BIDS Extension Proposal NIBS (BEP37NIBS):

version 4.2

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THIS DOCUMENT IS NOT CHECKED ANYMORE, THIS BEP HAS MIGRATED AT https://github.com/nigelrogasch/nibs-bids/tree/master

Mattermost channel: https://mattermost.brainhack.org/brainhack/channels/nibs-bids

Google drive:
https://drive.google.com/drive/folders/1g-iE4Z0YY1NbT46PVKl3fT-s3YgvELbz

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This document contains a draft for non-invasive brain stimulation (NIBS) BIDS proposal. It is a community effort to define standards in data/metadata storage for NIBS field. This is a working document in draft stage and any comments are welcome.

This specification is an extension of BIDS, and therefore follows the same general principles. The specification should work for many different NIBS settings and for the integration of NIBS with imaging methods.

The original BIDS specification can be found at this link. The present 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.

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1. Scope of NIBS-BIDS

This proposal extends the Brain Imaging Data Structure (BIDS) specification to non-invasive brain stimulation (NIBS) techniques, including transcranial magnetic stimulation (TMS), transcranial electrical stimulation (tES) and transcranial ultrasonic stimulation (TUS) for standalone experiments and in combination with a neuroimaging/neurophysiological techniques.

Although this BIDS extension proposal (BEP) has been framed for the non-invasive techniques specified above, its structure could serve as a guide for a broader spectrum of brain stimulation paradigms ranging from intracranial brain stimulation to sensory stimulation paradigms (such as audio/visual stimulation, peripheral nerve stimulation).

1.1. Why NIBS-BIDS?

NIBS encompasses a group of techniques that stimulate the brain through the skull/scalp. NIBS methods are intervention-based and do not record brain activity, but they are often used alongside neuroimaging and neurophysiological techniques, such as electroencephalography (EEG), magnetoencephalography (MEG), magnetic resonance imaging (MRI), electromyography (EMG) etc. Therefore NIBS techniques do not introduce new brain recording data formats. Instead, NIBS-BIDS aims to standardize the way NIBS metadata i.e., simulation intensity, area, equipment etc. are reported in a BIDS compliant format.

This is motivated by the desire to support FAIR (Findable, Accessible, Interoperable, and Reusable) data principles and address the lack of a reference schema for systematic and structured reporting of experimental procedures in the NIBS field.

There are multiple practical advantages in describing an experiment with NIBS in BIDS format:

1) [common to all BIDS] Enclosing relevant metadata directly in the dataset facilitates the understanding of the data for future users, including one's future self. This promotes replicability and reuse.

2) [common to all BIDS] Many public repositories for neuroscience require data to be structured in BIDS in order to be shared.

3) [common to all BIDS] Many data analysis software are able to import and understand data structured in BIDS format.

    a) [specific to NIBS-BIDS] A practical application of having this information standardized in BIDS is that it allows for the straightforward application of electric field (eField) or acoustic field simulations by embedding all the necessary information—such as coil positioning and stimulation parameters—directly within the dataset. This reduces the

need for external documentation and makes it easier for researchers to run simulations without needing to track down additional information.

1.2. Relation of NIBS-BIDS to BIDS

NIBS-BIDS inherits most core principles from the original BIDS-Raw specification, although some special considerations and additional fields are added. Please refer to the general BIDS specification document for context and general guidelines (definitions, units, directory structure, missing values, stimulus and event information, etc.): https://bids-specification.rtfd.io. 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].

As in BIDS-Raw, the following apply:

- All specifications of paths need to use forward slashes.
- The inheritance principle applies. Any metadata file (.json, .tsv, etc.) may be defined at any directory level. The values from the top level are inherited by all lower levels unless they are overridden by a file at the lower level. For details see BIDS-Raw (The Inheritance Principle).

2. How to describe a NIBS experiment in BIDS

To ensure usability and prevent overcomplication, this BEP follows the principle of "sticking to BIDS whenever possible," using existing BIDS file formats, structures, and methods as a foundation.

NIBS generates critical data—such as stimulation intensity related to motor thresholds or the position of the coil/electrode/transducer relative to a participant's MRI scan—which can be captured in a structured and standardized way.

We propose a flexible framework for integrating NIBS-relevant information into BIDS, **allowing users the discretion to determine the most appropriate level of detail for data storage**. Our primary focus is on describing machine-readable data related to NIBS that is not already captured by other modality-specific file types (e.g., EEG or MRI), such as coil/electrode/transducer position and stimulation intensity required for simulating NIBS-related electric fields.

Additionally, we provide options for storing NIBS-related methodological metadata (e.g., hardware and software details) when desired.

Since NIBS does not represent a neuroimaging technique by itself, most NIBS experiments are accompanied by other neuroimaging modalities. Therefore, as a first step, one should use existing modality specific BIDS extension as a reference for starting the BIDSification of their dataset. For example, one should use EEG-BIDS to BIDSify a NIBS-EEG dataset, as this specification already covers the data type acquired in a NIBS-EEG experiment. The same is valid for an NIBS-MRI experiment using

MRI-BIDS, and NIBS-MEG using MEG-BIDS. NIBS-EMG experiments do not have a specific BIDS specification yet, but another BEP (BEP042) is currently working on an EMG-BIDS proposal. See paragraph 2.6 for a further brief discussion. Once this step is completed, the data are already formatted according to the standard and can be mostly understood by BIDS-based pipelines.

The missing element pertains to the information on stimulation parameters and setup. While this information is not strictly necessary for analyzing the data itself, it is essential for understanding and replicating the experiment. It also allows more advanced types of analysis such as e-field or acoustic simulation, which are becoming a standard in the NIBS field. Typically, details about stimulation parameters and setup were found in the accompanying publication or in the README file.

Here, we **suggest a logic on how to store NIBS metadata in the BIDS structure**.

