BIDS Extension Proposal 6 (BEP006): Electroencephalography (EEG)

version 0.0.0

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This document contains a draft of the Brain Imaging Data Structure standard extension. It is a community effort to define standards in data / metadata. This is a working document in draft stage and any comments are welcome.

This specification is an extension of BIDS, and general principles are shared. The specification should work for many different settings and facilitate the integration with other imaging methods.

To see the original BIDS specification, see this link. This document inherits all components of the original specification (e.g. how to store imaging data, events, stimuli and behavioral data), and should be seen as an extension of it, not a replacement.

[examples can be pushed here https://github.com/bids-standard/bids-examples/tree/bep006_eeg/]

BEP006 is nearly in its final state! Today (Dec, 6th), a preprint of the final report on this extension has been published on PsyArXiv: https://doi.org/10.31234/osf.io/63a4y

Feedback and comments are still welcome until we begin with the process of merging the extension with the main specification!

1. Table of contents

2. Preliminary clarifications

This specification extends the Brain Imaging Data Structure (BIDS) Specification for integration of electroencephalography (EEG) data. Please refer to BIDS specification document for context and general guidelines (definitions, units, directory structure, etc.). For specifications about common EEG derivatives, please refer to the Common Electrophysiological Derivatives (BEP021).

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 (or phantom, etc) from whom data is being acquired
- Visit = a non-intermittent period in which the subject is at the location the experiment takes place
- Session = a non-intermittent period in which the subject is wearing the EEG cap
- Run = a non-intermittent period in which data for the subject(s) is continuously being acquired
- Task = instructions (and corresponding stimulus material) that is performed by the subject
- Responses = recorded behaviour of the subject in relation to the task and/or stimulus

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

3. BIDS-EEG

While there are many file formats to store EEG data, there are 2 preferred formats in BIDS EEG: European data format (`.edf`) and BrainVision (`.vhdr, .vmrk, .eeg`) by Brain Products. There are also 2 additional 'supported' formats: EEGLAB set files (`.set, .fdt`) and Biosemi (`.bdf`). The current selection is based on interoperability (one of the FAIR principles) between the main open source MEEG software, i.e. EEGLAB, FieldTrip (which supports SPM), Brainstorm and MNE Python. Note that most manufacturers' software offers options to convert to `.edf` and original data format can be stored in the `/sourcedata` folder (see below).

Future versions of BIDS may extend this list of supported file formats (in particular for `/derivatives`). File formats for consideration MUST have open access documentation, MUST have open source implementation for both reading and writing in at least two programming languages and SHOULD be widely supported in multiple software packages. Other formats that may be considered in the future should have a clear added advantage over the existing formats and should have wide adoption in the EEG community.

Original unprocessed EEG data in the native format, if different, can also be stored in the `/sourcedata` folder. The native file format is especially valuable in case conversion elicits the loss of crucial metadata specific to manufacturers and specific EEG systems. We also encourage users to provide additional meta information extracted from the manufacturer specific data files in the 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 EEG data.

Note that for proper documentation of EEG recording metadata it is important to understand the difference between electrode and channel: An EEG electrode is attached to the skin, whereas a channel is the combination of the analog differential amplifier and analog-to-digital converter that result in a potential (voltage) difference that is stored in the EEG dataset. We employ the following short definitions:

- Electrode = A single point of contact between the acquisition system and the recording site (e.g., scalp, neural tissue, ...). Multiple electrodes can be organized as caps (for EEG), arrays, grids, leads, strips, probes, shafts, etc.
- Channel = A single ADC in the recording system that regularly samples the value of a transducer, which results in a signal being represented as a time series in the data. This can be connected to two electrodes (to measure the potential difference between them), a magnetic field or magnetic gradient sensor, temperature sensor, accelerometer, etc.

Although the "reference" and "ground" are often referred to as channels, they are in most common EEG systems not amplified and recorded by themselves, and therefore should not be represented as channels but as electrodes. The type of referencing and (optionally) the location of the reference and electrode and the location of the ground electrode should be specified.

