BIDS Extension Proposal 8 (BEP008): Magnetoencephalography (MEG)

version 1.0

1. Table of contents

2. Preliminary clarifications

This specification extends the Brain Imaging Data Structure (BIDS) Specification for integration of magnetoencephalography data. Please refer to BIDS specification document for context and general guidelines (definitions, units, directory structure, etc.):
https://docs.google.com/document/d/1HFUkAEE-pB-angVcYe6pf_-fVf4sCpOHKesUvfb8Grc

The keywords "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [RFC2119].

Terminology that will be used in the following includes:

- Subject = human being that is scanned
- Visit = a non-intermittent period in which the subject is in the building
- Session = a non-intermittent period in which the subject is in the scanner
- Run = a non-intermittent period in which the subject is continuously being scanned
- Task = instructions (and corresponding stimulus material) that is performed by the subject
- Responses = recorded behaviour of the subject in relation to the task

3. BIDS-MEG

Unprocessed MEG data must be stored in the native file format of the respective manufacturers. The native file format is used as there is currently no widely accepted standard file format in the community, and conversion risks the loss of crucial metadata specific to manufacturers and specific MEG systems. We also encourage users to provide additional meta information extracted from the manufacturer specific data files in a sidecar JSON file. This allows for easy searching and indexing of key metadata elements without needing to parse the various proprietary (typically binary) native data files. Other relevant files should be included alongside the MEG data.

Throughout the document **[.]** indicate optional fields.

3.1. MEG Template

```
sub-<participant_label>/
  [ses-<label>]/
    anat/
      ...
  [ses-<label>]/
    [sub-<participant_label>[_ses-<label>]_scans.tsv]
    eeg/
      ...
    meg/
      [sub-<participant_label>[_ses-<label>][_acq-<label>]_photo.jpg]
```

```
[sub-<participant_label>[_ses-<label>][_acq-<label>]_fid.json]
[sub-<participant_label>[_ses-<label>][_acq-<label>]_fidinfo.txt]
[sub-<participant_label>[_ses-<label>][_acq-<label>]_headshape.<manufacturer_specific_extension>]


sub-<participant_label>[_ses-<label>]_task-<task_label>[_acq-<label>][_run-<index>][_proc-<label>]_meg.<manufacturer_specific_extension>
[sub-<participant_label>[_ses-<label>]_task-<task_label>[_acq-<label>][_run-<index>][_proc-<label>]_meg.json]
[sub-<participant_label>[_ses-<label>]_task-<task_label>[_acq-<label>][_run-<index>][_proc-<label>]_channels.tsv]
```

MEG data of any kind, including but not limited to task-based, resting state, and noise recordings. File labelling follows the same general rules as outlined for "8.4. Task (including resting state) imaging data" of the The Brain Imaging Data Structure (BIDS) Specification, with the only differences being that:

1. The "rec" (reconstruction algorithm) label does not apply and is omitted.
2. The "_bold" suffix is replaced with "_meg"
3. The .nii[.gz] extension is replaced with a manufacturer specific extension (e.g., .fif or .ds)
4. A "proc" (processed) label has been added, especially useful for files coming from Maxfilter (e.g. sss, tsss, trans, quat, mc, etc.)

Also worth noting is that some manufacturer file formats are in fact directories (e.g., CTF's .ds format, 4D/BTi) containing multiple files. See Appendix I to see particular examples for different MEG systems.

3.2. RUN specific files

A number of files may be included alongside each MEG recording data file (i.e. for every run). These files contain information that partially can be extracted from the raw data files. Having this information also in the json/tsv files facilitates querying large collections of MEG datasets. These include:

1. ***_meg.json:** A JSON document containing metadata about the MEG recording data file.
2. ***_channels.tsv:** A channels .tsv file listing channel names, types, and other optional information.

For behavioural data acquired independently of the MEG or MRI recording, see section "8.7 Behavioral experiments (with no MRI)" of the The Brain Imaging Data Structure (BIDS) Specification.

3.2.1. Sidecar JSON document (*_meg.json)

General fields, shared with MRI BIDS:

- `TaskName`: Name of the task (for resting state use the "rest" prefix). No two tasks should have the same name. Task label is derived from this field by removing all non alphanumeric ([a-zA-Z0-9]) characters.
- `SamplingFrequency`: Sampling frequency (in Hz) of the recording (e.g. 2400Hz)

