

D8.8.2 SEEGMIP database
(D8.8.2 - SGA2)

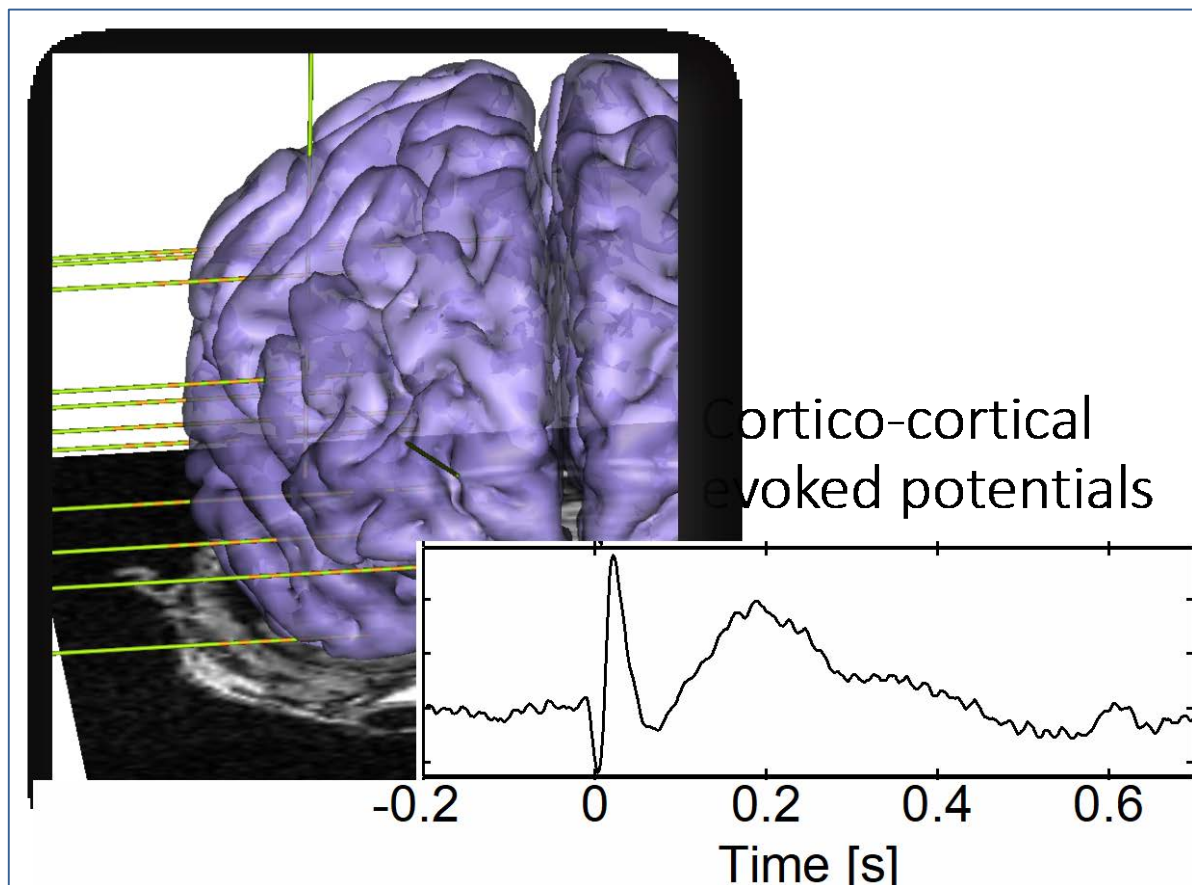


Figure 1: Computerised representation of intracranial SEEG electrodes and stimulation data.