3.1. Directory structure

Overall directories hierarchy is

- sub-<participant_label>[/ses-<session_label>]/<data_type>/
- [code/]
- [derivatives/]
- [stimuli/]
- [sourcedata/]
- participants.tsv
- dataset_description.json
- README

where [] depicts optional content. Session level is OPTIONAL

[derivatives/] are discussed in a separate document - BEP 21

Example of dataset_description.json

```
{
    "Name": "The best EEG experiment ever",
    "BIDSVersion": "1.2.0",
    "License": "CCBY 4.0",
    "Authors": ["Hans Berger", "2nd author"],
    "Acknowledgements": "say here what are your acknowledgments",
    "HowToAcknowledge": "say here how you would like to be acknowledged",
    "Funding": ["list your funding sources"],
    "ReferencesAndLinks": ["a data paper", "a resource to be cited when using
the data"],
    "DatasetDOI": "10.0.2.3/dfjj.10"
}
```

Example of participants.tsv

participant_id	age	sex	group
sub-01	34	M	control
sub-02	12	F	control
sub-03	33	F	patient

3.1.1. Single session EEG Template

sub-<participant_label>/

[sub-<participant_label>**_scans.tsv**]

```
  anat/
      ...
eeg/(see section 8.3. Of the MRI BIDS documentation https://docs.google.com/document/d/1HFUkAEE-pB-angVcYe6pf_-fVf4sCpOHKesUvfb8Grc/edit#heading=h.fm6ipijipc08)


      ...
            sub-<participant_label>_task-<task_label>[_acq-<acq_label>][_run-<index>]_eeg
      .<manufacturer_specific_extension>

      [sub-<participant_label>_task-<task_label>[_acq-<acq_label>][_run-<index>]_eeg.json]
      [sub-<participant_label>_task-<task_label>[_acq-<acq_label>][_run-<index>]_channels.
      tsv]
      [sub-<participant_label>[_acq-<acq_label>]_electrodes.tsv]
      [sub-<participant_label>[_acq-<acq_label>]_coordsystem.json]
      [sub-<participant_label>[_acq-<acq_label>]_photo.jpg]
```

The "task-<task_label>" key/value pair corresponds to a custom label - it is designed to be a short mnemonic, not necessarily an exact description of the task. Full description of the task (or tasks, even for a single session/run) should be included in the readme file and in a `MeasurementToolMetadata.json` (section 8.9 of the main BIDS specification) using the Cognitive Atlas ontology.

EEG data can be task-based or resting state. 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 "_eeg".
3. The `.nii[.gz]` extension is replaced with the `manufacturer_specific_extension` (see below for the restrictions on the format).

The OPTIONAL "acq-<acq_label>" key/value pair corresponds to a custom label one may use to distinguish different set of parameters used for acquiring the same task. For example using 2 different EEG cap, or different sampling rates.

3.1.2. Multiple sessions EEG Template

```
sub-<participant_label>/[ses-<session_label>/]

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

  anat/
      ...
```

(see section 8.3. Of the MRI BIDS documentation https://docs.google.com/document/d/1HFUkAEE-pB-angVcYe6pf_-fVf4sCpOHKesUvfb8Grc/edit#heading=h.fm6ipijipc08)

```
eeg/
    ...
    sub-<participant_label>_ses-<session_label>_task-<task_label>[_acq-<acq_label>][_run-<index>]_eeg.<manufacturer_specific_extension>
    [sub-<participant_label>_ses-<session_label>_task-<task_label>[_acq-<acq_label>][_run-<index>]_eeg.json]
    [sub-<participant_label>_ses-<session_label>task-<task_label>[_acq-<acq_label>][_run-<index>]_channels.tsv]
    [sub-<participant_label>_ses-<session_label>[_acq-<acq_label>]_electrodes.tsv]
    [sub-<participant_label>_ses-<session_label>[_acq-<acq_label>]_coordsystem.json]
    [sub-<participant_label>_ses-<session_label>[_acq-<acq_label>]_photo.jpg]
```

3.2. RUN specific files

A number of files may be included alongside each EEG recording data file (i.e. for every session and 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 EEG datasets. These include:

1. ***[_run-<index>]_eeg.json:** A JSON document containing metadata about the EEG recording data file.
2. ***[_run-<index>]_channels.tsv:** A channels .tsv file listing channel names, types, and other optional information.
3. *[_run-<index>]_events.tsv

Note that _eeg.json does not have to be specified in each session and run. Often the same experiment is repeated, and following the inheritance principle this can be stored at the root as task-<task_label>_eeg.json.