Furthermore, 'offline' NIBS paradigms (e.g., where stimulation is provided before/after neuroimaging recordings) are not associated with a corresponding neuroimaging file. As such, **we have suggested a new 'intervention' directory/file format to record information relating to the offline NIBS paradigm** (see section 2.4).

If coil/electrode/transducer positions are described using a coordinate system (i.e., have been recorded using a stereotaxic neuronavigation system), then it is REQUIRED to describe the details of the coordinate system including measurement units in a NeuronavigationDetails object within the corresponding .json file (see 2.5 Neuronavigation for details).

2.1. Relation of NIBS-BIDS with SimNIBS

We recognize that one practical application of NIBS-BIDS would be to have data and metadata standardized enough to allow automatization of data processing such as e-field or acoustic simulation. For this reason, many of the parameters we included here as OPTIONAL or RECOMMENDED are derived from the Simulation data structure of SimNIBS. This is done to avoid reinventing the wheel i.e. which parameters and with what names are needed for an e-field simulation. Since these naming conventions were already established, we opted to maintain a similar naming structure to facilitate use of e-field simulation on future NIBS-BIDS datasets with SimNIBS. This decision should not discourage the use of other parameters in case they are necessary for other softwares or simulations. The same logic is applied for acoustic simulations.

2.2. Online vs Offline experiments.

- **ONLINE** = NIBS delivered **while concurrently measuring behavior and/or neuroimaging**
- **OFFLINE**= NIBS delivered **without concurrently measuring behavior and/or neuroimaging**

2.3. Online NIBS experiments

NIBS refers to a collection of methods (e.g., TMS, tES, FUS) used to stimulate the brain that do not generate neural recordings (i.e., NIBS is technically not a neuroimaging modality). As a result, NIBS is

often applied during a concurrent neural recording (i.e., online NIBS) using another neuroimaging modality (e.g., EEG, fMRI, MEG, EMG). In this case, NIBS is similar to other external stimuli that might be given to a participant during an experiment.
For online NIBS experiments, It is RECOMMENDED that information relating to NIBS are stored in the events.tsv and events.json files of the corresponding neural recording file accompanying stimulation. This level of description is useful when NIBS-related information can vary from stimulus to stimulus (e.g., if the coil/electrode/transducer position is being recorded using a neuronavigation system, or if the experiment involves stimuli of different intensity etc.). NIBS information MAY also be stored in other files describing the corresponding neural recording such as the *scans.tsv* and *scans.json* (e.g., if the details of stimulation are fixed throughout the recording and description at an individual stimulus level is not required).
Importantly, information relating to NIBS that could vary either between participants or between stimuli (or both), or it is required in a machine-readable format for use in external software SHOULD be stored in TSV files (*events.tsv* or *scans.tsv*).
Methodological and hardware details related to NIBS SHOULD be stored in JSON files (*events.json* and *scans.json*). Notice that while a .json file should describe ALL all the columns present in the corresponding .tsv file, it can also contain other objects not directly linked to a column in the .tsv file for further details.

2.3.1. NIBS parameters (modified events.tsv or scans.tsv)

In addition to the columns REQUIRED, RECOMMENDED or OPTIONAL in the events.tsv or scans.tsv we suggest the following columns for each NIBS modality. Note that none of these columns are REQUIRED as with this BEP we intend to give guidelines on how to describe NIBS experiments in BIDS while allowing the maximum flexibility of the BIDS structure.

2.3.1.1. Transcranial magnetic stimulation (TMS)

The following are OPTIONAL column headers relating to TMS which MAY be added to an events.tsv file (when it changes over events) or a scans.tsv file (when it remains constant over events). It is RECOMMENDED to include details of stimulation which can change on a trial-to-trial basis or between recording blocks (e.g., stimulation intensity, coil position etc). Additional columns are also allowed if required.

Column name	**Requirement Level**	**Data type**	**Description**
tms_rmt	OPTIONAL	number	Resting motor threshold as a percentage of maximum stimulator output (MSO). Values are expressed as percent, not as fraction (so 80, not 0.80).
tms_amt	OPTIONAL	number	Active motor threshold as a percentage of

			maximum stimulator output (MSO).
tms_intensity_mso	OPTIONAL	number	Stimulation intensity as a percentage of maximum stimulator output (MSO).
tms_intensity_didt	OPTIONAL	number	Rate of change of current in the coil (in A/s). In some stimulators, this value is given on the screen shortly after a pulse is given.
tms_pos_centre	OPTIONAL	string	Description of the center of the coil. For example, could be in relation to an EEG 10-10 electrode position (e.g., 'C3') or a free form description ('over left primary motor cortex'). If the center of the coil is a coordinate, use tms_pos_centre_x,tms_pos_centre_y,tms_pos_centre_z.
tms_pos_centre_x	OPTIONAL	number	Center of the coil in relation to the x-axis coordinate (in mm).
tms_pos_centre_y	OPTIONAL	number	Center of the coil in relation to the y-axis coordinate (in mm).
tms_pos_centre_z	OPTIONAL	number	Center of the coil in relation to the z-axis coordinate (in mm).
tms_pos_ydir	OPTIONAL	string	Description of the position along the coil's y-axis (i.e., prolongation of the handle). For example, could be in relation to an EEG 10-10 electrode position (e.g., 'CP5') or a free form description ('45 degrees to the midline pointing posterior-lateral'). If the center of the coil is a coordinate, use tms_pos_ydir_x,tms_pos_ydir_y,tms_pos_ydir_z.
tms_pos_ydir_x	OPTIONAL	number	Position along the coil's y-axis (i.e., prolongation of the handle) in relation to the x-axis coordinate.
tms_pos_ydir_y	OPTIONAL	number	Position along the coil's y-axis (i.e., prolongation of the handle) in relation to the y-axis coordinate.
tms_pos_ydir_z	OPTIONAL	number	Position along the coil's y-axis (i.e., prolongation of the handle) in relation to