The output of this Deliverable is a fully anonymised database in BIDS-iEEG format that contains neurophysiological data obtained in implanted epileptic patients who were candidates to resective surgery. Direct cortical stimulations are used for epilepsy surgery and generate cortico-cortical evoked potentials (CCEPS) that can be used for developing whole brain models.



| | | | |
|-------------------------------|--|-----------------------|--------------------------|
| Project Number: | 785907 | Project Title: | Human Brain Project SGA2 |
| Document Title: | D8.8.2 SEEGMIP database | | |
| Document Filename: | D8.8.2 (D55.2 D125) SGA2 M22 ACCEPTED 200731.docx | | |
| Deliverable Number: | SGA2 D8.8.2 (D55.2, D125) | | |
| Deliverable Type: | data sets, microdata, etc | | |
| Work Packages: | WP8.8 | | |
| Key Result(s): | KR8.3 | | |
| Dissemination Level: | PU = Public | | |
| Planned Delivery Date: | SGA2 M22 / 31 Jan 2020 | | |
| Actual Delivery Date: | SGA2 M22 / 31 Jan 2020; Accepted 31 Jul 2020 | | |
| Author(s): | Olivier DAVID, UGA (P125) Blandine CHANTELOUP-FORET, UGA (P125) Maciej JEDYNAK, UGA (P125) Anthony BOYER, CHUGA (P126) Viateur TUYSIENGE, CHUGA (P126) Carole SAUBAT-GUIGUI, CHUGA (P126) Raouf ZOUGLECH (P126) Philippe KAHANE, CHUGA (P126) Lorella MINOTTI, CHUGA (P126) Stefano FRANCIONE, CERCE (P128) Christian BENAR, AMU (P78) Aude JEGOU, AMU (P78) Agnès TREBUCHON, AMU (P78) Fabrice BARTOLOMEI, AMU (P78) Andreas SCHULZE-BONHAGE, UKLFR (P127) Sylvain RHEIMS, UCBL (P108) | | |
| Compiled by: | Olivier DAVID, UGA (P125) | | |
| Contributor(s): | Olivier DAVID, UGA (P125) Anthony BOYER, CHUGA (P126) Aude JEGOU, AMU (P78) | | |
| SciTechCoord Review: | Martin TELEFONT, EPFL (P1) | | |
| Editorial Review: | Annemieke MICHELS, EPFL (P1) | | |
| Description in GA: | DATA | | |

| | |
|-----------------------|--|
| Abstract: | The output of this Deliverable is a fully anonymised database in BIDS-IEEG format that contains functional (neurophysiological) data obtained in implanted epileptic patients who were candidates to resective surgery. Direct cortical stimulations are used for epilepsy surgery and generate cortico-cortical evoked potentials (CCEPS) that can be used for developing whole brain models. |
| Keywords: | Cortico-cortical evoked potential; direct electrical stimulation; connectivity; epilepsy |
| Target Users/Readers: | Epileptologists, researchers, computational neuroscience community, neuroimaging community |

Table of Contents

| | |
|---|---|
| 1. Overview | 5 |
| 2. Experimental methods and materials | 5 |
| 2.1 Imaging | 5 |
| 2.2 Neurophysiology | 5 |
| 3. Computational methods | 6 |
| 3.1 Data preparation | 6 |
| 3.1.1 Imaging | 6 |
| 3.1.2 Neurophysiology | 6 |
| 3.2 Data format | 6 |
| 3.3 How the database was generated | 6 |
| 4. Validation and Impact | 7 |
| 4.1 Validation | 7 |
| 4.2 Database re-use | 7 |
| 4.3 Potential Use of Output(s) | 7 |
| 5. Publications | 7 |
| 6. References | 8 |

Table of Figures

| | |
|--|---|
| Figure 1: Computerised representation of intracranial SEEG electrodes and stimulation data | 1 |
|--|---|

1. Overview

Single-pulse direct electrical stimulation of cortical regions in patients, who suffer from focal drug-resistant epilepsy, explored using intracranial electrodes, induces electrophysiological responses. Such cortico-cortical evoked potentials (CCEP) can be used to infer functional and anatomical brain connectivity (Trebault et al., 2018). This is directly relevant to the specific HBP objective “FO2 – Gather, organise and disseminate data describing the brain and its diseases”, including atlas of the human brain.

