<0.0001, bootstrap analysis) and was similar to the anesthesia state (Figure S8).

-Clustering the whole dataset (data from awake, anesthesia, low CT-DBS, high CT-DBS, low VL-DBS and high VL-DBS) (Figure S7)

The occurrence of brain states in the awake condition was equiprobable (β=0.05; R²=0.003; p=0.91). Under anesthesia, this probability was shaped by the brain state 7 (β=1.87; R²=0.59; p=0.04). For the DBS sessions, brain state probability of occurrence was partly dominated by brain state 7 in the low CT-DBS condition (β=1.09; R²=0.49; p=0.08), balanced under high CT-DBS (β=0.28; R²=0.059; p=0.6308), partly dominated by the brain state 7 during the low VL-DBS experiments (β=1.52; R²=0.59; p=0.04) and dominated by brain state 7 in the high VL-DBS condition (β=2.57; R²=0.73; p=0.01) (Figure S7).
The mean rank was 4 in the awake state (3.81±1.05), 5 under anesthesia (5.37±1.34), 5 in the low CT-DBS condition (4.81±0.93), 4 in the high CT-DBS condition (4.14±1.03), 5 in the low VL-DBS condition (5.35±0.86) and 6 in the high VL-DBS condition (6.01±0.53). The brain state distribution was significantly different between structural and functional correlations (ANOVA; F(5;193)=19.65; p=8.31e-16) (Figure S7). The probability of occurrence of brain state 7 was low in the awake state (0.20), and high under anesthesia (0.54). Crucially, even though anesthesia continued, low CT-DBS and high CT-DBS reduced this probability down to an aware level (respectively 0.37 and 0.23). The probability of state 7 also decreased with low VL-DBS (0.38) but returned to high (0.63, p<0.001) under high VL-DBS. The mean similarity with the anatomical connectivity was also significantly different with 0.26 (±0.04) for the awake state, 0.32 (±0.06) for anesthesia, 0.29 (±0.04) for low CT-DBS, 0.27 (±0.04) for high CT-DBS, 0.31 (±0.04) for low VL-DBS and 0.35 (±0.03) and for high VL-DBS (ANOVA; F(5;193)=17.72; p=1.94e-14). The average duration of brain state 7 significantly decreased with high CT-DBS compared to the anesthesia state (p=1.61e-9, bootstrap analysis) and was similar to the awake state. Low CT-DBS and low VL-DBS decreased the duration the brain state 7 compared to anesthesia (low CT-DBS v/s anesthesia, p=6.72e-8; low VL-DBS v/s anesthesia, p=1.88e-7, bootstrap analysis). Under high VL-DBS, duration of the brain state 7 was similar to the anesthesia state (high VL-DBS v/s anesthesia, not significant) (Figure S7).
Active contact of the lead for CT-DBS Monkey T

A. Coregistration of the pre and post-operative MRI anatomical images (upper panel) and between MRI post-operative and MNI macaque brain atlas (lower panel) for monkey T. (B) Pre-reconstruction of the electrode lead trajectory using the entry point on the anatomical MRI image and manual correction of electrode localization adjusting the most inferior (contact 0) and most superior (contact 3) DBS contacts according to the electrode artifact in two dimensional planes presented orthogonally. (C) Location of the centro-median (CM) DBS contact and (D) ventral-lateral thalamus (VL) DBS contact in monkey T (left column) and monkey N (right column) on the sagittal, coronal and axial plan. The target is displayed in the CIVM MRI atlas (upper panel), pre-operative structural MRI (middle panel) and post-operative structural MRI (lower panel) warped in the MNI macaque space (73).

Figure S1: Localization of the DBS electrode contacts using the Lead-DBS macaque toolbox (71).
Figure S2: Suppression of EEG artifacts related to MR B₀ field, MR Gradients during fMRI acquisition and DBS. Examples of EEG recordings in anesthetized macaques inside a 3T MRI scanner without and with DBS of central thalamus (CT) thalamus at 3V.
Figure S3: Effects of thalamic DBS on EEG. Examples of EEG recordings in anesthetized macaques inside a 3T MRI scanner with DBS of central thalamus (CT) or ventral-lateral thalamus (VL) at low or high voltages. The DBS-induced changes in cortical activity depends on the anatomical site of the active DBS lead contact and the intensity of the electrical stimulation.
Figure S4: Cortical activity dynamic during and immediately after DBS

Examples of EEG recordings in anesthetized macaques inside a 3T MRI scanner before, during and after DBS of central thalamus (CT) at high voltage.
**Figure S5: Modulation of normalized spectral power and median power frequency in the DBS conditions compared to anesthesia.**

Distributions of the average values of normalized spectral power of (A) delta (1-4 Hz), (B) theta (4-8 Hz) and (C) alpha (8-13 Hz) oscillatory bands and (D) median power frequency (MSF) calculated on the epochs of the four stimulation conditions and under anesthesia. MSF is the frequency that divides the power spectrum in two equal areas. The figures consist of a distribution - smoothened version of a histogram, a box plot and a representation of the data points. Each dot in the figure represents the average value of a given marker across epochs during one recording session. a.u., arbitrary units. The significance lines represent FDR corrected Mann-Whitney U two-sided tests (see Methods). p-value annotation legend: ns: 5.00e-02 < p ≤ 1.00e+00, *: 1.00e-02 < p ≤ 5.00e-02, **: 1.00e-03 < p ≤ 1.00e-02, ***: 1.00e-04 < p ≤ 1.00e-03, ****: p ≤ 1.00e-04. P-values are FDR corrected.
Figure S6: p values matrices for the ANOVA comparison of the awake state versus different experimental conditions of the static functional correlations within the macaque Global Neuronal Workspace (GNW) nodes and sensori-motor areas.