Note that _channels.tsv are run specific as the sampling rate, filters, good/bad channel status can be changed. In contrast, the electrode.tsv (see below) is session specific as typically they do not change (but see `acq-<acq_label>` if they do).

For behavioural data acquired independently of the EEG 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 (*_eeg.json)

General fields, shared with MRI BIDS:

- `TaskName`: REQUIRED - 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.

- `TaskDescription`: RECOMMENDED - Longer description of the task.
- `Instructions`: RECOMMENDED - Text of the instructions given to participants before the scan. This is not only important for behavioural or cognitive tasks but also for resting state paradigms (e.g. to distinguish between eyes open and eyes closed).
- `CogAtlasID`: RECOMMENDED - URL of the corresponding Cognitive Atlas Task term (e.g. Resting State with eyes closed "http://www.cognitiveatlas.org/term/id/trm_54e69c642d89b") .
- `CogPOID`: RECOMMENDED - URL of the corresponding CogPO term.
- `InstitutionName`: RECOMMENDED - The name of the institution in charge of the equipment that produced the composite instances.
- `InstitutionAddress`: RECOMMENDED - The address of the institution in charge of the equipment that produced the composite instances.
- `InstitutionalDepartmentName`: RECOMMENDED - The department in the institution in charge of the equipment that produced the composite instances.
- `DeviceSerialNumber`: RECOMMENDED - 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 EEG fields:

- `CapManufacturer`: RECOMMENDED - name of the cap manufacturer (e.g. `"ECI"`, `"EasyCap"`).
- `CapManufacturersModelName`: OPTIONAL - Manufacturer's designation of the EEG cap model (e.g. `"CAPML128"`, `"actiCAP 64Ch Standard-2"`).
- `ECGChannelCount`: RECOMMENDED - Number of ECG channels included in the recording (e.g. `1`).
- `EEGChannelCount`: REQUIRED - Number of EEG channels included in the recording (e.g. `128`).
- `EEGGround`: RECOMMENDED - Description of the location of the ground electrode ("placed on right mastoid (M2)")
- `EEGReference`: REQUIRED - Description of the type of reference used and (when applicable) of location of the reference electrode (`"common reference placed at the left mastoid (M1)"`, `"average"`, `"CMS/DRL"`, `"bipolar"`). If different channels have a different reference, you should specify the reference electrode in channels.tsv.
- `EEGPlacementScheme`: RECOMMENDED - Placement scheme of the EEG electrodes. Either the name of a placement system (e.g. `"10-20"`, `"equidistant"`, `"geodesic"`) or a list of electrode positions (e.g. `["Cz", "Pz"]`).
- `EMGChannelCount`: RECOMMENDED - Number of EMG channels included in the recording (e.g. `2`).
- `EOGChannelCount`: RECOMMENDED - Number of EOG channels included in the recording (e.g. `2`).
- `EpochLength`: RECOMMENDED - Duration of individual epochs in seconds (e.g. `1`). If recording was continuous, leave out the field.
- `HardwareFilters`: OPTIONAL - List of hardware (amplifier) filters applied with key:value pairs of filter parameters and their values.
- `HeadCircumference`: RECOMMENDED - Circumference of the participants head, expressed in cm (e.g. 58).
- `Manufacturer`: RECOMMENDED - name of the EEG amplifier manufacturer (e.g. `"Biosemi"`, `"Brain Products"`)

- `ManufacturersModelName`: OPTIONAL - Manufacturer's designation of the EEG amplifier model (e.g. `"ActiveTwo", "BrainAmp DC"`).
- `MiscChannelCount`: OPTIONAL - Number of miscellaneous analog channels for auxiliary signals (e.g. `0`).
- `PowerLineFrequency`: REQUIRED Frequency (in Hz) of the power grid where the EEG is installed (i.e. `50` or `60`).
- `RecordingDuration`: RECOMMENDED - Length of the recording in seconds (e.g. `3600`).
- `RecordingType`: RECOMMENDED - Type of recording (e.g. `"continuous", "epoched"`).
- `SamplingFrequency`: REQUIRED - Generic Sampling frequency (in Hz) of the EEG recording (e.g. `2400`) ; all other channels should have frequency specified as well in the `channels.tsv` file.
- `SoftwareFilters`: REQUIRED - List of temporal software filters applied or ideally key:value pairs of pre-applied filters and their parameter values. (`n/a` if none)
- `TriggerChannelCount`: RECOMMENDED - Number of channels for digital and analog triggers (e.g. `1`).
- `SoftwareVersions`: RECOMMENDED - Manufacturer's designation of the acquisition software.
- `SubjectArtefactDescription`: OPTIONAL - 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 a source of (constantly present) artifacts.