This Deliverable is the main Deliverable of WP8.8. It comprises a fully anonymised extract of a part of the F-TRACT database on intracortical stimulations in epileptic patients implanted with SEEG (stereotactic electroencephalography) electrodes (project funded by ERC 2014-2019, <https://f-tract.eu/>) in BIDS-iEEG format. This database can thus contribute to the development and validation of human brain atlases and modelling by bringing relevant information from CCEPs.

In this report, we summarise the database specification and how it was created. This refers directly to Component C3067 “CCEP database”. Below we refer to “CCEP database” instead of “SEEGMIP database” (title of this Deliverable), as it is more explicit on its content. The DOI of the database is 10.25493/SV5Z-FSB.

2. Experimental methods and materials

Data were initially collected for the F-TRACT study, following the ethical procedures for conducting international multicentre post-processing of clinical data defined by the International Review Board at INSERM (protocol number: INSERM IRB 14-140).

Methods and materials for recording the data differed between Epilepsy surgery units, and followed strict clinical procedures as defined in every hospital. No standardisation of the recording protocol was performed for research, as research encompasses only data re-use. We summarise below the common properties of the data.

2.1 Imaging

For each patient, an anatomical MRI (most of the time T1 contrast, and/or T2 contrast, and/or FLAIR contrast), an image with SEEG electrodes (T1 MRI or CT scan) and an implantation scheme were obtained in order to localise SEEG electrodes. The average number of recording bipolar contacts per patient was about 150.

2.2 Neurophysiology

iEEG recordings and low-frequency stimulations were performed as part of a pre-surgical evaluation of drug-resistant epilepsy. In the database, we considered only stimulations performed at low frequency (<5 Hz) for a limited amount of time per stimulated area (typically less than 40 pulses). Bipolar stimuli were delivered using a constant current rectangular pulse generator designed for a safe diagnostic stimulation of the human brain, according to parameters proved to produce no structural damage. All stimulations were performed between two contiguous contacts in the grey matter, and sometimes in the white matter, using monophasic or biphasic pulses. Pulse width and intensity of stimulation could vary (typically 1 ms duration pulses at 3 mA). The clinical goals of the stimulations were the reproduction of the aura, the induction of an electroclinical seizure, and/or the localisation of an eloquent cortical area that has to be spared during surgery. Signals were acquired at a sampling frequency which varied between 512 Hz and 2048 Hz.

3. Computational methods

We summarise here the main steps required to generate the database. We refer to (Trebaul *et al.*, 2018) for full scientific details.

3.1 Data preparation

3.1.1 *Imaging*

The electrode contacts were localised and anatomically labelled using the IntrAnat Electrodes software (Deman *et al.*, 2018) compatible with the BrainVisa software (Rivière *et al.*, 2009). Briefly, the volumetric images acquired before and after the electrodes implantation were co-registered using a rigid-body transformation computed either by ANTs (Avants *et al.*, 2011) or SPM12 (Ashburner, 2009) software. The grey and white matter volumes were segmented from the pre-implantation MRI using Morphologist as included in BrainVisa (<http://brainvisa.info>). The electrode contact positions were computed in the native and MNI referentials using the spatial normalisation of SPM12 software. For each patient, cortical parcels were obtained for different anatomical atlases defined either in the MRI native space (MarsAtlas (Auzias *et al.*, 2016), Freesurfer (Destrieux *et al.*, 2010), Lausanne Atlas (Hagmann *et al.*, 2008)) or in the MNI space (Brodmann (Brodmann, 1909), Automated Anatomical Labeling AAL (Tzourio-Mazoyer *et al.*, 2002), MaxProbMap (Hammers *et al.*, 2003), and Human Connectome Project (Glasser *et al.*, 2016)). Each electrode contact was assigned to the grey or white matter and to specific anatomical parcels by taking the most frequent voxel label in a sphere of 3 mm radius around each contact centre (Deman *et al.*, 2018). For each participant, the database does not contain imaging data but a tsv file summarising contact's anatomical information.