			the z-axis coordinate.
tms_pos_distance	OPTIONAL	number	Distance from the coil to the scalp (in mm).
tms_pos_r1_c1	OPTIONAL	number	Corresponds to the [1,1] row/column position in the affine transformation matrix.
tms_pos_r1_c2	OPTIONAL	number	Corresponds to the [1,2] row/column position in the affine transformation matrix.
tms_pos_r1_c3	OPTIONAL	number	Corresponds to the [1,3] row/column position in the affine transformation matrix.
tms_pos_r1_c4	OPTIONAL	number	Corresponds to the [1,4] row/column position in the affine transformation matrix.
tms_pos_r2_c1	OPTIONAL	number	Corresponds to the [2,1] row/column position in the affine transformation matrix.
tms_pos_r2_c2	OPTIONAL	number	Corresponds to the [2,2] row/column position in the affine transformation matrix.
tms_pos_r2_c3	OPTIONAL	number	Corresponds to the [2,3] row/column position in the affine transformation matrix.
tms_pos_r2_c4	OPTIONAL	number	Corresponds to the [2,4] row/column position in the affine transformation matrix.
tms_pos_r3_c1	OPTIONAL	number	Corresponds to the [3,1] row/column position in the affine transformation matrix.
tms_pos_r3_c2	OPTIONAL	number	Corresponds to the [3,2] row/column position in the affine transformation matrix.
tms_pos_r3_c3	OPTIONAL	number	Corresponds to the [3,3] row/column position in the affine transformation matrix.

tms_pos_r3_c4	OPTIONAL	number	Corresponds to the [3,4] row/column position in the affine transformation matrix.
tms_pos_r4_c1	OPTIONAL	number	Corresponds to the [4,1] row/column position in the affine transformation matrix.
tms_pos_r4_c2	OPTIONAL	number	Corresponds to the [4,2] row/column position in the affine transformation matrix.
tms_pos_r4_c3	OPTIONAL	number	Corresponds to the [4,3] row/column position in the affine transformation matrix.
tms_pos_r4_c4	OPTIONAL	number	Corresponds to the [4,4] row/column position in the affine transformation matrix.
Additional Columns	OPTIONAL	n/a	Additional columns are allowed.

NOTE: Additional columns can be added for more detailed description. The coordinate system of the xyz coordinate and the path to the corresponding MRI (if used) will be specified in the corresponding JSON file within the Neuronavigation system.

NOTE: For simulations with simNIBS, the position of the coil SHOULD be specified with ONE of the following:

1. A text description of the coil center (tms_pos_centre), coil handle direction(tms_pos_ydir) and coil to scalp distance (tms_pos_distance);
2. Coordinates of the coil centre (tms_pos_centre_x, tms_pos_centre_y, tms_pos_centre_z, handle direction (tms_pos_ydir_x, tms_pos_ydir_y, tms_pos_ydir_z) and coil to scalp distance (tms_pos_distance);
3. A 4x4 affine transformation matrix (tms_pos_r1_c1, tms_pos_r1_c2 etc.). If this method is used, the following details MUST also be stored under the NeuronavigationDetails key in the corresponding .json file:
    a. Manufacturer
    b. NeuronavigationCoordinateSystem
    c. NeuronavigationCoordinateUnits

2.3.1.2. Transcranial electrical stimulation (tES)

The following are OPTIONAL column headers relating to tES which MAY be added to an events.tsv file or a scans.tsv file. Additional columns are also allowed if required.

Column name	**Requirement Level**	**Data type**	**Description**
tes_electrode1_current	OPTIONAL	number	Current value (in Ampere). Positive values indicate anode (e.g., 0.001), negative values indicate cathode (e.g., -0.001). Sum of current values with other electrodes MUST equal zero.
tes_electrode1_channelnr	OPTIONAL	number	Number of the channel this electrode is connected to.
tes_electrode2_current	OPTIONAL	number	Current value (in Ampere). Positive values indicate anode (e.g., 0.001), negative values indicate cathode (e.g., -0.001). Sum of current values with other electrodes MUST equal zero.
tes_electrode2_channelnr	OPTIONAL	number	Number of the channel this electrode is connected to.
tes_electrode1_pos_centre	OPTIONAL	String	Description of the center of the first electrode. For example, could be in relation to an EEG 10-10 electrode position (e.g., ‘C3’) or a free form description (‘over left primary motor cortex’).
tes_electrode2_pos_centre	OPTIONAL	String	Description of the center of the second electrode. For example, could be in relation to an EEG 10-10 electrode position (e.g., ‘C3’) or a free form description (‘over left primary motor cortex’).
tes_electrode1_pos_ydir	OPTIONAL	String	Position along the first electrode’s y-axis. For example, could be in relation to an EEG 10-10 electrode position (e.g., ‘F6’) or a free form description.
tes_electrode2_pos_ydir	OPTIONAL	String	Position along the second electrode’s y-axis. For example, could be in relation to an EEG 10-10 electrode position (e.g., ‘F6’) or a free form description.

Additional Columns	OPTIONAL	n/a	Additional columns are allowed.

NOTE: Additional columns can be added for more detailed description.

NOTE: Additional electrodes can be described using the above naming convention. Additional electrodes MUST use a unique number. For example, tes_electrode3_current, tes_electrode3_pos_centre etc.

NOTE: Electrode information (shape, dimensions, material etc.) are stored in the corresponding .json file under NIBSDetails -> ElectrodeDetails (2.3.2).

NOTE: Electrode position can also be described using an affine transformation matrix. See TMS (2.3.1.1) for an example.

2.3.1.3. Transcranial ultrasonic stimulation (TUS)

The following are OPTIONAL column headers relating to TUS which MAY be added to an events.tsv file or a scans.tsv file. Additional columns are also allowed if required.