Statistical p values obtained by ANOVA to compare static functional correlations within the macaque GNW nodes and sensori-motor areas in the different experimental conditions. X-axis displays the experimental conditions (awake, anesthesia, low central thalamic (CT) DBS, high CT-DBS, low ventral-lateral thalamic (VL) DBS and high VL-DBS states), y-axis represents the macaque GNW areas correlated to the seed (p < 0.001, FDR corrected). For each region, the matrix stands for the p value for the comparison of the awake state versus anesthesia, low CT-DBS, high CT-DBS, low VL-DBS and high VL-DBS between the seed and the rest of the macaque GNW nodes and sensori-motor areas.

Anterior cingulate cortex (ACC); Prefrontal cortex (area 9/46, 8A, 6 Ventral); Primary motor cortex (M1); Parietal cortex (area PFG); Ventral Intraparietal sulcus (VIP); Primary auditory cortex (A1); Primary visual area (V1); Posterior cingulate cortex (PCC).
Figure S7: DBS effect on cortical dynamical correlations

(A) Seven functional brain states obtained by unsupervised clustering of the Z score matrix (all conditions pooled together, awake state, anesthesia, low central thalamic (CT) DBS, high CT-DBS, low ventral-lateral thalamic (VL) DBS and high VL-DBS). (B) Structural connectivity matrix derived from the CoCoMac atlas of anatomical macaque cortical connectivity. Colors represent the four grades of connection intensity (black=0; white=1; blue=2 and red=3). (C) Brain renders displaying the 400 strongest links for each functional brain state. Red line represent positive connections between regions of interests; blue represent negative connections. (D) Probability of occurrence of each functional brain state as a function of the similarity with the structural connectivity, for the awake state (green), anesthesia (red), low CT-DBS (light blue), high CT-DBS (dark blue), low VL-DBS (light purple) and high VL-DBS (dark purple). (E) Probability distributions of functional brain states for the for the awake state (green), anesthesia (red), low CT-DBS (light blue), high CT-DBS (dark blue), low VL-DBS (light purple) and high VL-DBS (dark purple). Error bars stand for 1 SEM.
Figure S8: Average life time of brain states in the awake state, under anesthesia and during high central thalamic (CT) DBS (left) or high ventral-lateral thalamic (VL) DBS (right); normalized probability distribution and two-dimensional normalized histograms

Average life time of brain states for the awake, anesthesia and high central thalamic (CT) DBS condition (A) or high ventral-lateral thalamic (VL) DBS (B) for 7 brain states obtained by k-means clustering. Error bars stand for 1 SEM. Normalized probability distribution of all Z values for the functional brain state 1 (the least similar to the structural brain connectivity) and functional brain state 7 (the most similar to the structural brain connectivity) for awake, anesthesia and high CT-DBS resting state pooled together. Similar results were obtained regardless the inputs conditions for the clustering (C). Two-dimensional normalized histograms for functional brain state 1 and functional brain state 7 for the clustering of awake, anesthesia and high CT-DBS condition. (D) Z values as a function of distance between pairs of regions of interest for brain state 1 (upper right) and brain state 7 (lower right) for the clustering of awake, anesthesia and high CT-DBS condition.
**Figure S9: Local-global auditory paradigm**

Description of the event-related auditory paradigm called local-global used in the auditory event-related fMRI experiments. Local deviants occur at the trial level (1\textsuperscript{st} order) whereas Global deviants occur at the series level (2\textsuperscript{nd} order).  

Local effect = Local deviants – Local standards  
Global effect = Global deviants – Global standards
fMRI activations during the auditory “Local-global” experiment

Local effect: High CT-DBS > Anesthesia

Individual results: Monkey N

A. Local effect: High CT-DBS > Anesthesia

B. T score p < 0.001 uncorrected

C. Individual results: Monkey T

D. T score p < 0.001 uncorrected

Figure S10: Activations maps for the local effect showing stronger activations under high central thalamic (CT) DBS compared to anesthesia state

Activation maps for the local effect showing stronger activations under high CT-DBS compared to anesthesia state (A, C). fMRI signal changes in areas responsive to the local effect (green cursor) (B,D). Individual results for monkey N (top panel - A,B) and monkey T (lower panel - C,D), p < 0.001, uncorrected. 
PaAL, paraauditory cortex, lateral part; PaAc, paraauditroy cortex, caudal part; ProKM, auditory cortex, prokonio cortex, medial part.
Global effect: High CT-DBS > Anesthesia

Individual results: Monkey N

Figure S11: Activations maps for the global effect showing stronger activations under high central thalamic (CT) DBS compared to anesthesia state for monkey N. Activation maps for the local effect showing stronger activations under high CT-DBS compared to anesthesia state (A). fMRI signal changes in areas responsive to the local effect (green cursor) (B). Individual results for monkey N, p < 0.001, uncorrected.

Cd, Caudate nucleus; Pu, Putamen; VPL, ventro-postero-lateral thalamus.
fMRI activations during the auditory “Local-global” experiment

Global effect: High CT-DBS > Anesthesia

Individual results: Monkey T

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Figure S12: Activations maps for the global effect showing stronger activations under high central thalamic (CT) DBS compared to anesthesia state for monkey T. Activation maps for the local effect showing stronger activations under high CT-DBS compared to anesthesia state (A). fMRI signal changes in areas responsive to the local effect (green cursor) (B). Individual results for monkey N, p < 0.001, uncorrected.