- `Manufacturer`: Manufacturer of the MEG system (e.g. "CTF")
- `[ManufacturersModelName]`: Manufacturer's designation of the MEG scanner model (e.g. "CTF-275"). See Appendix with preferred names (read field from MEG data).
- `[TaskDescription]`: Longer description of the task.
- `[Instructions]`: Text of the instructions given to participants before the scan. This is not only important for behavioural or cognitive tasks but also in resting state paradigms (e.g. to distinguish between eyes open and eyes closed).
- `[CogAtlasID]`: URL of the corresponding Cognitive Atlas Task term (e.g. Resting State with eyes closed "http://www.cognitiveatlas.org/term/id/trm_54e69c642d89b")
- `[CogPOID]`: URL of the corresponding CogPO term
- `[InstitutionName]`: The name of the institution in charge of the equipment that produced the composite instances.
- [`InstitutionAddress`]: The address of the institution in charge of the equipment that produced the composite instances.
- [`DeviceSerialNumber`]: The serial number of the equipment that produced the composite instances. A pseudonym can also be used to prevent the equipment from being identifiable, as long as each pseudonym is unique within the dataset.

Specific MEG fields:

- `MEGChannelCount`: Number of MEG channels included in the recording (e.g. 275).
- `MEGREFChannelCount`: Number of MEG reference channels included in the recording (e.g. 23). For systems without such channels (e.g. Neuromag Vectorview), set it to 0.
- `EEGChannelCount`: Number of EEG channels included in the recording (e.g. 21).
- `EOGChannelCount`: Number of EOG channels included in the recording (e.g. 2).
- `ECGChannelCount`: Number of ECG channels included in the recording (e.g. 1).
- `EMGChannelCount`: Number of EMG channels included in the recording (e.g. 2).
- `MiscChannelCount`: Number of miscellaneous analog channels for auxiliary signals
- `TriggerChannelCount`: Number of channels for digital (TTL bit level) triggers.
- `[PowerLineFrequency]`: Frequency (in Hz) of the power grid where the MEG scanner is installed (i.e. 50 or 60).
- `[EEGPlacementScheme]`: Placement scheme of the EEG electrodes. Either the name of a standardised placement system (e.g. "10-20") or a list of standardised electrode positions (e.g. ["Cz", "Pz"]).
- `[EEGReference]`: Description of the type of EEG reference used (e.g. "M1" for left mastoid, "average", or "longitudinal bipolar")
- `[DewarPosition]`: Position of the dewar during the MEG scan (e.g. "upright" or "supine")
- `[SoftwareFilters]`: List of temporal and/or spatial software filters applied or ideally key:value pairs of pre-applied software filters and their parameter values (e.g. {"SSS": {"frame": "head", "badlimit": 7}}, {"SpatialCompensation": {"GradientOrder": Order of the gradient compensation}})
- `[RecordingDuration]`: Length of the recording in seconds (e.g. 3600)
- `[RecordingType]`: "continuous", "epoched"
- `[EpochLength]`: Duration of individual epochs in seconds (e.g. 1). If recording was continuous, set value to Inf.
- `[DeviceSoftwareVersion]`: Manufacturer's designation of the acquisition software.
- `[ContinuousHeadLocalization]`: Boolean (true or false) value indicating whether continuous head localisation was performed or not.

- `[CoilFrequency]`: List of frequencies used by the head localisation coils ('HLC' in CTF systems, 'HPI' in Elekta, 'COH' in 4D/BTi) that track the subject's head position in the MEG helmet (e.g. [293, 307, 314, 321])
- `[MaxMovement]`: Maximum head movement (in mm) during the recording as measured by the head localisation coils (e.g., 4.8).
- `[SubjectArtefactDescription]`: Freeform description of the observed subject artefact and its possible cause (e.g. "Vagus Nerve Stimulator", "non-removable implant"). If this field is left empty, it will be interpreted as absence of artifacts.
- `[DigitizedLandmarks]`: Boolean ("true" or "false") value indicating whether anatomical landmark points are contained within this recording.
- `[DigitizedHeadPoints]`: Boolean ("true" or "false") value indicating whether head points outlining the scalp surface are contained within this recording.

Example:

```
{
	"TaskName": "rest",
	"SamplingFrequency": 2400,
	"Manufacturer": "CTF",
	"ManufacturerModelName": "CTF-275",
	"InstitutionName": "Stanford University",
	"InstitutionAddress: "450 Serra Mall, Stanford, CA 94305-2004, USA"
	"DeviceSerialNumber": "11035"
	"MEGChannelCount": 270,
	"MEGREFChannelCount": 26,
	"EEGChannelCount": 0,
	"EOGChannelCount": 2,
	"ECGChannelCount": 1,
	"EMGChannelCount": 0,
	"PowerLineFrequency": "60",
	"EEGPlacementScheme": "",
	"EEGReference": "",
	"DewarPosition": "Upright",
	"SoftwareFilters": {
		"SpatialCompensation": {"GradientOrder": "3rd"}
	},
	"AssociatedAnatomicalMRI": "",
	"RecordingStart": "12:33",
	"RecordingDuration": 600,
	"RecordingType": "continuous",
	"EpochLength": 0,
	"TriggerChannels": "",
	"MiscChannels": "",
	"DeviceSoftwareVersion": "Acq 5.4.2-linux-20070507",
	"TaskInstructions": "",
	"TaskDescription": "",
	"ContinuousHeadLocalization": true,
	"CoilFrequency": [1470,1530,1590],
	"MaxMovement": "",
	"SubjectArtefact": "",
	"SubjectArtefactDescription": "",
	"DigitizedLandmarks": true,
	"DigitizedHeadPoints": true
}
```