Examples of `*_eeg.json`

```
{
"TaskName": "Seeing stuff",
"TaskDescription": "Subjects see various images for which phase, amplitude
spectrum, and color vary continuously",
"Instructions": "Your task is to detect images when they appear for the 2nd
time, only then press the response button with your right/left hand
(counterbalanced across subjects)",
"InstitutionName": "The world best university, 10 beachfront avenue, Papeete",
"SamplingFrequency": 2400,
"Manufacturer": "Brain Products",
"ManufacturersModelName": "BrainAmp DC",
"CapManufacturer": "EasyCap",
"CapManufacturersModelName": "M1-ext",
"EEGChannelCount": 87,
"EOGChannelCount": 2,
"ECGChannelCount": 1,
"EMGChannelCount": 0,
"MiscChannelCount": 0,
"TriggerChannelCount": 1,
"PowerLineFrequency": 50,
"EEGPlacementScheme": "10% system",
"EEGReference": "single electrode placed on FCz",
```

```
"EEGGround": "placed on AFz",
"HardwareFilters": {
        "ADC's decimation filter (hardware bandwidth limit)": {
             "-3dB cutoff point (Hz)": 480,
             "Filter order sinc response": 5
         }
,
"RecordingDuration": 600,
"RecordingType": "continuous"
}
```

Note that the date time information should be stored in the Study key file (`runs.tsv`), see section 3.4.1.Runs.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 often be extracted from the EEG recording, listing it in a simple .tsv document makes it easy to browse or search. The required columns are channel `name`, `type` and `units`. Channels should appear in the table in the same order they do in the EEG data file. Any number of additional columns may be provided to provide additional information about the channels. Note that electrode positions should not be added to this file, but to `*_electrodes.tsv`.

Channel description table fields:

- `name`: REQUIRED - Label of the channel .
- `type`: REQUIRED - Type of the channel, see below for keys.
- `units`: REQUIRED - Physical units of the value represented in this channel specified according to the SI unit symbol and possibly prefix name (e.g. milliV, microV), see BIDS spec for Units and Prefixes.
- `description`: OPTIONAL - Brief description of the channel for type `EOG`, `TRIG` and `MISC`.
- `sampling_frequency`: RECOMMENDED - Sampling rate of the channel in Hz.
- `reference`: RECOMMENDED - Name of the reference electrode(s) (not needed when it is common to all channels, in that case it can be specified in eeg.json as EEGReference) .
- `low_cutoff`: OPTIONAL - Frequencies used for the high pass filter applied to the channel in Hz. If no high pass filter applied, use `0`.
- `high_cutoff`: OPTIONAL -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`: OPTIONAL - Frequencies used for the notch filter applied to the channel, in Hz. If no notch filter applied, do not use the field.
- `status`: OPTIONAL - State of the channel `(good/bad)`. Indicate a channel is bad if it is e.g., excessively noisy or broken, throughout the whole recording. More subtle descriptions should go in status_description.

- `status_description`: OPTIONAL - Freeform text to specify subtle noise, or why a channel is bad.

The restricted list of channel `type` keywords is shared with BIDS-MEG (Note: MEG-specific types are not listed):

- `AUDIO`: Audio signal
- `EEG`: ElectroEncephaloGram channels
- `EOG`: Generic ElectroOculoGram (eye), different from HEOG and VEOG, e.g. Diagonal (in the description)
- `ECG`: ElectroCardioGram (heart)
- `EMG`: ElectroMyoGram (muscle)
- `EYEGAZE`: Eye Tracker gaze
- `GSR`: Galvanic Skin Resistance
- `HEOG`: Horizontal EOG (electrooculogram)
- `MISC`: Miscellaneous
- `PUPIL`: Eye Tracker pupil diameter
- `SYSCLOCK`: System time showing elapsed time since trial started
- `REF`: Reference channel
- `RESP`: Respiration
- `TEMP`: Temperature
- `TRIG`: System Triggers
- `VEOG`: Vertical EOG (electrooculogram)