Column name	Requirement Level	Data type	Description
tus_transducer_pos_x	OPTIONAL	Number	Center of the transducer in relation to the x-axis coordinate (in mm)
tus_transducer_pos_y	OPTIONAL	Number	Center of the transducer in relation to the y-axis coordinate (in mm)
tus_transducer_pos_z	OPTIONAL	Number	Center of the transducer in relation to the z-axis coordinate (in mm)
pulse_duration	OPTIONAL	Number	The shortest continuous period of sonication in milliseconds (e.g., 50 ms). Note: equal to pulse train duration for continuous TUS
pulse_repetition_frequency	OPTIONAL	Number	Frequency (number of pulses emitted in a second) of pulse delivery within the pulse train duration in Hz (e.g., 150 Hz)
pulse_train_duration	OPTIONAL	Integer	The length of time a train of pulses is delivered in seconds (e.g., 30 s)
pulse_train_repetition_interval	OPTIONAL	Integer	The length of time between the onset of pulse trains in seconds (e.g., 30 s)

pulse_train_repetition_interval_count	OPTIONAL	Integer	How many times the pulse train repetition interval is repeated (e.g., 10)
spatial_peak_pulse_avg_intensity	OPTIONAL	Integer	-Isppa derated v non-derated - Value
spatial_peak_temporal_avg_intensity	OPTIONAL	Integer	-Ispta derated v non-derated - Value
mechanical_index	OPTIONAL	Structure	-Name of index -Integer of index
thermal_index	OPTIONAL	Structure	-Name of index -Integer of index
duty_cycle	OPTIONAL	Integer	Percentage of time sonication is delivered during the pulse repetition interval (e.g., 5%)
pulse_repetition_interval	OPTIONAL	Integer	Time between the onset of two pulses within a train of pulses in milliseconds (e.g., 50 ms)
thermal_dose	OPTIONAL	Integer	
Additional Columns	OPTIONAL	n/a	Additional columns are allowed.

NOTE: Additional columns can be added for more detailed description.

NOTE: Transducer position can also be described using an affine transformation matrix. See TMS (2.3.1.1) for an example.

2.3.2. NIBS details (modified events.json or scans.json)

The JSON file events.json or scans.json will follow the structure of the corresponding TSV file i.e., describing each column present in the TSV.
In addition, it is RECOMMENDED to include the details of the NIBS device used in the experiment, even if this is not related to any specific column of the TSV, similarly to what is done in StimulusPresentation.

Key name	**Requirement Level**	**Data type**	**Description**

NIBSDetails	RECOMMENDED	Object or object of objects	Object containing key-value pairs related to the NIBS device used to apply stimulation during the experiment. If multiple devices are used concurrently, then multiple objects can be used to describe the different devices (for example: {“NIBSDetails”: {“Device 1”: {“NIBSType”: “TMS”}} {“Device 2”: {“NIBSType”: “tES”}}}).

The object supplied for NIBSDetails SHOULD include the following key-value pairs.

Key name	**Requirement Level**	**Data type**	**Description**
NIBSType	RECOMMENDED	string	Type of NIBS used. (e.g., ‘TMS’, ‘tES’, ‘TUS’).
NIBSDescription	RECOMMENDED	string	Free text description of the NIBS protocol.
Manufacturer	RECOMMENDED	string	Manufacturer of the NIBS device used in the experiment. Coil/electrodes/transducers manufacturer details should be included in the coil/electrodes/transducers details.
ManufactureModelName	RECOMMENDED	string	Manufacturer’s model name of the NIBS device used in the experiment.
ManufacturerSerialNumber	RECOMMENDED	string	Manufacturer’s serial number of the NIBS device used in the experiment.
SoftwareVersions	OPTIONAL	string	Manufacturer's designation of software version of the device that produced the stimulation.
CoilDetails	OPTIONAL	object of objects	Object of the TMS coils used in the experiment. Each key-value pair in the JSON object is a name of the coil and an object in which its parameters are defined as key-value pairs (for example: {“CoilDetails”: {“Coil 1”: {“ModelName”: “D70”, “SerialNumber”: “4150-00”}} {“Coil 2”: {“ModelName”: “DCC”, “SerialNumber”: “4610-00”}}}).

ElectrodeDetails	OPTIONAL	object of objects	Object of the tES electrodes used in the experiment. Each key-value pair in the JSON object is a name of the electrode and an object in which its parameters are defined as key-value pairs (for example: {“ElectrodeDetails”: {“Electrode 1”: {“Shape”: “Rect”, “Dimensions”: [50, 70], “Thickness”: [5, 2]}}{“Electrode 2”: “Shape”: “Ellipse”, “Dimensions”: [20, 20], “Thickness”: [5, 2]}}}).
TransducerDetails	OPTIONAL	object of objects	Object of the TUS transducers used in the experiment. Each key-value pair in the JSON object is a name of the transducer and an object in which its parameters are defined as key-value pairs (for example: {“TransducerDetails”: {“Transducer 1”: {“Manufacturer”: “Brainsonix”, “ModelName”: “BX Pulsar 1002”, “SerialNumber”: 123, “Type”: “Spherical”, “Elements”: 1, “FocalLengthType”: “Fixed”, “FocalLength”: 80 (mm), “CenterFrequency”: 650 (kHz), “Geometry”: [radius of curvature, aperture diameter, full width half maximum}}).