Note that the date time information should be stored in the Study key file (scans.tsv), see section 3.4.1. Scans.tsv. As it is indicated there, date time information should be expressed in the following format YYYY-MM-DDThh:mm:ss (ISO8601 date-time format). For example: 2009-06-15T13:45:30. It does not need to be fully detailed, depending on REB/IRB policy.

3.2.2. Channels description table (*_channels.tsv)

Although this information can be extracted from the MEG recording, listing it in a simple .tsv document makes it easy to browse or search. The two required columns are channel `name` and channel `type`. Channels should appear in the table in the same order they do in the MEG data file. Any number of additional columns may be provided to provide additional information about the channels.

Channel description table fields:

- `name`: Label of the channel .
- `type` : Type of channel, see below for adequate keywords in this field.
- `[description]`: Brief description of the channel.
- `[sampling_frequency]`: Sampling rate of the channel in Hz.
- `[low_cutoff]`: Frequencies used for the high pass filter applied to the channel in Hz. If no high pass filter applied, use `0`.
- `[high_cutoff]`: Frequencies used for the low pass filter applied to the channel in Hz. If no low pass filter applied, use `Inf`. Note that anti-alias is a low pass filter, specify its frequencies here if applicable.
- `[notch]`: Frequencies used for the notch filter applied to the channel, in Hz. If no notch filter applied, use `0`.
- `[software_filters]`: List of temporal and/or spatial software filters applied (e.g. "SSS", "`SpatialCompensation`"). Note that, parameters should be defined in the general meg sidecar .json file.
- [`status`]: State of the channel `(good/bad)`. Indicate a channel is bad if it is e.g., excessively noisy or broken, throughout the whole recording.

Example:

name	**type**	**description**	**sampling_frequency**	**...**
UDIO001	TRIG	analogue trigger	1200	
MLC11-4408	MEG	sensor 1st-order grad	1200	

...	**low_cutoff**	**high_cutoff**	**notch**	**software_filters**	**status**
	0.1	300	0	none	good
	0	Inf	50	SSS	bad

Possible keywords for field `type`:

- `MEGMAG`: MEG magnetometers
- `MEGGRAD`: MEG gradiometers
- `MEGREF`: MEG reference sensors
- `EEG`: ElectroEncephaloGram
- `EOG`: ElectroOculoGram (eyes)
- `ECG`: ElectroCardioGram (`heart`)

- `EMG:` ElectroMyoGram (muscle)
- `TRIG:` Triggers
- `AUDIO:` Audio signal
- `PD:` Photodiode
- `ET:` Eye Tracker
- `MISC:` Miscellaneous

Some examples of `keywords` for field `description`:

- stimulus, response, vertical EOG, horizontal EOG, skin conductance, sats, intracranial, eyetracker

Example:

name	type	description
VEOG	EOG	vertical EOG
FDI	EMG	left first dorsal interosseous
UDIO001	TRIG	analogue trigger
UADC001	AUDIO	envelope of audio signal sent to the subject

3.2.3. Task events (*_events.tsv)

Task events are part of the general (see section 8.5 from The Brain Imaging Data Structure (BIDS) Specification)

Template:

```
sub-<label>/[ses-<_label>]
   meg/
      <matches>_events.tsv
```

Where `<matches>` corresponds to task file name. For example: `sub-control01_task-nback`

3.3. SESSION specific files

A number of optional files may be included once for a given MEG session. These include:

1. ***_fid.json:** A JSON document specifying the coordinates of the anatomical landmarks and the head localization coils for the MEG session in relation to a given anatomical MRI.
2. ***_photo.jpg:** Photos of the anatomical landmarks and/or head localisation coils on the subject's head. ***_fidinfo.txt:** A freeform text document documenting where the anatomical landmarks and the head localization coils were placed.
3. ***_headshape.<manufacturer_specific_format>:** Scalp surface points and EEG electrode position digitisation files.