Depth of Intraparietal sulcus (DIP), Caudate nucleus (Cd); centro-lateral thalamus (Cl).
### Table S1: Simulation of the stimulated thalamic nuclei around the DBS lead using the LEAD DBS macaque toolbox

Estimation of the thalamic nuclei that were included in the volume of activated tissue around the DBS lead active contact (71) for monkey N and monkey T across the four experimental conditions (low central thalamic (CT) DBS, high CT-DBS, low ventral thalamic (VL) DBS and high VL-DBS).

| Condition | Animal | Heart Rate (HR in bpm) | Oxygen Saturation (SpO₂ in %) | Blood Pressure (SBP in mmHg) | Blood Pressure (DBP in mmHg) | Blood Pressure (MBP in mmHg) | Respiration Rate (RR in breath/min) | End-tidal CO₂ (EtCO₂ in mmHg) | Temperature (T in °C) |
|-----------|--------|------------------------|-------------------------------|------------------------------|-------------------------------|-------------------------------|-----------------------------------|-------------------------------|----------------------|
| Anesthesia | monkey N | 111 ± 9 | 98 ± 2 | 116 ± 10 | 59 ± 7 | 87 ± 9 | 20 ± 1 | 41 ± 2 | 37.0 ± 0.7 |
| | monkey T | 116 ± 17 | 97 ± 3 | 95 ± 8 | 46 ± 7 | 68 ± 9 | 18 ± 2 | 37 ± 2 | 38.3 ± 0.7 |
| Low CT-DBS | monkey N | 134 ± 13 | 99 ± 1 | 129 ± 13 | 70 ± 12 | 101 ± 13 | 21 ± 2 | 43 ± 2 | 37.1 ± 0.3 |
| | monkey T | 123 ± 18 | 99 ± 1 | 98 ± 12 | 47 ± 7 | 71 ± 8 | 18 ± 2 | 39 ± 2 | 38.6 ± 0.3 |
| High CT-DBS | monkey N | 164 ± 16 | 98 ± 2 | 129 ± 15 | 71 ± 15 | 99 ± 14 | 21 ± 2 | 45 ± 2 | 37.3 ± 0.4 |
| | monkey T | 181 ± 18 | 98 ± 2 | 133 ± 15 | 74 ± 15 | 104 ± 14 | 19 ± 2 | 43 ± 2 | 39.6 ± 0.4 |
| Low VL-DBS | monkey T | 140 ± 18 | 98 ± 2 | 113 ± 12 | 54 ± 12 | 81 ± 12 | 19 ± 2 | 38 ± 2 | 39.0 ± 0.4 |
| High VL-DBS | monkey T | 163 ± 14 | 98 ± 1 | 127 ± 15 | 71 ± 19 | 99 ± 19 | 18 ± 2 | 42 ± 2 | 39.1 ± 0.6 |

### Table S2: Physiological data during the fMRI resting-state experiments.

Oxygen saturation (SpO₂); systolic, diastolic and mean blood pressure (respectively SBP, DBP, MBP); respiration rate (RR); end-tidal CO₂ (EtCO₂) and temperature (T) for each animal (monkey N and T) under general anesthesia, general anesthesia plus low central thalamic (CT) DBS, general anesthesia plus high CT-DBS, general anesthesia plus low ventral-lateral thalamic (VL) DBS and general anesthesia plus high VL-DBS.
### fMRI activations during the DBS block-design experiment

#### Area ProM (promotor)

| Area                        | Abbreviation | Hemisphere | T score | p value | p value | T score | p value | T score | p value | T score | p value |
|-----------------------------|--------------|------------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| Area 13 of cortex           | 13           | Right      | n.s     |         |         | 19.15   | *p*<10^-12 | n.s     |         |         |         |
| Area 13a of cortex          | 13a          | Left       | 5.11    | *p*<10^-3 | 5.11    | *p*<10^-3 | n.s     |         |         |         |         |
| Area 14o                    | 14o          | Right      | n.s     |         | 5.91    | *p*<10^-4 | n.s     |         |         |         |         |
| Area 25 of cortex           | 25           | Left       | 5.48    | *p*<10^-4 | 5.48    | *p*<10^-4 | n.s     |         |         |         |         |
| Orbitofrontal cortex        | OPro         | Right      | n.s     |         | 19.15   | *p*<10^-12 | n.s     |         |         |         |         |