3.1.2 *Neurophysiology*

The SEEG signals were pre-processed automatically using a pipeline composed of the following steps, supervised at the end for data quality check: i) detection and cropping of each stimulation run from stimulation artefacts in raw iEEG files (i.e. a set of pulses consecutively applied between the same pair of contacts); ii) bad channels detection with a machine learning approach (Tuyisenge *et al.*, 2018). The detection of bad channels was based on a supervised machine-learning model trained on a learning database with channels already classified by experts and using a set of features quantifying the signal variance, spatio-temporal correlation and non-linear properties.

3.2 Data format

The database was created according to the BIDS-iEEG specification that we co-developed as member of the BIDS international community. The BIDS-iEEG specification is available in Holdgraf *et al.*, 2019 (P2033).

3.3 How the database was generated

Operationally, the BIDS-iEEG database was generated on the F-TRACT infrastructure of UGA (P135), as an independent folder created by a F-TRACT to BIDS converter developed by AMU (P78) for UGA (P135)'s use. F-Tract to BIDS converter is a module of BIDS Manager software developed by AMU (P78) to organise any database in BIDS format (paper submitted for publication). The BIDS Manager has been uploaded in the HBP Software catalogue (BIDS Manager and Pipeline, version 0.2.4; <https://collab.humanbrainproject.eu/#/collab/19/nav/2108?state=software,Bids-Manager>).

A tsv file contains some minimal population data (participant code, age category, sex, handedness, epilepsy type).

To avoid any chance of de-identification, several measures were considered when extracting the F-TRACT database to iEEG-BIDS: 1) meaningless participant code of 12 digits was generated using an encryption key; 2) imaging data were not included; 3) clinical information were very much restricted.

4. Validation and Impact

4.1 Validation

The database is currently used by WP8.8 for developing SEEG MIP software. Modelling methods of CCEP are being developed by UKLFR (P127). Impact of temporal lobe epilepsy on CCEPs is being investigated by UKLFR (P127). Relationships between CCEPs and sensory motor responses are being studied by CNR (P12). CCEPs are being compared with diffusion tractography by UGA (P125) and CEA (P11). In addition, it has been used by UGA (P125) to develop the F-TRACT atlas of cortico-cortical connectivity, available at f-tract.eu/atlas (Trebault et al, 2018; and a manuscript in preparation).

4.2 Database re-use

The CCEP database can be read with any research software able to upload a BIDS structure, such as Brainstorm, NME or Fieldtrip. During SGA3, it should evolve within the Human Intracerebral Platform (HIP) to be created in EBRAINS, with a portfolio of software and tutorials to facilitate its re-use.

The Knowledge Graph link to the dataset card (containing the metadata of the dataset):

<https://kg.ebrains.eu/search/instances/Dataset/ebe50517-41d5-4029-9355-04f1e49e23c8>

The data DOI is: 10.25493/SV5Z-FSB.

4.3 Potential Use of Output(s)

The CCEP database contains unique information on dynamical properties of the white matter tracts. It can thus be used for developing brain atlases and whole brain models.

5. Publications

P2280 Job AS, David O, Minotti L, Bartolomei F, Chabardès S, Kahane P. Epileptogenicity maps of intracerebral fast activities (60-100 Hz) at seizure onset in epilepsy surgery candidates. *Front. Neurosci.* 2019 Nov 28;10:1263.

P2033 Holdgraf C, Appelhoff S, Bickel S, Bouchard K, D'Ambrosio S, David O, Devinsky O, Dichter B, Flinker A, Foster BL, Gorgolewski KJ, Groen I, Groppe D, Gunduz A, Hamilton L, Honey C, Jas M, Knight R, Lachaux JP, Lau JC, Lundstrom BN, Miller KJ, Ojemann JG, Oostenveld R, Petridou N, Piantoni G, Pigorini A, Pouratian N, Ramsey NF, Stolk A, Swann N, Tadel F, Voytek B, Wandell BA, Winawer J, Zehl L, Hermes D. BIDS-iEEG: an extension to the brain imaging data structure (BIDS) specification for human intracranial electrophysiology. *Sci Data.* 2019 Jun 25;6(1):102.