Note in case of conflict between fields of different runs/sessions, it should be applied the inheritance principle (the description file closer to the data, is the one that prevails), see section '3.5 The Inheritance Principle' of the The Brain Imaging Data Structure (BIDS) Specification

3.3.1. Anatomical landmark and head localization coordinates JSON document (*_fid.json)

MEG and EEG sensors:

- `MEGCoordinateSystem`: this refers to how the coordinates of the MEG sensors are to be interpreted, can be system (=dewar), (e.g. “CTF gradiometer”, “CTF MRI”, “Neuromag/Elekta”, “4D/BTi”, “Yokogawa”, “Chieti ITAB”, “DICOM”, “Analyze”, “Talairach-Tournoux”, “MNI”, “NIfTI”, “freesurfer”, “Paxinos-Franklin”, “Allen Institute”, “brainstorm_mri” or "other"). See 7. Appendix: preferred names of Coordinate systems for more details. If "other" use the “MEGCoordinateSystemDescription” field for more details.
- `MEGCoordinateUnits`: Units in which the coordinates that are listed in the field ‘MEGCoordinateSystem’ are represented, e.g. “m”, “cm”, “mm”.
- `[MEGCoordinateSystemDescription]`: Freeform description of the coordinate system. May also include a link to a documentation page or paper describing the system in greater detail.

- `[EEGCoordinateSystem]`: this refers to how the coordinates of the EEG sensors are to be interpreted.
- `[EEGCoordinateUnits]`: Units in which the coordinates that are listed in the field ‘EEGCoordinateSystem’ are represented, e.g. “m”, “cm”, “mm”.
- `[EEGCoordinateSystemDescription]`: Freeform description of the coordinate system. May also include a link to a documentation page or paper describing the system in greater detail.

Anatomical MRI:

- `IntendedFor`: Path relative to the subject subfolder pointing to the anatomical MRI to be used with the MEG recording. The path needs to use forward slashes instead of backward slashes (e.g. "ses-<label>/anat/sub-01_T1w.nii.gz")
- `AnatomicalMRICoordinateSystem`: MRI coordinate system used to represent the coordinates that are listed in the other fields in this file, according to the software used (e.g. “CTF gradiometer”, “CTF MRI”, “Neuromag/Elekta”, “4D/BTi”, “Yokogawa”, “Chieti ITAB”, “DICOM”, “Analyze”, “Talairach-Tournoux”, “MNI”, “NIfTI”, “freesurfer”, “Paxinos-Franklin”, “Allen Institute”, “brainstorm_mri” or "other"). See 7. Appendix: preferred names of Coordinate systems for more details. If "other" use the “AnatomicalMRICoordinateSystemDescription” field for more details.
- `AnatomicalMRICoordinateUnits`: Units in which the coordinates that are listed in the other fields in this file are represented, e.g. “m”, “cm”, “mm”.
- `[AnatomicalMRICoordinateSystemDescription]`: Freeform description of the coordinate system. May also include a link to a documentation page or paper describing the system in greater detail.

Fiducials (HLC/HPI Coils):

- `CoilCoordinates`: Key:value pairs describing head localisation coil labels and their coordinates relative to the associated anatomical MRI. (e.g. {"NAS": [127,213,139], "LPA": [52,113,96], "RPA": [202,113,91]}). Note that coils are not always placed at a location that has a known anatomical name (e.g. Elekta, Yokogawa), in that case generic labels could be used (e.g. {"coil1": [122,213,123], "coil2": [67,123,86], "coil3": [219,110,81]})
- `CoilCoordinateSystem`: this refers to how the coordinates of the coils are to be interpreted

- `CoilCoordinateUnits`: Units in which the coordinates that are listed in the field 'CoilCoordinateSystem' are represented, e.g. "m", "cm", "mm".
- `[CoilCoordinateSystemDescription]`: Freeform description of the coordinate system. May also include a link to a documentation page or paper describing the system in greater detail. See 3.3.3. Fiducials information for more details.

Anatomical landmarks:

- `LandmarkCoordinates`: Key:value pairs of any number of additional anatomical landmarks and their coordinates relative to the associated anatomical MRI (e.g. {"AC": [127,119,149], "PC": [128,93,141], "IH": [131,114,206]}, or {"NAS": [127,213,139], "LPA": [52,113,96], "RPA": [202,113,91]})
- `LandmarkCoordinateSystem`:
- `LandmarkCoordinateUnits`: Units in which the coordinates that are listed in the field 'LandmarkCoordinateSystem' are represented, e.g. "m", "cm", "mm".
- `[LandmarkCoordinateSystemDescription]`: Freeform description of the coordinate system. May also include a link to a documentation page or paper describing the system in greater detail. See 3.3.3. Fiducials information for more details.