#### Frontal cortex

| Area 4 of cortex (primary motor) | Abbreviation | Hemisphere | T score | p value | p value | T score | p value | T score | p value | T score | p value |
|---------------------------------|--------------|------------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| Area 4 of cortex, Medial part   | 4M           | Left       | n.s     |         |         | 18.47   | *p*<10^-12 | n.s     |         |         |         |
| Area 4 of cortex, Caudal subdivision (Matellis F2) | 4DC         | Right      | n.s     |         | 6.54    | *p*<10^-6 | n.s     |         |         |         |         |
| Area 4 of cortex, Ventral part, Caudal subdivision (Matellis F4) | 4VR         | Left       | n.s     |         | 6.16    | *p*<10^-5 | n.s     |         |         |         |         |
| Area 4 of cortex, Ventral part, Rostral subdivision (Matellis F5) | 4DR         | Right      | n.s     |         | 19.15   | *p*<10^-12 | n.s     |         |         |         |         |
| Area 6/32 of cortex            | 632          | Left       | 4.96    | *p*<10^-10 | 19.15   | *p*<10^-12 | n.s     |         |         | 9.94    | *p*<10^-12 |
| Area 8A of cortex              | 8A           | Right      | n.s     |         | 5.79    | *p*<10^-4 | n.s     |         |         | 5.77    | *p*<10^-4 |
| Area 8f of cortex, AnteriorOveral part | 8AD      | Left       | 7.10    | *p*<10^-8 | 19.47   | *p*<10^-12 | n.s     |         |         | 12.81   | *p*<10^-12 |
| Area 8 of cortex, AnteriorVentral part | 8AV   | Right      | n.s     |         | 19.15   | *p*<10^-12 | n.s     |         |         | 12.81   | *p*<10^-12 |
| Area 8 of cortex               | 8B           | Left       | n.s     |         | 7.10    | *p*<10^-8 | n.s     |         |         |         |         |
| Area 8 of cortex               | 8B           | Right      | n.s     |         | 19.15   | *p*<10^-12 | n.s     |         |         |         |         |
| Area 9 of cortex, Medial part  | 9M           | Left       | n.s     |         | 19.15   | *p*<10^-12 | n.s     |         |         |         |         |
| Area 9 of cortex, Ventral part, Caudal subdivision (Matellis F4) | 9VR         | Right      | n.s     |         | 14.54   | *p*<10^-12 | n.s     |         |         |         |         |
| Area 9 of cortex               | 932          | Right      | 7.72    | *p*<10^-10 | 7.24    | *p*<10^-10 | n.s     |         |         |         |         |
| Area 9 of cortex               | 946          | Right      | 6.98    | *p*<10^-8 | 19.15   | *p*<10^-12 | n.s     |         |         | 9.94    | *p*<10^-12 |
| Area 44 of cortex              | 44           | Left       | n.s     |         | 6.66    | *p*<10^-6 | n.s     |         |         |         |         |
| Area 45 of cortex              | 45A          | Right      | 7.30    | *p*<10^-9 | 19.15   | *p*<10^-12 | n.s     |         |         | 9.94    | *p*<10^-12 |
| Area 45 of cortex              | 45B          | Left       | n.s     |         | 6.66    | *p*<10^-6 | n.s     |         |         |         |         |
| Area 46 of cortex              | 46D          | Right      | 6.98    | *p*<10^-8 | 19.15   | *p*<10^-12 | n.s     |         |         | 9.94    | *p*<10^-12 |
| Area 46 of cortex              | 46V          | Left       | 5.27    | *p*<10^-3 | n.s     |         | n.s     |         |         |         |         |
| Area 47 of cortex (old 12) of cortex, Lateral part | 47L         | Right      | 6.98    | *p*<10^-8 | 7.08    | *p*<10^-8 | n.s     |         |         |         |         |
| Area 47 of cortex (old 12) of cortex, Orbital part | 47O         | Left       | 6.27    | *p*<10^-6 | 8.28    | *p*<10^-6 | n.s     |         |         |         |         |
| Area ProM (promotor)           | ProM         | Left       | n.s     |         | 6.66    | *p*<10^-6 | n.s     |         |         |         |         |
### Area PGM/31 of cortex

| Area | Abbreviation | Hemisphere | T score | p value | T score | p value | T score | p value | T score | p value |
|------|--------------|------------|---------|---------|---------|---------|---------|---------|---------|---------|
| Area 23 of cortex | 23 | midline | 6.98 | $p_{\text{FWE}} < 1x10^{-12}$ | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. |
| Area 25 of cortex | 25 | Right | 7.38 | $p_{\text{FWE}} = 2.08x10^{-8}$ | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. |
| Area 26 of cortex | 26 | Left | 6.98 | $p_{\text{FWE}} = 2.08x10^{-8}$ | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. |
| Area 28 of cortex | 28 | Right | 7.38 | $p_{\text{FWE}} = 2.08x10^{-8}$ | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. |

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### fMRI activations during the DBS block-design experiment

| Area | Abbreviation | Hemisphere | T score | p value | T score | p value | T score | p value | T score | p value |
|------|--------------|------------|---------|---------|---------|---------|---------|---------|---------|---------|
| Area 1 of cortex | 1 | Left | 18.47 | $p_{\text{FWE}} < 1x10^{-12}$ | n.s. | 9.47 | $p_{\text{FWE}} < 1x10^{-12}$ | n.s. | n.s. | n.s. |
| Area 2 of cortex | 2 | Right | 18.47 | $p_{\text{FWE}} < 1x10^{-12}$ | n.s. | 9.47 | $p_{\text{FWE}} < 1x10^{-12}$ | n.s. | n.s. | n.s. |
| Area 3 of cortex | 3 | Left | 18.47 | $p_{\text{FWE}} < 1x10^{-12}$ | n.s. | 9.47 | $p_{\text{FWE}} < 1x10^{-12}$ | n.s. | n.s. | n.s. |
| Area 4 of cortex | 4 | Right | 18.47 | $p_{\text{FWE}} < 1x10^{-12}$ | n.s. | 9.47 | $p_{\text{FWE}} < 1x10^{-12}$ | n.s. | n.s. | n.s. |
| Area 5 of cortex | 5 | Right | 18.47 | $p_{\text{FWE}} < 1x10^{-12}$ | n.s. | 9.47 | $p_{\text{FWE}} < 1x10^{-12}$ | n.s. | n.s. | n.s. |
| Area 6 of cortex | 6 | Right | 18.47 | $p_{\text{FWE}} < 1x10^{-12}$ | n.s. | 9.47 | $p_{\text{FWE}} < 1x10^{-12}$ | n.s. | n.s. | n.s. |
| Area 7 of cortex | 7 | Right | 18.47 | $p_{\text{FWE}} < 1x10^{-12}$ | n.s. | 9.47 | $p_{\text{FWE}} < 1x10^{-12}$ | n.s. | n.s. | n.s. |
### fMRI activations during the DBS block-design experiment