Example

Example of the content of an events.tsv file with a TMS pulse.

onset	duration	trial_type	tms_rmt	tms_intensity_mso	tms_pos_centre	tms_pos_ydir
4.013	0	TMS1	63	63	Left M1	Cz
9.154	0	TMS2	63	69	Left M1	Cz
14.984	0	TMS3	63	76	Left M1	Cz

*Example of the accompanying *_events.json sidecar:*

```
{
   "NIBSDetails": {
      "NIBSType": "TMS",
          "NIBSDescription": "Input-output curve of single monophasic TMS pulses applied to the left primary motor cortex",
      "Manufacturer": "Magstim",
      "ManufactureModelName": "BiStim^2",
```

```
    "ManufacturerSerialNumber": "3234-00",
    "CoilDetails": {
      "Coil 1": {
        "ModelName": "D70",
        "SerialNumber": "4150-00"
      }
    }
  },
  "onset": {
    "LongName": "Event Onset",
    "Description": "Time from the start of the recording when the event occurred.",
    "Units": "seconds"
  },
  "duration": {
    "LongName": "Event Duration",
    "Description": "Duration of the event.",
    "Units": "seconds"
  },
  "trial_type": {
    "LongName": "Stimulation type",
    "Description": "Type of stimulation that is applied to the participant.",
    "Levels": {
      "TMS1": "A single monophasic TMS pulse at RMT",
      "TMS2": "A single monophasic TMS pulse at 110% RMT",
      "TMS3": "A single monophasic TMS pulse at 120% RMT",
    }
  },
  "tms_rmt": {
    "LongName": "TMS Resting Motor Threshold",
      "Description": "Lowest stimulation intensity required to evoke at least 5 out of 10 MEPs with a peak-to-peak amplitude > 0.05 mV, described as a percentage of maximum stimulator output (MSO). ",
    "Units": "percent"
  },
  "tms_intensity_mso": {
    "LongName": "TMS Stimulation Intensity",
      "Description": "The intensity of the TMS pulse delivered as a percentage of maximum stimulator output (MSO).",
    "Units": "percent"
  },
  "tms_pos_centre": {
    "LongName": "TMS Coil Position Relative to EEG Cap",
    "Description": "The position of the TMS coil center on the left primary motor cortex.",
    "Levels": {
```

```
        "Left M1": "Coil center positioned over Left M1 (primary motor cortex)"
      }
    },
    "tms_pos_ydir": {
      "LongName": "TMS Coil Handle Direction",
      "Description": "The angular direction of the TMS coil handle relative to the y-axis of the EEG cap.",
      "Units": "degrees"
    }
}
```


2.4. Offline NIBS experiments

In addition to NIBS protocols associated with a concurrent neural recording file (i.e., online NIBS), many NIBS protocols are performed without concurrent neural recordings (i.e., offline NIBS interventions), where neural/behavioral recordings are performed before and/or after NIBS. This creates a challenge for the BIDS format which assumes corresponding neural recording files. However, usable data is often generated by offline NIBS protocols, such as the position of the coil/electrode/transducer relative to the participant's head (e.g., as recorded with neuronavigation) or the intensity of the stimulation.

2.4.1. New directory "intervention/" and files *[]_intervention.tsv* and *[]_intervention.json*

The details of these NIBS interventions MAY be stored in the "*int*" directory using intervention files (*intervention.tsv* and *intervention.json*). Intervention files have the same format as event files, however do not require an onset and duration column, MUST be labeled *_intervention.tsv* and *_intervention.json*, and are not associated with a corresponding neural recording file. Basically, these files are equivalent to the beh.tsv / beh.json pair (i.e., behavioral experiments with no neural recordings), however are specifically for interventions designed to modulate neural activity in some way. Using a specific file for interventions instead of beh files ensures clarity on the experimental structure.

As with online NIBS protocols, details MAY be stored at either the *_intervention.tsv* / *_intervention.json* or the *_scans.tsv* / *_scans.json* level, although the *_intervention.tsv* / *_intervention.json* level is RECOMMENDED.

It is RECOMMENDED to store intervention data/information in the TSV file when those are needed in a machine-readable format (i.e., that could be used for additional analyses, such as coil/electrode/transducer position and stimulation intensity).

Note that files stored in the 'int' directory MAY store information from interventions other than NIBS which are also performed without neural recordings (e.g., pharmacological or behavioral interventions).

We acknowledge the the presence in the BIDS standard of ways to describe pharmaceutical interventions during a scan (see for example the pharmaceuticals spec in PET-BIDS) or electrical stimulation during iEEG sessions. However, we did not find a way already integrated in BIDS to describe events that happens between data recordings.

Template:

sub-<label>/
  [ses-<label>/]
    intervention/
      sub-<label>[_ses-<label>]_task-<label>[_acq-<label>][_run-<index>]_intervention.json
      sub-<label>[_ses-<label>]_task-<label>[_acq-<label>][_run-<index>]_intervention.tsv

2.4.1.1. Intervention data files (*_intervention.tsv)

The same OPTIONAL columns as other NIBS-related files are pre-defined for intervention data files. Additional OPTIONAL columns for intervention data files include:

Column name	**Requirement Level**	**Data type**	**Description**
intervention_type	OPTIONAL	string	Primary categorisation if multiple interventions are administered. For example: it could take on values ‘pharmacological’ and ‘nibs’ if between neural recordings a drug was given followed by a NIBS intervention.
Additional Columns	OPTIONAL	n/a	Additional columns are allowed.

2.4.1.2. Sidecar JSON (*_intervention.json)

It is RECOMMENDED to add the following metadata to the JSON files of this directory.

Key name	**Requirement Level**	**Data type**	**Description**
InterventionName	RECOMMENDED	string	Name of the intervention. No two interventions should have the same name.
InterventionDescription	RECOMMENDED	string	A longer description of the intervention.