Digitized head points:

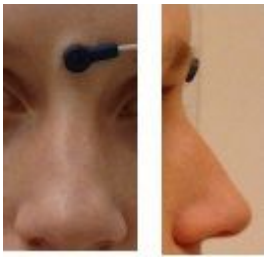
- `[DigitizedHeadPoints]`: Relative path to the file containing the locations of the associated digitized head points collected at the session (e.g., "sub-01_headshape.pos"). Especially important for CTF and 4D/BTi systems.
- `[DigitizedHeadPointsCoordinateSystem]`:
- `[DigitizedHeadPointsCoordinateUnits]`: Units in which the coordinates that are listed in the field 'DigitizedHeadPointsCoordinateSystem' are represented, e.g. "m", "cm", "mm".
- `[DigitizedHeadPointsCoordinateSystemDescription]`: Freeform description of the coordinate system. May also include a link to a documentation page or paper describing the system in greater detail.

3.3.2. Photos of the anatomical landmarks and/or head localization coils (*_photo.jpg)

Photos of the anatomical landmarks and/or head localisation coils on the subject's head. If the coils are not placed on the landmarks, the landmarks can be marked with a felt-tip marker. The photo's may need to be cropped and blurred to conceal identifying features—or entirely omitted—prior to sharing, depending on obtained consent.

Example of the NAS fiducial placed between the eyebrows rather than at the nasion:

`sub-0001_ses-001_acq-NAS_photo.jpg`



3.3.3. Fiducials information (*_fidinfo.txt)

A freeform text document documenting where the anatomical landmarks and head localization coils were placed. This may be copied over from subject to subject if practice is consistent within a group or centre. This document could, for instance, describe whether the true left and right pre-auricular points were used, or the junction between the tragus and the helix, the ear canal, or other points close to the ears.

Example:

See more information on how anatomical landmarks are defined:
http://www.fieldtriptoolbox.org/faq/how_are_the_lpa_and_rpa_points_defined

See more information on coordinate systems for coregistration:
http://www.fieldtriptoolbox.org/faq/how_are_the_different_head_and_mri_coordinate_systems_defined
http://neuroimage.usc.edu/brainstorm/CoordinateSystems

3.3.4. Digitalization files (*_headshape.<manufacturer_specific_format>)

Head points and EEG sensor position digitisation files. This may be one file containing both the EEG sensor positions and a sampling of head points or two separate files (i.e. one for head points and one for EEG sensor positions). These files are stored in the original manufacturer specific format.

3.3.5. Acquisition time (scans.tsv)

See section "8.10 Scans key file" of The Brain Imaging Data Structure (BIDS) Specification for a detailed description.
Optional: Yes

Template:

```
sub-<participant_label>/[ses-<session_label>/]
       sub-<participant_label>[_ses-<session_label>]_scans.tsv
```

Example:

filename	**acq_time**
meg/sub-control01_task-rest_meg.fif	1877-06-15T13:45:30
meg/sub-control01_task-motor_meg.fif	1889-06-15T13:55:33

3.3.6. Sessions file (sessions.tsv)

See section "9.1 Sessions file" of The Brain Imaging Data Structure (BIDS) Specification for a detailed description.
Optional: Yes

Template:

```
sub-<participant_label>/[ses-<session_label>/]
       sub-<participant_label>[_ses-<session_label>]_sessions.tsv
```

Example:

session_id	acq_time	systolic_blood_pressure
ses-predrug	2009-06-15T13:45:30	120
ses-postdrug	2009-06-16T13:45:30	100
ses-followup	2009-06-17T13:45:30	110

3.4. STUDY keyfiles

3.4.1. Participants.tsv

See section "8.11 Participant key file" of The Brain Imaging Data Structure (BIDS) Specification for a detailed description. This is an optional file.

As described in the main BIDS:

The purpose of this file is to describe properties of participants such as age, handedness, sex,gender etc. In case of single session studies this file has one compulsory column `participant_id` that consists of `sub-<participant_label>`, followed by a list of optional columns describing participants. Each participant needs to be described by one and only one row.
If the dataset includes multiple sets of participant level measurements (for example responses from multiple questionnaires) they can be split into individual files separate from participants.tsv. Those measurements should be kept in `phenotype/` folder and end with the .tsv extension. They can include arbitrary set of columns, but one of them has to be `participant_id` with matching `sub-<participant_label>`.

Please always refer to the main BIDS for the most recent description of the file and its parameters.