| Area                                      | Abbreviation | Hemisphere | T score | p value       | T score | p value       | T score | p value       | T score | p value       |
|-------------------------------------------|--------------|------------|---------|---------------|---------|---------------|---------|---------------|---------|---------------|
| **Temporal cortex**                       |              |            |         |               |         |               |         |               |         |               |
| Area PG associated, region of            | PGa          | Right      |         | n.s           | 18.47   | \(p_{\text{FWE}} = 4.08 \times 10^{-4}\) | n.s     | n.s           | n.s     | n.s           |
| superior temporal sulcus                  |              |            |         |               |         |               |         |               |         |               |
| Auditory Koilocortex, Lateral part        | AKL          | Left       | n.s     | \(p_{\text{FWE}} < 1 \times 10^{-12}\) | 7.27    | \(p_{\text{FWE}} = 1.52 \times 10^{-8}\) | n.s     | n.s           | n.s     | n.s           |
| Auditory Koilocortex, Medial part         | AKM          | Right      | n.s     | \(p_{\text{FWE}} < 1 \times 10^{-12}\) | 18.47   | \(p_{\text{FWE}} = 1.52 \times 10^{-8}\) | n.s     | n.s           | n.s     | n.s           |
| Fundus of Superior Temporal sulcus        | FST          | Left       | n.s     | \(p_{\text{FWE}} < 1 \times 10^{-12}\) | 6.48    | \(p_{\text{FWE}} = 3.37 \times 10^{-6}\) | n.s     | n.s           | n.s     | n.s           |
| Medial Superior Temporal area             | MST          | Left       | n.s     | \(p_{\text{FWE}} < 1 \times 10^{-12}\) | 18.47   | \(p_{\text{FWE}} = 1.52 \times 10^{-8}\) | n.s     | n.s           | n.s     | n.s           |
| Middle Temporal area (visual area 5)      | MT           | Left       | 7.27    | \(p_{\text{FWE}} = 1.52 \times 10^{-8}\) | n.s     |               |         |               |         |               |
| ParaAuditory area, Caudal part            | PaAC         | Left       | n.s     | \(p_{\text{FWE}} < 1 \times 10^{-12}\) | 7.27    | \(p_{\text{FWE}} = 1.52 \times 10^{-8}\) | n.s     | n.s           | n.s     | n.s           |
| ParaAuditory area, lateral part           | PaAL         | Right      | n.s     | \(p_{\text{FWE}} < 1 \times 10^{-12}\) | 18.47   | \(p_{\text{FWE}} = 1.52 \times 10^{-8}\) | n.s     | n.s           | n.s     | n.s           |
| ParaAuditory area, Rostral part           | PaAR         | Right      | n.s     | \(p_{\text{FWE}} < 1 \times 10^{-12}\) | 12.62   | \(p_{\text{FWE}} < 1 \times 10^{-12}\) | n.s     | n.s           | n.s     | n.s           |
| ProKoniocortex                            | ProK         | Right      | n.s     | \(p_{\text{FWE}} < 1 \times 10^{-12}\) | 18.47   | \(p_{\text{FWE}} = 1.52 \times 10^{-8}\) | n.s     | n.s           | n.s     | n.s           |
| Retrolinsular area                         | Rel          | Right      | n.s     | \(p_{\text{FWE}} < 1 \times 10^{-12}\) | 18.47   | \(p_{\text{FWE}} = 1.52 \times 10^{-8}\) | n.s     | n.s           | n.s     | n.s           |
| Retrolinsular area, Temporal part          | ReIT         | Left       | n.s     | \(p_{\text{FWE}} < 1 \times 10^{-12}\) | 18.47   | \(p_{\text{FWE}} = 1.52 \times 10^{-8}\) | n.s     | n.s           | n.s     | n.s           |
| Superior Temporal sulcus area 1            | ST1          | Right      | n.s     | \(p_{\text{FWE}} < 1 \times 10^{-12}\) | 8.83    | \(p_{\text{FWE}} = 1.52 \times 10^{-8}\) | n.s     | n.s           | n.s     | n.s           |
| Superior Temporal area, gyril part         | ST2g         | Left       | 11.36   | \(p_{\text{FWE}} < 1 \times 10^{-12}\) | n.s     |               |         |               |         |               |
| Superior Temporal area, sulcal part        | ST2s         | Left       | 11.36   | \(p_{\text{FWE}} < 1 \times 10^{-12}\) | n.s     |               |         |               |         |               |
| Temporal area T1a                          | TAla         | Right      | 18.47   | \(p_{\text{FWE}} < 1 \times 10^{-12}\) | n.s     |               |         |               |         |               |
| Temporal area T1e                          | Tel          | Right      | 18.47   | \(p_{\text{FWE}} < 1 \times 10^{-12}\) | n.s     |               |         |               |         |               |
| Temporal area TL, Medial part              | TEM          | Right      | 18.47   | \(p_{\text{FWE}} < 1 \times 10^{-12}\) | n.s     |               |         |               |         |               |
| Temporal area TL, OccipitoMedial part      | TEMOM        | Right      | 18.47   | \(p_{\text{FWE}} < 1 \times 10^{-12}\) | n.s     |               |         |               |         |               |
| Temporal ParietoOccipital associated area in | TPO          | Right      | 7.38    | \(p_{\text{FWE}} = 3.90 \times 10^{-9}\) | 18.47   | \(p_{\text{FWE}} = 1.52 \times 10^{-8}\) | n.s     | n.s           | n.s     | n.s           |
| Temporal ParietoOccipital associated area in | TPOC         | Right      | 7.27    | \(p_{\text{FWE}} = 1.52 \times 10^{-8}\) | n.s     |               |         |               |         |               |
| Temporoparietal cortex                     | Tpt          | Left       | 5.02    | \(p_{\text{FWE}} = 1.15 \times 10^{-2}\) | n.s     |               |         |               |         |               |
|                                           | Tpt          | Right      | 7.38    | \(p_{\text{FWE}} = 3.90 \times 10^{-9}\) | 18.47   | \(p_{\text{FWE}} < 1 \times 10^{-12}\) | n.s     | n.s           | n.s     | n.s           |
| **Occipital cortex**                       |              |            |         |               |         |               |         |               |         |               |
| Visual area 1 (primary visual cortex)      | V1           | Left       | 7.22    | \(p_{\text{FWE}} = 1.26 \times 10^{-8}\) | n.s     |               |         |               |         |               |
| Visual area 2                              | V2           | Left       | 5.70    | \(p_{\text{FWE}} = 4.08 \times 10^{-4}\) | n.s     |               |         |               |         |               |
| Visual area 3, Dorsal part                 | V3D          | Right      | 18.47   | \(p_{\text{FWE}} < 1 \times 10^{-12}\) | 7.97    | \(p_{\text{FWE}} = 3.94 \times 10^{-11}\) | n.s     | n.s           | n.s     | n.s           |
| Visual area 3A                             | V3A          | Right      | n.s     | \(p_{\text{FWE}} < 1 \times 10^{-12}\) | 7.27    | \(p_{\text{FWE}} = 1.52 \times 10^{-8}\) | n.s     | n.s           | n.s     | n.s           |
| **Insular cortex**                         |              |            |         |               |         |               |         |               |         |               |
| Dysgranular Insular cortex                 | DI           | Left       | 6.18    | \(p_{\text{FWE}} < 2.9 \times 10^{-5}\) | n.s     |               |         |               |         |               |
| Granular Insular cortex                    | GI           | Left       | 12.62   | \(p_{\text{FWE}} < 1 \times 10^{-12}\) | n.s     |               |         |               |         |               |
| Insular Prokiniocortex                     | IPro         | Right      | 7.52    | \(p_{\text{FWE}} = 2.56 \times 10^{-9}\) | n.s     |               |         |               |         |               |
| **Striatum**                              |              |            |         |               |         |               |         |               |         |               |
| Caudate nucleus                            | Cd           | Left       | 18.47   | \(p_{\text{FWE}} < 1 \times 10^{-12}\) | n.s     |               |         |               |         |               |
| Putamen                                    | Pu           | Right      | 18.47   | \(p_{\text{FWE}} < 1 \times 10^{-12}\) | n.s     |               |         |               |         |               |
|                                           |             |             | 13.68   | \(p_{\text{FWE}} < 1 \times 10^{-12}\) | 18.47   | \(p_{\text{FWE}} < 1 \times 10^{-12}\) | n.s     | n.s           | n.s     | n.s           |
| Area                                      | Abbreviation | Hemisphere | CT-DBS T score | p value | VL-DBS T score | p value |
|-------------------------------------------|--------------|------------|----------------|---------|----------------|---------|
| Thalamus                                  |              |            |                |         |                |         |
| Lateral Geniculate Nucleus                 | LGN          | Right      | 14.54          | n.s     | 14.47          | p<0.000001 |
| Lateral pulvinar                          | Lpul         | Left       | 5.20           | p<0.00001 | 5.87           | p<0.00001 |
| Medial Geniculate nucleus, Ventral part   | MGV          | Right      | 5.87           | p<0.00001 | 5.55           | p<0.00001 |
| Medial pulvinar                           | Mpul         | Right      | 5.59           | p<0.00001 | 5.17           | p<0.00001 |