Some examples of keywords for field `description`:

- n/a, stimulus, response, skin conductance, battery status

Examples of `*_channels.tsv`

name	units	type	status	description
VEOG	uV	VEOG	good	vertical
FDI	uV	EMG	good	left first dorsal interosseous
UDIO001	n/a	TRIG	good	analogue trigger
UADC001	n/a	MISC	good	envelope of audio signal sent to the subject
EEG1	uV	EEG	good	n/a
EEG2	uV	EEG	good	n/a
EEG3	uV	EEG	bad	n/a
EEG4	uV	EEG	good	n/a

name	unit	type	description	sampling_frequency	...
STATUS	uV	TRIG	analogue trigger	1200	
Cz	uV	EEG	n/a	1200	

...	low_cutoff	high_cutoff	notch	status
	0.1	300	0	good

```
            Inf          50           0           bad
```

3.2.3. Task events (*_events.tsv)

Task events are part of the general (see section 8.4 from The Brain Imaging Data Structure (BIDS) Specification) Unless the collected data are for sleep or rest, task event is mandatory (onset/duration). Two specific (optional) EEG columns used are the `value` that corresponds to markers typically used during recording (on the `TRIG` channel specified in the _channels.tsv), and the `sample` column corresponding to the onset of the event according to the sampling scheme.

Template:

```
sub-<participant_label>/[ses-<session_label>]
   eeg/
      <matches>_events.tsv
```

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

Example of *_events.tsv

onset	duration	trial_type	response_time	value	sample
1.2	0.6	go	0.435	1	1200
1.635	n/a	response	n/a	4	1635
2.4	0.6	stop	0.739	2	2400
3.139	n/a	response	n/a	4	3139

Note that the `trial_type` column is optional according to the BIDS specification. Furthermore, it is optional to add columns not listed in the BIDS specification. If you use multiple triggers with different values per trial, you should document what these values mean. A straightforward way would be to include a `value` column in your *_events.tsv file and document the levels of its values in an accompanying *_events.json file, as shown in the following example.

Example of *_events.json

```
{
      "onset": {
          "Description": "Onset of the event",
          "Units": "seconds"
      },
      "duration": {
          "Description": "Duration of the event",
          "Units": "seconds"
      },
      "trial_type": {
          "Levels": {
              "go": " ... explanation of what this means ... ",
```

```
            "response": " ... explanation of what this means ... "
            "stop": " ... explanation of what this means ... "
            }
    },
          "response_time": {
        "Units": "seconds"
    },
    "value": {
        "Description": "The event TTL trigger value (EEG Marker value)
associated with an event ",
        "Levels": {
             "1": " ... explanation of what this means ... ",
             "2": " ... explanation of what this means ... "
             "4": " ... explanation of what this means ... "
             }
    },
    "sample": {
        "Description": "The sample within the EEG data at which an event
occurred"
    }
}
```

3.2.4. Acquisition time (*_scans.tsv)

See section "8.10 Scans key file" of The Brain Imaging Data Structure (BIDS) Specification for a detailed description. Note that this is renamed `scans.tsv`. Optional: Yes

Template:

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

Example of *_scans.tsv

filename	**acq_time**
eeg/sub-control01_task-rest_eeg.edf	1877-06-15T13:45:30
eeg/sub-control01_task-motor_eeg.edf	1889-06-15T13:55:33

3.3. SESSION specific files

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

1. `*[_ses-<session_label>]_electrodes.tsv`: An optional electrodes .tsv file listing electrode names and positions.

2. ***[_ses-<session_label>]_coordsystem.json**: A JSON document documenting (1) the coordinates system of the EEG electrodes in relation to a given anatomical landmarks/MRI (2) the anatomical landmarks and associated coordinate system (3) the associated MRI.
3. ***[_ses-<session_label>]_photo.jpg**: Photos of the anatomical landmarks and/or head localisation coils on the subject's head.
4. ***[_ses-<session_label>]_headshape.<manufacturer_specific_format>**: Scalp surface points and EEG electrode position digitisation files.
5. ***[_ses-<session_label>]_scans.tsv**

Note in case of conflict between fields of different runs/sessions, the inheritance principle should be applied (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. Electrode description table (*_electrodes.tsv)

File that gives the location of EEG electrodes. Note that coordinates are expected in cartesian coordinates according to the EEGCoordinateSystem and EEGCoordinateSystemUnits fields in _coordsystem.json. If an *_electrodes.tsv file is specified, a *_coordsystem.json file must be specified as well.