Template: (single session case)

```
participants.tsv
participants.json

phenotype/<measurement_tool_name>.tsv
phenotype/<measurement_tool_name>.json
```

Example:

participant_id	age	sex	group
sub-control01	34	M	control
sub-control02	12	F	control
sub-patient01	33	F	patient

3.4.2. Emptyroom files (sub-emptyroom)

Emptyroom files recording the ambient noise in the system are very advisable for each recording session and should be stored separate inside a subject folder set to `sub-emptyroom`. Session label should be named with the date of the recording (e.g. ses-YYYYMMDD) and the `scans.tsv` file with the date/time of the acquisition should also be included. Hence, users will be able to retrieve the empty-room recording that best matches a particular session with a participant, based on date/time of recording.

Example:

```
sub-control01/
sub-control02/
sub-emptyroom/
 ses-20170801/
   sub-emptyroom_ses-20170801_scans.tsv
   meg/
        sub-emptyroom_ses-20170801_task-noise_meg.ds
        sub-emptyroom_ses-20170801_task-noise_meg.json
```

3.5. Multi-site or multi-center studies

See section "10 Multi-site or multi-center studies" of The Brain Imaging Data Structure (BIDS) Specification for a detailed description. Extracted from there:
This version of the BIDS specification does not explicitly cover studies with data coming from multiple sites or multiple centers (such extension is planned in BIDS 2.0.0). There are however ways to model your data without any loss in terms of metadata.

3.5.1. Option 1: Treat each site/center as a separate dataset

The simplest way of dealing with multiple sites is to treat data from each site as a separate and independent BIDS dataset with a separate `participants.tsv` and other metadata files. This way you can feed each dataset individually to BIDS Apps and everything should just work.

3.5.2. Option 2: Combining sites/centers into one dataset

Alternatively you can combine data from all sites into one dataset. To identify which site each subjects comes from you can add a "site" column in the `participants.tsv` file indicating the source site. This solution allows you to analyze all of the subjects together in one dataset. One caveat is that subjects from all sites will have to have unique labels. To enforce that and improve readability you can use a subject label prefix identifying the site. For example `sub-NUY001`, `sub-MIT002`, `sub-MPG002` etc. Remember that hyphens and underscores are not allowed in subject labels.

4. BIDS-MEG Example datasets

4.1. OMEGA Resting State Example dataset

Five minutes of eyes-open, resting-state MEG data is available for 5 subjects from The Open MEG Archive (OMEGA, Niso et al. 2016). The data are available from the Brainstorm Tutorial: tutorial MEG resting state & OMEGA database. The first release of data in BIDS-MEG format (~10.5GB) available here: https://box.bic.mni.mcgill.ca/s/omega?path=%2FContributions%20(in%20BIDS%20format)%2Fsample_BIDS_omega
(access to these datasets require registration to OMEGA, https://www.mcgill.ca/bic/omega-registration).

4.2. Brainstorm Auditory Example dataset

Brainstorm Auditory tutorial dataset (Tadel et al. 2011): https://box.bic.mni.mcgill.ca/s/omega?path=%2FContributions%20(in%20BIDS%20format)%2Fsample_BIDS_auditory (released in Public Domain; includes defaced anatomical T1 of participant, access to these datasets require registration to Brainstorm, http://neuroimage.usc.edu/bst/register.php).

4.3. MNE Sample data

Sample data with visual and auditory stimuli described in (Gramfort et al. 2014): https://drive.google.com/drive/folders/0B_sb8NJ9KsLUQ3BMS0dxZW5nSHM?usp=sharing (released in Public Domain; includes anatomical T1 of participant as well as flash MRI sequences).

4.4. OpenfMRI study ds000117

A multi-subject, multi-modal human neuroimaging dataset of 19 subjects on a MEG visual task (Wakeman & Henson, 2015). Data in BIDS-MEG format available here: https://openfmri.org/dataset/ds000117/

5. Appendix I: different MEG systems

Each of the different MEG systems has its specific organization of files and specific file formats (manufacturer_specific_extensions)

- **ctf** = CTF (folder with .ds extension)
- **fif** = Elekta-Neuromag and BabyMEG (file with extension .fif)
- **4d** = BTi / 4D Neuroimaging (folder containing multiple files without extensions)
- **kit** = Yokogawa / KIT (file with extension .sqd, .con, .raw, .ave or .mrk)
- **kdf** = KRISS MEG (file with extension .kdf)
- **itab** = Chieti system (file with extension .raw and .mhd)
- (Ricoh MEG)
- (Compumedics Neuroscan MEG - Orion)
- (York Instruments)

Here we show an example for each of them:

5.1. CTF

Each experimental run on the CTF system yields a folder with a **.ds** extension, containing several files. The (optional) digitized positions of the head points are usually stored in a separate **.pos** file, not necessarily within the **.ds** folder.