| Area                                      | Abbreviation | Hemisphere | CT-DBS T score | p value | VL-DBS T score | p value |
|-------------------------------------------|--------------|------------|----------------|---------|----------------|---------|
| Mediodorsal thalamic nucleus, Central part| MDC          | Left       | 5.65           | p<0.00001 | 3.56           | p<0.00001 |
| Mediodorsal thalamic nucleus, Dorsal part | MDD          | Left       | 11.07          | p<0.00001 | 11.07          | p<0.00001 |
| Mediodorsal thalamic nucleus, Medial part | MDMA         | Left       | 11.07          | p<0.00001 | 11.07          | p<0.00001 |
| Paraventricular thalamic nucleus          | PV           | Left       | 6.66           | p<0.00001 | 7.30           | p<0.00001 |
| Paraventricular Thalamus                  | PVT          | Right      | 14.54          | p<0.00001 | 14.54          | p<0.00001 |
| Reticular thalamic nucleus                | RIH          | Right      | 5.91           | p<0.00001 | 1.22           | p<0.00001 |

| Area                                      | Abbreviation | Hemisphere | CT-DBS T score | p value | VL-DBS T score | p value |
|-------------------------------------------|--------------|------------|----------------|---------|----------------|---------|
| Hypothalamus                              | Hy           | Left       | 14.54          | p<0.00001 | 14.54          | p<0.00001 |
| Pons                                      | EGP          | Left       | 5.25           | p<0.00001 | 4.91           | p<0.00001 |
| Paraseptal subpallium                     |              |            |                |         |                |         |
| Accumbens nucleus, Core                   | AcbC         | Left       | 18.47          | p<0.00001 | 18.47          | p<0.00001 |
| Accumbens nucleus, Shell                  | AcsSh        | Left       | 18.47          | p<0.00001 | 18.47          | p<0.00001 |
| Bterior nucleus, Meynert                  | BM           | Left       | 14.54          | p<0.00001 | 14.54          | p<0.00001 |
| Substancia innominata                     | Sii          | Left       | 15.09          | p<0.00001 | 5.83           | p<0.00001 |
| Subpallial amygdala                       |              |            |                |         |                |         |
| Anterior Amygdaloid area                  | AA           | Left       | 14.54          | p<0.00001 | 14.54          | p<0.00001 |
| Bed nucleus of the Stria                  | BSTa         | Left       | 15.09          | p<0.00001 | 15.09          | p<0.00001 |
| Central amygdaloid nucleus, Lateral division | Cel          | Left       | 14.54          | p<0.00001 | 14.54          | p<0.00001 |
| Central amygdaloid nucleus, Medial division | CeM         | Left       | 14.54          | p<0.00001 | 14.54          | p<00001 |
| Ventral pallium                           |              |            |                |         |                |         |
| Balloc medial amygdaloid nucleus          | BM           | Left       | 14.54          | p<0.00001 | 14.54          | p<0.00001 |
| Medical amygdaloid nucleus                | Me           | Left       | 14.54          | p<0.00001 | 14.54          | p<0.00001 |
| Midbrain                                  | MD           | Left       | 5.83           | p<0.00001 | 8.32           | p<0.00001 |
|                                           |              | Right      | 11.07          | p<0.00001 | 8.32           | p<0.00001 |
| Cerebellum                                | Cb           | Left       | 8.38           | p<0.00001 | 14.03          | p<0.00001 |
|                                           |              | Right      | 8.41           | p<0.00001 | 14.03          | p<0.00001 |