Example - intervention using intermittent theta-burst stimulation (iTBS)

In this example, stimulation intensity and coil position information are stored in the TSV file in a machine-readable format, enabling use with tools like SIMNIBS to estimate the E-field. However, important details such as stimulation frequency are not included in the TSV file but are stored in the accompanying JSON file. This decision reflects the consensus that such details are not essential in a

machine-readable format. That said, this is not a strict requirement, and researchers converting their datasets to BIDS format have the flexibility to decide whether to include additional information in the TSV file:

```
└─ sub-001/
  └─ int/
    ├─ sub-001_task-rest_acq-itbs_intervention.tsv
    └─ sub-001_task-rest_acq-itbs_intervention.json
```

Example of the content of the TSV file.

tms_rmt	tms_intensity_mso	tms_intensity_didt	tms_coil_pos_centre	tms_coil_pos_ydir
64	45	20000000	C3	FC5

Example of the accompanying JSON sidecar:

```
{
  "InterventionName": "Intermittent theta burst stimulation",
  "InterventionDescription": "Intermittent theta burst stimulation (iTBS) was applied to the left primary motor cortex. Stimulation included 600 pulses with 3 stimuli bursts at 50 Hz repeated at 5 Hz. Stimuli were applied for 2 s followed by an 8 s interval in a repeating pattern. Stimuli were applied at 70% or resting motor threshold.",
  "tms_rmt": {
    "LongName": "Resting motor threshold",
     "Description": "Lowest stimulation intensity required to evoke at least 5 out of 10 MEPs with a peak-to-peak amplitude > 0.05 mV, described as a percentage of maximum stimulator output (MSO).",
    "Units": "percent",
    }
  "tms_intensity_mso": {
    "LongName": "Stimulation intensity",
    "Description": "Stimulation intensity expressed relative to maximum stimulator output",
    "Units": "percent",
    }
  "tms_intensity_didt": {
    "LongName": "Stimulation intensity",
    "Description": "Stimulation intensity expressed as rate of change of current in the coil",
    "Units": "A/s",
    }
  "tms_coil_pos_centre": {
    "LongName": "Centre of the TMS coil",
    "Description": "Centre of the TMS coil based on 10-10 EEG electrode positions",
    }
  "tms_coil_pos_ydir": {
```

```
    "LongName": "Position along the coil's y-axis",
    "Description": "Position along the coil's y-axis (i.e., prolongation of the handle) based on 10-10 EEG electrode positions",
    }
  "NIBSDetails": {
    "NIBSType": "TMS",
    "NIBSDescription": "Intermittent theta burst stimulation to the left primary motor cortex",
    "Manufacturer": "Magstim",
    "ManufactureModelName": "Rapid^2",
    "ManufacturerSerialNumber": "3004-00",
    "CoilDetails": {
      "Coil 1": {
        "ModelName": "D70 AFC",
        "SerialNumber": "3910-00"
      }
    }
  }
}
```


2.5. Neuronavigation

If a neuronavigation system is used to track NIBS coil/electrode/transducer position, it is RECOMMENDED to include the hardware details of the neuronavigation device used in the experiment in the corresponding events.json file of the neural recording accompanying stimulation (online NIBS) or the corresponding intervention.json file (offline NIBS). Furthermore, if position coordinates are provided in the corresponding *.tsv* file, it is REQUIRED to include details of the coordinate system used to describe the coil/electrode/transducer position.
Note that no new neuronavigation-specific file is added in this BEP, but might be worth exploring this path in future extensions.

Hardware information

Key name	**Requirement Level**	**Data type**	**Description**
NeuronavigationDetails	REQUIRED (if coil/electrode/transducer coordinates reported)	object	Object containing key-value pairs related to the neuronavigation device used to track coil/electrode/transducer during the experiment.

The object supplied for NeuronavigationDetails SHOULD include the following key-value pairs.

Key name	Requirement Level	Data type	Description
Manufacturer	RECOMMENDED	string	Manufacturer of the neuronavigation device used in the experiment.
ManufactureModelName	RECOMMENDED	string	Manufacturers model name of the neuronavigation device used in the experiment.
SoftwareVersions	OPTIONAL	string	Manufacturer's designation of software version of the neuronavigation system.
IntendedFor	OPTIONAL	String or array	The paths to files for which the associated file is intended to be used. This identifies the MRI or CT scan associated with neuronavigation.
NeuronavigationCoordinateSystem	REQUIRED (if coil/electrode/transducer coordinates reported)	string	Defines the coordinate system for the xyz coordinate provided in the corresponding TSV file. See the Coordinate Systems Appendix for a list of restricted keywords for coordinate systems. If "Other", provide definition of the coordinate system in NeuronavigationCoordinateSystemDescription. For a list of valid values for this field, see the associated glossary entry.
NeuronavigationCoordinateUnits	REQUIRED (if coil/electrode/transducer coordinates reported)	string	Units of the coordinates of NeuronavigationCoordinateSystem. Must be one of: "m", "mm", "cm", "n/a".
NeuronavigationCooridinateSystemDescription	RECOMMENDED	string	Free-form text description of the coordinate system. May also include a link to a documentation page or paper describing the system in greater detail.
NeuronavigationCoilCoordiateSystemDescription	RECOMMENDED	string	Free-form text description of the coordinate system. May also include a link to a documentation page or paper describing the system in greater detail.

Example

Example of the content of an events.tsv file with a TMS pulse.

onset	duration	trial_type	tms_pos_centre_x	tms_pos_centre_y	tms_pos_centre_z
4.013	0	TMS	-1.2	-15.8	116.0
9.154	0	TMS	-1.1	-15.7	116.1
14.984	0	TMS	-1.3	-15.6	115.9