- [**sub-**<participant_label>[_ses-<label>]**_headshape.**pos]
- **sub-**<participant_label>[_ses-<label>]**_task-**<task_label>[_run-<index>]**_meg.**ds>

In this case, the manufacturer file formats are in fact directories containing multiple files. The files contained within the .ds directory are named such that they match the parent directory, but conserving the original file extension (e.g., .meg4, .res4, etc.). Renaming of CTF datasets should be done using the CTF newDs command-line application.

Example:

```
sub-control01/
  ses-001/
    sub-control01_ses-001_scans.tsv
    meg/
      sub-control01_ses-001_fid.json
      sub-control01_ses-001_fidinfo.txt
      sub-control01_ses-001_headshape.pos
      sub-control01_ses-001_task-rest_run-01_meg.ds
      sub-control01_ses-001_task-rest_run-01_meg.json
      sub-control01_ses-001_task-rest_run-01_channels.tsv
```

You can see more on the CTF data organization at:
http://www.fieldtriptoolbox.org/getting_started/ctf

5.2. Elekta/Neuromag

Elekta-Neuromag and BabyMEG gives a file with extension **.fif**. The digitized positions of the head points are saved inside the fif file along with the MEG data.

- **sub-**<participant_label>[_ses-<label>]**_task-**<task_label>[_run-<index>]**_meg.**fif

In this case, there won't usually be a *_headshape file.

Please note that there isn't a specific place for cross-talk and fine-calibration matrix files in this specification.

Example:

```
sub-control01/
  ses-001/
    sub-control01_ses-001_scans.tsv
    meg/
      sub-control01_ses-001_fid.json
      sub-control01_ses-001_fidinfo.txt
      sub-control01_ses-001_task-rest_run-01_meg.fif
      sub-control01_ses-001_task-rest_run-01_meg.json
      sub-control01_ses-001_task-rest_run-01_channels.tsv
```

After applying MaxFilter for SSS ot tSSS, files should be renamed with the corresponding label (e.g. tsss_meg).
Example:

```
sub-control01_ses-001_task-rest_run-01_proc-tsss_meg.fif
sub-control01_ses-001_task-rest_run-01_proc-tsss_meg.json
```

In the case of files exceeding 2Gb, the file is divided into two:

```
sub-control01_ses-001_task-rest_run-01_meg.fif
sub-control01_ses-001_task-rest_run-01_meg-1.fif
```

These parts can be read independently. However, every file has a pointer to the next file. In some softwares, like MNE, you can simply specify the name of the first file and it will read in all the files thanks to this pointer. For this reason, it is advisable to rename it once read and wrote it back, to avoid a pointer to the old file name. This is the naming convention:

```
sub-control01_ses-001_task-rest_run-01_part-01_meg.fif
sub-control01_ses-001_task-rest_run-01_part-02_meg.fif
```

You can see more on the Elekta-Neuromag data organization at:
http://www.fieldtriptoolbox.org/getting_started/neuromag
And and BabyMEG :
http://www.fieldtriptoolbox.org/getting_started/babysquid

5.3. 4D neuroimaging/BTi

Each experimental run on a 4D neuroimaging//BTi system results in a folder containing multiple files without extensions.

- [**sub-**<participant_label>[_ses-<label>]**_headshape.**pos]
- **sub-**<participant_label>[_ses-<label>]**_task-**<task_label>[_run-<index>]**_meg**>

In this case, we should rename/create a father run specific directory and keep the original files for each run inside (e.g. "`c,rfhp0.1Hz`", "`config`" and "`hs_file`").

Example:

```
sub-control01/
  ses-001/
    sub-control01_ses-001_scans.tsv
    meg/
       sub-control01_ses-001_fid.json
       sub-control01_ses-001_fidinfo.txt
       sub-control01_ses-001_headshape.pos
       sub-control01_ses-001_task-rest_run-01_meg
       sub-control01_ses-001_task-rest_run-01_meg.json
       sub-control01_ses-001_task-rest_run-01_channels.tsv
```

Where:

```
       sub-control01_ses-001_task-rest_run-01_meg/
          config
          hs_file
          e,rfhp1.0Hz.COH
          c,rfDC
```

You can see more on the 4D neuroimaging/BTi data organization at:
http://www.fieldtriptoolbox.org/getting_started/bti

5.4. KIT/Yokogawa

Each experimental run on a KIT/Yokogawa system yields a raw (***.sqd, *.con**) file with its associated marker coil file (***.mrk**), which contain coil positions in the acquisition system's native space. Head points and marker points in head space are acquired using third-party hardware.