Table S3: fMRI activations during low central thalamic (CT), high CT-DBS, low ventral-lateral thalamic (VL) and high VL-DBS

Thalamic DBS-induced fMRI activity during the electrical stimulation block-design experiment, p < 0.05, FWE corrected, ns: non significant.
### Interpretation of the Bayes Factors

| Value | BF10                        | BF01                        |
|-------|-----------------------------|-----------------------------|
| >100  | Obvious evidence for H1     | Obvious evidence for H0     |
| 30 to 100 | Very strong evidence for H1 | Very strong evidence for H0 |
| 10 to 30 | Strong evidence for H1      | Strong evidence for H0      |
| 3 to 10 | Substantial evidence for H1 | Substantial evidence for H0 |
| 1 to 3  | Anecdotal evidence for H1   | Anecdotal evidence for H0   |
| 1     | No evidence for H1 or H0    |                             |
| 1 to 0.33 | Anecdotal evidence for H0   | Anecdotal evidence for H1   |
| 0.33 to 0.10 | Substantial evidence for H0 | Substantial evidence for H1 |
| 0.10 to 0.03 | Strong evidence for H0     | Strong evidence for H1     |
| 0.03 to 0.01 | Very strong evidence for H0 | Very strong evidence for H1 |
| <0.01 | Obvious evidence for H0     | Obvious evidence for H1     |

**Table S4: Interpretation of the Bayes Factors.**

Value of the Bayes Factor BF10 and BF01 to interpret statistical evidence in favor of the H1 or H0 hypothesis. A BF greater than 3 significantly support the evidence of the tested hypothesis.
## Local effect

### Group

| Area                                      | Abbreviation | Hemisphere | T score | p value     | T score | p value     | T score | p value     |
|-------------------------------------------|--------------|------------|---------|-------------|---------|-------------|---------|-------------|
| Orbitofrontal cortex                      | OPro         | Left       | 4.44    | \(p_{FDR} = 0.047\) | n.s     | n.s         | 4.44    | \(p_{FDR} = 0.047\) |
| Orbital Proisocortex                      |              |            |         |             |         |             |         |             |
| Parietal cortex                           |              |            |         |             |         |             |         |             |
| Area 3b of cortex (somatosensory)         | 3b           | Left       | 4.59    | \(p_{FDR} = 0.039\) | n.s     | n.s         | 4.24    | \(p_{FDR} = 0.044\) |
| Parietal area PG#1                        | PG#1         | Right      | n.s     |             | n.s     |             | n.s     |             |
| Visual area 4, Ventral part               | V4V          | Left       | n.s     |             | 4.80    | \(p_{FDR} = 0.049\) | n.s     |             |
| Cingulate cortex                          |              |            |         |             |         |             |         |             |
| Parietal area PE, Cingulate part          | PECg         | Left       | 4.80    | \(p_{FDR} = 0.037\) | n.s     | n.s         | n.s     |             |
| Temporal cortex                           |              |            |         |             |         |             |         |             |
| Fundus of Superior Temporal sulcus        | FST          | Left       | 4.27    | \(p_{FDR} = 0.048\) | n.s     | n.s         | n.s     |             |
| ProKoniocortex, Medial part               | ProKM        | Left       | n.s     |             | n.s     |             | 4.59    | \(p_{FDR} = 0.040\) |
| Temporal ParietoOccipital associated area in STS | TPO    | Right      | n.s     |             | n.s     |             | 4.42    | \(p_{FDR} = 0.040\) |
| Temporoparietal cortex                    | Tpt          | Right      | n.s     |             | n.s     |             | 4.38    | \(p_{FDR} = 0.040\) |
| Occipital cortex                          |              |            |         |             |         |             |         |             |
| Visual area 1 (primary visual cortex)     | V1           | Left       | 4.41    | \(p_{FDR} = 0.047\) | n.s     | n.s         | n.s     |             |
| Striatum                                  |              |            |         |             |         |             |         |             |
| Caudate nucleus                           | Cd           | Right      | 4.28    | \(p_{FDR} = 0.048\) | n.s     | n.s         | n.s     |             |
| Midbrain                                  | MB           | Right      | n.s     |             | n.s     |             | 4.13    | \(p_{FDR} = 0.044\) |

### Table S5: Cerebral activations for the local effect

fMRI activations for the local effect under anesthesia, high central thalamic (CT) DBS and comparison between high CT-DBS > anesthesia. Group results, \(p < 0.05\), FDR corrected, ns: non significant.
### fMRI activations during the auditory “Local-Global” experiment