- name: REQUIRED Name of the electrode (expected to match channel.tsv)
- [x]: REQUIRED recorded position along the x-axis.
- [y]: REQUIRED recorded position along the y-axis .
- [z]: REQUIRED recorded position along the z-axis.
- [type]: OPTIONAL type of the electrode, e.g. cup, ring, clip-on, wire, needle
- [material]: OPTIONAL material of the electrode, e.g. Tin, Ag/AgCl, Gold
- [impedance]: OPTIONAL Impedance of the electrode in kOhm.

Example of *_electrodes.tsv

name	x	y	z	type	material
A1	-0.0707	0.0000	-0.0707	clip-on	Ag/AgCl
F3	-0.0567	0.0677	0.0469	cup	Ag/AgCl
Fz	0.0000	0.0714	0.0699	cup	Ag/AgCl
F4	0.0566	0.0677	0.0469	cup	Ag/AgCl
C3	-0.0742	0.0000	0.0668	cup	Ag/AgCl
Cz	0.0000	0.0000	0.1000	cup	Ag/AgCl
C4	0.0743	0.0000	0.0669	cup	Ag/AgCl
P3	-0.0567	-0.0677	0.0469	cup	Ag/AgCl
Pz	0.0000	-0.0714	0.0699	cup	Ag/AgCl
P4	0.0566	-0.0677	0.0469	cup	Ag/AgCl
O1	-0.0307	-0.0949	-0.0047	cup	Ag/AgCl
Oz	0.0000	-0.0999	-0.0021	cup	Ag/AgCl
O2	0.0307	-0.0949	-0.0047	cup	Ag/AgCl
REF	-0.0742	-0.0200	-0.0100	cup	Ag/AgCl

GND	0.0742	-0.0200	-0.0100	cup	Ag/AgCl

3.3.2. Coordinate system JSON document (*_coordsystem.json)

- `[IntendedFor]`: relative path to associate the electrodes and landmarks to an MRI/CT. .
- `[FiducialsDescription]`: Freeform description of how the fiducials such as vitamin-E capsules were placed relative to anatomical landmarks, and how the position of the fiducials were measured (e.g. both with Polhemus and with T1w MRI). If the position of fiducials is measured using the same system used to measure electrode positions, the fiducial locations can be specified in electrodes.tsv

Fiducials are "objects" with a well defined location used to facilitate the localization of electrodes and co-registration with other geometric data (e.g. the participant's own T1w image, a T1w template or a spherical model). Examples are vitamin-E markers, LEDs, felt-tip marker dots placed on the face, etc. Fiducials are often placed at a known location relative to (or right on top of) anatomical landmarks.

EEG electrodes:

- `EEGCoordinateSystem`: This refers to the coordinate space to which the EEG electrodes xyz positions are to be interpreted - see main BIDS specification and the appendix viii therein.
- `EEGCoordinateUnits`: Units in which the coordinates that are listed in the field `EEGCoordinateSystem` are represented (e.g. "`mm`", "`cm`").
- `[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 landmarks measured during an EEG session/run:

- `AnatomicalLandmarkCoordinates`: OPTIONAL. Key:value pairs of the labels and 3-D digitized locations of anatomical landmarks, interpreted following the AnatomicalLandmarkCoordinateSystem, e.g., {"NAS": [12.7,21.3,13.9], "LPA": [5.2,11.3,9.6], "RPA": [20.2,11.3,9.1]}.
- `AnatomicalLandmarkCoordinateSystem`: This refers to the coordinate space to which the landmarks positions are to be interpreted - preferably the same as the `EEGCoordinateSystem`.
- `AnatomicalLandmarkCoordinateUnits`: Units in which the coordinates that are listed in the field 'AnatomicalLandmarkCoordinateSystem' are represented, e.g. "`mm`", "cm".
- `[AnatomicalLandmarkCoordinateSystemDescription]`: Freeform description of the coordinate system. May also include a link to a documentation page or paper describing the system in greater detail.