Example:

```
sub-control01/
  ses-001/
    sub-control01_ses-001_scans.tsv
    meg/
       sub-control01_ses-001_fid.json
       sub-control01_ses-001_fidinfo.txt
       sub-control01_ses-001_headshape.txt
       sub-control01_ses-001_task-rest_run-01_meg.<con,sqd>
       sub-control01_ses-001_task-rest_run-01_meg.json
       sub-control01_ses-001_task-rest_run-01_channels.tsv
```

You can see more on the KIT/Yokogawa data organization at:
http://www.fieldtriptoolbox.org/getting_started/yokogawa

5.5. KRISS

Each experimental run on the KRISS MEG gives a file with extension **.kdf**. Additional files can be available in the same folder: the digitized positions of the head points (_digitizer.txt), the position of the center of the MEG coils (.chn) and the event markers (.trg).

- [**sub-<participant_label>[_ses-<label>]_digitizer.**txt]
- **sub-**<participant_label>[_ses-<label>]**_task-**<task_label>[_run-<index>]**_meg.**kdf
- **sub-**<participant_label>[_ses-<label>]**_task-**<task_label>[_run-<index>]**_meg.**chn
- **sub-**<participant_label>[_ses-<label>]**_task-**<task_label>[_run-<index>]**_meg.**trg

Example:

```
sub-control01/
  ses-001/
    sub-control01_ses-001_scans.tsv
    meg/
       sub-control01_ses-001_fid.json
       sub-control01_ses-001_fidinfo.txt
       sub-control01_ses-001_digitizer.txt
       sub-control01_ses-001_task-rest_run-01_meg.chn
       sub-control01_ses-001_task-rest_run-01_meg.kdf
       sub-control01_ses-001_task-rest_run-01_meg.trg
       sub-control01_ses-001_task-rest_run-01_meg.json
       sub-control01_ses-001_task-rest_run-01_channels.tsv
```

5.6. ITAB

Each experimental run on a ITAB-ARGOS153 system yields a raw (***.raw**) data file plus an associated binary header file (***.mhd**). Raw data file has an ASCII header that holds detailed information about data acquisition system followed by binary data. The associated binary header file holds part of the information from ASCII header, specifically the one needed to process data, plus other information obtained from offline preprocessing performed right after data acquisition (e.g., sensor position relative to subject's head, head markers, stimulus information).

```
Example:
sub-control01/
 ses-001/
       sub-control01_ses-001_task-rest_run-01_meg.raw
       sub-control01_ses-001_task-rest_run-01_fidinfo.raw.mhd
```

6. Appendix: preferred names of MEG scanner models

Summary:

- CTF 151
- CTF 275
- Elekta Vectorview
- Elekta TRIUX
- 4D Magnes WH2500
- 4D Magnes WH3600
- KIT-157
- KIT-208
- ITAB-ARGOS153

6.1. CTF

- CTF 151:
- CTF 275: OMEGA 2000

https://www.ctfmeg.com/products

6.2. Elekta/Neuromag

- Elekta Vectorview (102 magnetometers + 204 planar gradiometers)
- Elekta TRIUX

https://www.elekta.com/diagnostic-solutions/

6.3. 4D neuroimaging/BTi

- 4D Magnes WH2500
- 4D Magnes WH3600

6.4. KIT/Yokogawa

- KIT-157
- KIT-208

6.5. ITAB

- ITAB-ARGOS153

7. Appendix: preferred names of Coordinate systems

There is a very good description of every system in the Fieldtrip toolbox web page:
http://www.fieldtriptoolbox.org/faq/how_are_the_different_head_and_mri_coordinate_systems_defined

A summary extracted from this website:

System	Units	Orientation	Origin	Notes
CTF gradiometer	cm	ALS	between the ears	
CTF MRI	mm	ALS	between the ears	voxel order can be arbitrary
Neuromag/Elekta	m	RAS	between the ears	
4D/BTi	m	ALS	between the ears	
KIT/Yokogawa	m	ALS		
Chieti ITAB	mm	RAS	between the ears	
DICOM	mm	LPS		
Analyze	mm	LAS		
Talairach-Tournoux	mm	RAS		
MNI	mm	RAS		
NIfTI	mm	RAS	scanner origin (centre of gradient coil)	
freesurfer	mm	RAS	centre voxel of isotropic 256-cubic 1 mm volume	
Paxinos-Franklin	mm	RSP	Bregma point	
Allen Institute	mm	RAS	Bregma point	
brainstorm_mri	mm	RAS	Bottom-left-posterior corner of the MRI volume	Coordinates of the first voxel = [1,1,1].*voxsize

A/P means anterior/posterior
L/R means left/right
S/I means superior/inferior

As an example: RAS means that the first dimension orients towards Right, the second dimension orients towards Anterior, the third dimension orients towards Superior.