**Global effect**

| Group          | Awake      | Anesthesia | High CT-DBS | High CT-DBS > Anesthesia |
|----------------|------------|------------|-------------|--------------------------|
| **Parietal cortex** |            |            |             |                          |
| Area 3a of the cortex (somatosensory) | 3a | Right | n.s. | n.s. | 3.66 | p<sub>raw</sub> = 0.023 |
| Area 7a of the cortex (somatosensory) | 7a | Left | 3.9 | p<sub>raw</sub> = 0.031 | 4.17 | p<sub>raw</sub> = 0.013 |
| Precentral area | 46P | Left | n.s. | n.s. | n.s. | n.s. |
| **Cingulate cortex** |            |            |             |                          |
| Area 23c or cortex | 23c | Left | 3.65 | p<sub>raw</sub> = 0.039 | 3.60 | p<sub>raw</sub> = 0.024 |
| Area 23b or cortex | 23b | Right | n.s. | n.s. | n.s. | n.s. |
| **Temporal cortex** |            |            |             |                          |
| Medial Superior Temporal area | MST | Left | 4.01 | p<sub>raw</sub> = 0.019 | 3.24 | p<sub>raw</sub> = 0.049 |
| Lateral orbitofrontal area, Temporal | OFL | Right | n.s. | n.s. | n.s. | n.s. |
| Temporal area 17 | TPO | Left | n.s. | n.s. | n.s. | n.s. |
| Temporal Pole | POM | Left | n.s. | n.s. | n.s. | n.s. |
| **Occipital cortex** |            |            |             |                          |
| Visual area 1 (primary visual cortex) | V1 | Left | n.s. | n.s. | n.s. | n.s. |
| Visual area 2 | V2 | Right | n.s. | n.s. | n.s. | n.s. |
| Visual area 3, Ventral part | V3V | Right | n.s. | n.s. | n.s. | n.s. |
| Visual area 3, Dorsal part | V3D | Right | n.s. | n.s. | n.s. | n.s. |
| Visual area 5A | V5A | Right | n.s. | n.s. | n.s. | n.s. |
### Table S6: Cerebral activations for the global effect

fMRI activations for the global effect in the awake, anesthesia and high central thalamic (CT) DBS condition and comparison between high CT-DBS versus anesthesia. For the global effect, no regions are significantly different for the awake > high CT-DBS comparison. Group results, \( p < 0.05 \), FDR corrected, ns: non significant.
| Level | Cerebral areas labelling using the CIVM macaque brain atlas Revised version |
|-------|--------------------------------------------------------------------------------|
| Abbreviation | Description | Value | Value |
| cortex | prefrontal cortex | 14 | 14 |
| medulla | medulla oblongata | 15 | 15 |
| cerebellum | cerebellum | 16 | 16 |
| thalamus | anterior thalamic nuclei | 17 | 17 |
| thalamus | ventromedial thalamic nucleus, lateral part | 18 | 18 |
| thalamus | ventromedial thalamic nucleus, mediodorsal part | 19 | 19 |
| thalamus | ventral anterior thalamic nuclei | 20 | 20 |
| thalamus | ventral anterior thalamic nuclei, lateral part | 21 | 21 |
| thalamus | ventral anterior thalamic nuclei, mediodorsal part | 22 | 22 |
| thalamus | ventral posterior thalamic nuclei | 23 | 23 |
| hypothalamus | hypothalamus | 24 | 24 |
| cerebellum | dentate nucleus | 25 | 25 |
| cerebellum | lateral vestibular nucleus | 26 | 26 |
| cerebellum | lateral vestibular nucleus | 27 | 27 |
| cerebellum | lateral vestibular nucleus | 28 | 28 |
| cerebellum | lateral vestibular nucleus | 29 | 29 |
| cerebellum | lateral vestibular nucleus | 30 | 30 |
| cerebellum | lateral vestibular nucleus | 31 | 31 |
| cerebellum | lateral vestibular nucleus | 32 | 32 |
| cerebellum | lateral vestibular nucleus | 33 | 33 |
| cerebellum | lateral vestibular nucleus | 34 | 34 |
| cerebellum | lateral vestibular nucleus | 35 | 35 |
| cerebellum | lateral vestibular nucleus | 36 | 36 |
| cerebellum | lateral vestibular nucleus | 37 | 37 |
| cerebellum | lateral vestibular nucleus | 38 | 38 |
| cerebellum | lateral vestibular nucleus | 39 | 39 |
| cerebellum | lateral vestibular nucleus | 40 | 40 |
| cerebellum | lateral vestibular nucleus | 41 | 41 |
| cerebellum | lateral vestibular nucleus | 42 | 42 |
| cerebellum | lateral vestibular nucleus | 43 | 43 |
| cerebellum | lateral vestibular nucleus | 44 | 44 |
| cerebellum | lateral vestibular nucleus | 45 | 45 |
| cerebellum | lateral vestibular nucleus | 46 | 46 |
| cerebellum | lateral vestibular nucleus | 47 | 47 |
| cerebellum | lateral vestibular nucleus | 48 | 48 |
| cerebellum | lateral vestibular nucleus | 49 | 49 |
| cerebellum | lateral vestibular nucleus | 50 | 50 |
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| cerebellum | lateral vestibular nucleus | 137 | 137 |
| cerebellum | lateral vestibular nucleus | 138 | 138 |
| cerebellum | lateral vestibular nucleus | 139 | 139 |
| cerebellum | lateral vestibular nucleus | 140 | 140 |
| cerebellum | lateral vestibular nucleus | 141 | 141 |
| cerebellum | lateral vestibular nucleus | 142 | 142 |
| cerebellum | lateral vestibular nucleus | 143 | 143 |
| cerebellum | lateral vestibular nucleus | 144 | 144 |

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**Note:** The table above provides a list of cerebral areas labelling using the CIVM macaque brain atlas Revised version. Each area is identified by an abbreviation and a description, followed by numeric values representing specific parameters or values.
Table S7: Whole brain areas labelling of the Center for In Vivo Microscopy atlas (CIVM) atlas Revised (CIVM_R) for functional correlations analysis.

Whole brain regions considered for the functional correlations analysis using the macaque CIVM atlas(76) that was revised into CIVM_R to match fMRI spatial resolution. Regions merged together (for instance dorsal, medial and ventral part of the medullic geniculate nucleus in the original CIVM atlas into medullic geniculate nucleus) share the same abbreviation and value in the CIVM_R. Brackets represent the biggest regions unified. Empty cells stands for deleted regions.