*Example of the accompanying *_events.json sidecar:*

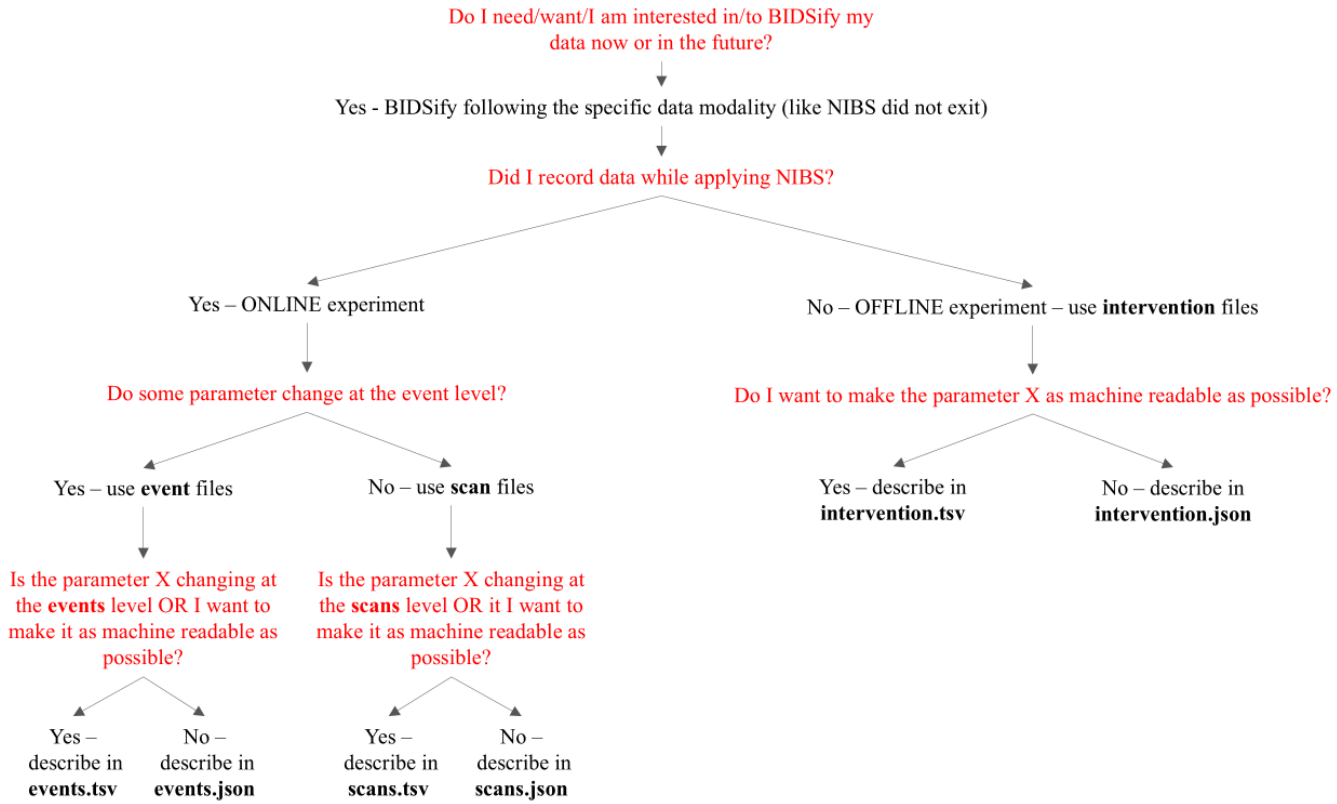

```
{
  "NIBSDetails": {
    "NIBSType": "TMS",
    "NIBSDescription": "Single monophasic TMS pulses applied to a targeted brain region",
    "Manufacturer": "Magstim",
    "ManufactureModelName": "BiStim^2",
    "ManufacturerSerialNumber": "3234-00",
    "CoilDetails": {
      "Coil 1": {
        "ModelName": "D70",
        "SerialNumber": "4150-00"
      }
    }
  },
  "NeuronavigationDetails": {
    "Manufacturer": "Brainsight",
    "ManufactureModelName": "Brainsight TMS",
    "SoftwareVersions": "Brainsight 2.5.4",
    "IntendedFor": "bids::sub-01/ses-01/anat/sub-01_T1w.nii",
    "NeuronavigationCoordinateSystem": "Other",
    "NeuronavigationCoordinateUnits": "mm",
      "NeuronavigationCoordinateSystemDescription": "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.",
       "NeuronavigationCoilCoordinateSystemDescription": "Origin is centre of the coil, positive x-axis towards the right of the coil, positive y-axis orthogonal to x-axis through and away from the coil handle, z-axis orthogonal to xy-plane along the planar surface of the coil, positive pointing up (i.e., away from the participant's head) of the active side of the coil."
  },
  "onset": {
    "LongName": "Event Onset",
```

```
    "Description": "Time from the start of the recording when the event occurred.",
    "Units": "seconds"
  },
  "duration": {
    "LongName": "Event Duration",
    "Description": "Duration of the event.",
    "Units": "seconds"
  },
  "trial_type": {
    "LongName": "Stimulation type",
    "Description": "Type of stimulation that is applied to the participant.",
    "Levels": {
      "TMS": "A single monophasic TMS pulse"
    }
  },
  "tms_pos_centre_x": {
    "LongName": "TMS Coil Position X Coordinate",
    "Description": "The x-coordinate of the TMS coil center in 3D space, relative to the head.",
    "Units": "millimeters"
  },
  "tms_pos_centre_y": {
    "LongName": "TMS Coil Position Y Coordinate",
    "Description": "The y-coordinate of the TMS coil center in 3D space, relative to the head.",
    "Units": "millimeters"
  },
  "tms_pos_centre_z": {
    "LongName": "TMS Coil Position Z Coordinate",
    "Description": "The z-coordinate of the TMS coil center in 3D space, relative to the head.",
    "Units": "millimeters"
  }
}
```


2.6. NIBS-EMG

EMG data are not directly supported in the BIDS standard yet, although the BEP042 is currently working on an EMG-BIDS proposal. Since NIBS-EMG experiments are very common here we provide some guidance on how to deal with this type of data. Currently, the best solution is to describe EMG data within the EEG-BIDS extension. An example of how to achieve this is provided using the fieldtrip data2bids converter here.

3. Decision tree



.json => hardware/software details *and/or* fixed methodological details that are not required as machine readable (e.g., used as a record of methods, like the description of offline rTMS protocol).

.tsv => stimulation parameters that can change between trials/participants *and/or* are required as machine readable (e.g., for use in another software system, like stimulation intensity, coil position, or motor threshold).