6. References

- Ashburner, J., 2009. Computational anatomy with the SPM software. *Magn Reson Imaging* 27, 1163-1174. doi:10.1016/j.mri.2009.01.006
- Auzias, G., Coulon, O., Brovelli, A., 2016. MarsAtlas: A cortical parcellation atlas for functional mapping. 37, 1573-1592. doi:10.1002/hbm.23121
- Avants, B.B., Tustison, N.J., Wu, J., Cook, P.A., Gee, J.C., 2011. An open source multivariate framework for n-tissue segmentation with evaluation on public data. *Neuroinformatics* 9, 381-400. doi:10.1007/s12021-011-9109-y
- Brodmann, K., 1909. *Vergleichende Lokalisationslehre der Grosshirnrinde*. Johann Ambrosius Barth, Leipzig.
- David, O., Job, A.-S., De Palma, L., Hoffmann, D., Minotti, L., Kahane, P., 2013. Probabilistic functional tractography of the human cortex. *NeuroImage* 80, 307-317. doi:10.1016/j.neuroimage.2013.05.075
- Deman, P., Bhattacharjee, M., Rivière, D., Tadel, F., Cointepas, Y., David, O., 2018. IntraAnat Electrodes: A free database software to visualize intracranial electroencephalographic data in patient's referential and to initiate group studies. *Front. Neuroinform.* 12, 40.
- Hammers, A., Allom, R., Koeppe, M.J., Free, S.L., Myers, R., Lemieux, L., Mitchell, T.N., Brooks, D.J., Duncan, J.S., 2003. Three-dimensional maximum probability atlas of the human brain, with particular reference to the temporal lobe 19, 224-247. doi:10.1002/hbm.10123
- Rivière, D., Geffroy, D., Denghien, I., Souedet, N., Cointepas, Y., 2009. BrainVISA: an extensible software environment for sharing multimodal neuroimaging data and processing tools. *NeuroImage* 47, S163. doi:10.1016/S1053-8119(09)71720-3
- Roehri N, Medina Villalon S, Jegou A, Colombet B, Ponz A, Bénar C. Data transfer, collection and organization for multi-centric clinical studies. INCF-France Workshop on Data Management and Sharing in Neuroinformatics. Presentation. May 21, 2019. Marseille, France. <http://www.neuroinfo.fr/#!/workshops/geant2019>
- Trebaul, L., Deman, P., Tuyisenge, V., Jedynak, M., Hugues, E., Rudrauf, D., Bhattacharjee, M., Tadel, F., Chanteloup-Forêt, B., Saubat, C., Reyes Mejia, G.C., Adam, C., Nica, A., Pail, M., Dubeau, F., Rheims, S., Trébuchon, A., Wang, H., Liu, S., Blauwblomme, T., Garces, M., De Palma, L., Valentín, A., Metsahonkala, E.-L., Petrescu, A.M., Landré, E., Szurhaj, W., Hirsch, E., Valton, L., Rocamora, R., Schulze-Bonhage, A., Mîndruță, I., Francione, S., Maillard, L., Taussig, D., Kahane, P., David, O., 2018. Probabilistic functional tractography of the human cortex revisited. *NeuroImage* 181, 414-429. doi:10.1016/j.neuroimage.2018.07.039
- Tuyisenge, V., Trebaul, L., Bhattacharjee, M., Chanteloup-Forêt, B., Saubat-Guigui, C., Mîndruță, I., Rheims, S., Maillard, L., Kahane, P., Taussig, D., David, O., 2018. Automatic bad channel detection in intracranial electroencephalographic recordings using ensemble machine learning. *Clin Neurophysiol* 129, 548-554. doi:10.1016/j.clinph.2017.12.013
- Tzourio-Mazoyer, N., Landeau, B., Papathanassiou, D., Crivello, F., Etard, O., Delcroix, N., Mazoyer, B., Joliot, M., 2002. Automated anatomical labeling of activations in SPM using a macroscopic anatomical parcellation of the MNI MRI single-subject brain. *NeuroImage* 15, 273-289. doi:10.1006/nimg.2001.0978