Anatomical landmarks or fiducials measured on an anatomical MRI that match the landmarks or fiducials during an EEG session/run, must be stored separately in the corresponding *T1w.jon or *T2w.jon file and should be expressed in voxels (starting from [0,0,0]).

```
{
"IntendedFor":"/sub-01/ses-01/anat/sub-01_T1w.nii",
"EEGCoordinateSystem":"Other",
"EEGCoordinateUnits":"mm",
"EEGCoordinateSystemDescription": “RAS orientation: Origin halfway between LPA and RPA, positive x-axis towards RPA, positive y-axis orthogonal to x-axis through Nasion, z-axis orthogonal to xy-plane, pointing in superior direction.”
"FiducialsDescription": "Electrodes and fiducials were digitized with Polhemus, fiducials were recorded as the centre of vitamin E capsules sticked on the left/right pre-auricular and on the nasion, these are also visible on the T1w MRI"
}
```

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

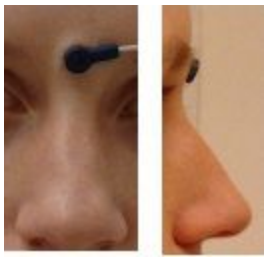
See more information on coordinate systems for coregistration:
http://www.fieldtriptoolbox.org/faq/how_are_the_different_head_and_mri_coordinate_systems_defined
http://neuroimage.usc.edu/brainstorm/CoordinateSystems

3.3.4. 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 channels are not placed on the landmarks, the landmarks can be marked with a felt-tip marker. The photos may need to be cropped and blurred to conceal identifying features—or entirely omitted—prior to sharing, depending on obtained consent. There is no specified format but jpg, png, and tiff are recommended and it should be a standard and easy to read format otherwise.

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

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



3.4 SUBJECT keyfiles

3.4.1 Sessions file (`*_sessions.tsv`)

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

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

Example of *_sessions.tsv

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

3.5. STUDY keyfiles

3.5.1. 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 multiple participants are recorded in a single session, a column `SimultaneousRecording` can be set with key values `1`, `2`, `3` appearing for multiple subjects. It is also recommended in this case to add `*_runs.tsv` files which will make even more explicits data were acquired at the same time.

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
```

Examples of `participants.tsv`:

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

participant_id	age	sex	SimultaneousRecording
sub-control01	34	M	1
sub-control02	12	F	1
sub-control03	34	M	2
sub-control04	12	F	2

4. BIDS-EEG Example datasets

4.1.1 Face Repetition (Wakeman and Henson)

Single session, multiple runs, anatomical data: ds000117_eeg_only in the bep006_eeg branch. Full data available here: https://openneuro.org/datasets/ds000117/versions/1.0.2

4.1.2 Rishikesh (Arno Delorme)

Multiple session, single run: eeg_rishikesh in the bep006_eeg branch. Find the full data here: https://doi.org/10.5281/zenodo.1490922

4.1.3 Matching Pennies (Stefan Appelhoff)

Single session, single run, ... multi-file system (BrainVision): eeg_matchingpennies in the bep006_eeg branch. Find the full data here: https://osf.io/cj2dr/

4.3.2 Resting state (Jon Wirsich)

See eeg_rest_fmri in the bep006_eeg branch. Find the full data here: https://osf.io/94c5t/files/

5. Appendix I: contributors

Legend (source: https://github.com/kentcdodds/all-contributors)

Emoji	Represents
💬	Answering Questions (on the mailing list, NeuroStars, GitHub, or in person)
🐛	Bug reports

📝	Blogposts
💻	Code
📖	Documentation and specification
🎨	Design
💡	Examples
📋	Event Organizers
💵	Financial Support
🔍	Funding/Grant Finders
🤔	Ideas & Planning
🚇	Infrastructure (Hosting, Build-Tools, etc)
🔌	Plugin/utility libraries
👀	Reviewed Pull Requests
🔧	Tools
🌍	Translation
⚠	Tests
✔	Tutorials
📢	Talks
📹	Videos

Cyril Pernet 📖💻💬💡
Robert Oostenveld 📖💻💬💡
Stefan Appelhoff 📖💬🤔🐛💡💻👀⚠
Arnaud Delorme 📖💡
Dora Hermes 📖
Christophe Phillips 💡
Guillaume Flandin 📖💻
Guiomar Niso 📖
Teon Brooks 👀💻💬
Mainak Jas 📖