4. FAQ

Q: Why not considering PRE POST and the INTERVENTION (ses-PRE, ses-POST and ses-INTERVENTION) as sessions and describe the intervention in the session files?

A: That could be a solution, but not all “PRE POST” experiments are sessions, can also be PRE POST in the same session (between acquisitions) e.g., eeg-TUS-eeg without removing the cap or fMRI-tDCS-fMRI without exiting from the scanner. If the intervention happens between two acquisitions, the intervention folder should go in the same folder as the other modalities and the the scans.tsv should be used to describe the temporal evolution of the steps (data acquisitions and interventions). If the intervention happens between sessions, then the intervention files should go in a dedicated session folder e.g., ses-INTERVENTION, containing the intervention folder. The session.tsv should then be used to describe the temporal evolution of the sessions.

Q: What if I have many interventions in many days between a pre and post sessions? How would I structure that?

A: You will have thre sessions folders like ses-PRE, ses-INTERVENTION, ses-POST. In the ses-INTERVENTION you will have the intervention files. In the intervention.tsv you will have as many rows as the interventions number, describing the parameters that change each time, the timestamp etc. The sidcare JSON will describe the setting, hardware etc.. . It is true that since the participant exit and renter the lab for each intervention those should be captured in separated session folders, but this would result in an inconveniently large number of sessions folders.

Q: Why not use the session and participant files when the stimulation do not change between sessions or withing the same participant?

A: that was an initial idea. It was discarded for (1) keeping the participant file as close as possible to its purpose (demographic data in general) (2) because neither the session nor the participant files are tied to a specific data acquisition, while the scans and event files are tied to data. It seemed clearer for ONLINE stimulation to tie the stimulation to the data that affects, even if this might imply some level of repetition. We opted for clarity over simplification in this case.

Q: How do I choose if a parameter goes in a TSV or JSON format?

A: the short answer is: it is up to whom it is BIDSifiying the data. The long answer is: it depends. If the specific parameter changes at the event level (the smallest level), the parameter should be described in the TSV file. If the parameter does not change at the event level, and you are describing it in the scans or

interventions files, the decision is tied to machine readability and future applications that you are forseeing. For example, if you think that some of your TMS parameters are important to be easly fetched with a script, they should go in the TSV. If you think that a certain set of parameters can be useful for e-field or ultrasonic simulations, they should be easily fetched by a machine, hence they go in the TSV. If you think that a parameter is not as important to be fetched by a machine e.g., tDCS machine name or motor threshold, they can go in the JSON file. Also JSON files are machine readable, although less straightforward than TSV files.

Q: Why using the intervention files and not just the README for simple interventions?

A: the use of the README file is totally fine, especially for simple interventions. The use of the interventions files allow a more machine readable description of the stimulation for future applications (i.e., e-field or acoustic stimulation) and is a bit more inducive to the accurate description of the hardware setting and parameters, which is the point of BIDS. Therefore we think that once should opt for the intervention files over the README. However we also acknowledge that if the choice is to use the README or not BIDSify (and share) the dataset, one should choose to BIDSify and share the data.

Q: Can I add a parameter that does not exist in this BEP?

A: Yes. This BEP has the goal of guiding and give a logic to the description of NIBS experiment in BIDS format. We acknowledge that there might be important parameters that we oversaw or are not used yet. These parameters can be added in the TSV and JSON files with the same logic of all the others.

Q: What about "seamless" experiment, in which I turn on my device and the subject perform a series of task, but the stimulation is not tied to any task in particular.

A: see vittorio.iacovella@unitn.it 's example on this here, for this paper. Basically one should always think first if the experiment is ONLINE i.e., I am stimulating while recording data even if the data are just behavioural, or OFFLINE i.e., data is not collected while I am stimulating. Please consider that this can change between sessions, participants and scans. For a specific participant, session and scan, a seamless stimulation can be online while for others can be offline.

Q: why having an intervention folder instead of just putting the intervention files at the level where the intervention happens i.e., between acquisitions, between sessions etc… .

A: While that could be possible, we feel that using an intervention folder is clearer than free floating interventions files. It helps also when intervention affect different modalities e.g., an experiment with EEG and BEHAVIOURAL task - intervention - and then EEG and BEHVIOURAL task. The intervention will affect both EEG and BEH folders, so we would need to put the intervention files at the same level of the scan files. With a folder, we clarify that the intervention is not tied to a specific modality per-se.

5. NIBS-BIDS Example dataset

Old version:

- https://gin.g-node.org/CIMeC/TMS-EEG_brain_connectivity_BIDS

New versions:

- tES-behavioural
- …

6. Change-log

- v1.0 2020-11-09:
  - Initial work on specification with vittorio.iacovella@unitn.it carlo.miniussi@unitn.it marta.bortoletto@cognitiveneuroscience.it
- v1.0 2021-04:
  - First example of a NIBS-BIDS dataset https://gin.g-node.org/CIMeC/TMS-EEG_brain_connectivity_BIDS
- V1.0 2021-11
  - Brainhack @Donosti with eleonora.marcantoni@cognitiveneuroscience.it martinabulgari3@gmail.com and g.guidali@campus.unimib.it
- V1.0 2022-02
  - First international NIBS-BIDS meeting
- V1.0 2022-11
  - First update of the BEP
- V2.0 2023-08
  - BEP 2.0 available with the new NIBS-BIDS logic for describing NIBS experiments
- V3.0 2024-07
  - BEP 3.0 available with a draft of the final BIDS structure.
- V4.0 2024-11
  - BEP 4.0 updated with a new, more comprehensive structure. Added int files for offline stimulation. Harmonized parameters with SimNIBS. Use of events and scans files for online stimulation.
- V4.1 2024-12
  - BEP 4.1 Comments form December 9th, 2024 5th general meeting implemented, added FAQ section.
  - Met with the BIDS maintenance team in January 2025. Agreed on closing the open discussions, lock the google doc and start the PR.