**This document was used to initiate discussions, following steps were made using BIDS github tools. Currently (Dec 2022), we are working on a PR to document the proposal:**
**https://github.com/bids-standard/bids-specification/pull/1128**
**Contributions are still welcome , but you no longer can comment on this outdated document and should instead use Github.**
**Note that you can join the matrix channel to discuss this proposal more directly: https://matrix.to/#/%23bids-bep020:matrix.org or contact the extension lead or co-lead.**

# BIDS Extension Proposal 20 (BEP020):

## Eye Tracking including Gaze Position and Pupil Size

version 1.0

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**To contribute**: join the discussion by adding and responding to comments in this google document. This is our main discussion forum until we merge this BEP with the specifications on Github (Nov 2020).

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.

*<Please note, the following document is based on the extension proposal for MEG data>*

1. Table of contents

# 2. Background

This specification extends the Brain Imaging Data Structure (BIDS) general specifications for integration of eye tracking and pupillometry data. The aim of this proposal is to provide a standard for rich and detailed standalone eye-tracking data sets, which go beyond the specifications of https://bids-specification.readthedocs.io/en/stable/04-modality-specific-files/06-physiological-and-other-continuous-recordings.html. In the case when eye-tracking data is corregistered with M/EEG or fMRI data, the specifications below can be used as described in the 06 physiological standard. In this case, the template directory name corresponds to any data recording modality used. For example func, anat, dwi, meg, eeg, ieeg, or beh.
Please refer to the main BIDS specification document for context and general guidelines (definitions, units, directory structure, etc.): https://bids-specification.readthedocs.io/en/stable/

NOTE#1: we used the following keywords below: "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL". They are to be interpreted as described in [RFC2119].

NOTE#2: We refer to the eye tracker as a tracker.

TERMINOLOGY:

- Responses = recorded behaviour of the subject in relation to the Task.

# 3. Eye-Tracking-BIDS

Unprocessed eye-tracking data SHOULD be stored in the following formats (see Table).

## 3.1 Data formats

Below is a list of pros and cons for potential data formats that we considered for sharing segmented data:

| Data format | Pros | Cons |
|---|---|---|
| .tsv | ● Standard text format<br>● Simple and easy I/O | |
| .csv | ● Standard text format<br>● Simple and easy I/O | |

The eye-tracking data files naturally contain gaze position (x/y coordinates) and pupil size data. With Eye-Tracking-BIDS, we wish to promote the adoption of good practices in the management of scientific data. Hence, the emphasis of Eye-Tracking-BIDS is not to impose a new, generic data format for the modality, but rather to standardize the way data is stored in repositories. Further, there is currently no widely accepted standard file format for eye-tracking data, but some software applications for

eye-tracking data analysis provide readers of some raw files. Note, there is a lack of standard processing software. As a consequence, many laboratories develop their own software.

Some software readers may skip important metadata that is specific to tracker manufacturers. It is therefore REQUIRED that users provide additional meta information extracted from the manufacturer raw data files in a sidecar JSON file. This allows for easy searching and indexing of key metadata elements without the need to parse files in proprietary data format. Other relevant files MAY be included alongside the eye-tracking data; examples are provided below.

**NOTE:**
**[.] brackets indicate optional fields,**
**All empty optional fields should be omitted from the JSON files.**

## 3.2. Eyetrack template

```
sub-<participant_label>/
    eyetrack/
      sub-<participant_label>[_ses-<label>]_task-<task_label>[_acq-<label>]_eye
        track.tsv
      [sub-<participant_label>[_ses-<label>]_task-<task_label>[_acq-<label>]_ey
        etrack.json]
      [sub-<participant_label>[_ses-<label>]_task-<task_label>[_acq-<label>]_ev
        ents.tsv]
```

This template is for eye-tracking data of any kind. File labelling follows the same general rules as outlined in "8.4. Task (including resting state) imaging data" of the The Brain Imaging Data Structure (BIDS) Specification, with the difference being that:

1. The "rec" (reconstruction algorithm) label does not apply and is omitted.
2. The "_bold" suffix is replaced with "_eyetrack"
3. The .nii[.gz] extension is replaced with a manufacturer-specific extension (e.g., .edf or .asc)

According to inheritance principle and to avoid unnecessary duplication, all the required fields shared across multiple Subjects can be contained in a single JSON file located at the root of the dataset

## 3.3. RUN specific files

Several additional files MAY be included alongside each eye-tracking recording data file. These files contain information that can not be extracted from the original raw data files in proprietary (Areas of interest or stimulus characteristics). Having such information stored in JSON/.tsv or the event files facilitates data-request queries on large collections of ET data. These files include:

1. ***_eyetrack.json:*** A JSON document containing metadata information about the eye-tracking recording data file,
2. ***_events.tsv**: A .tsv file that describes information concerning the Task: e.g., event latency and description.

For behavioural data acquired independently of the eye tracking, see section "Behavioral experiments (with no MRI)" of the BIDS specification.

### 3.3.1. Sidecar JSON document (*_eyetrack.json)

**ET BIDS fields**

Generic fields MUST be present:

| | | | |
|---|---|---|---|
| TaskName | REQUIRED | string | REQUIRED. Name of the task (for resting state use the rest prefix). No two tasks should have the same name. The task label included in the file name is derived from this TaskName field by removing all non-alphanumeric ([a-zA-Z0-9]) characters. |

Generic fields SHOULD be present (note labels between brackets):

For consistency between studies and institutions, we encourage users to extract the values of these fields from the actual raw data. Whenever possible, please avoid using ad-hoc wording.

| | | | |
|---|---|---|---|
| [InstitutionName] | RECOMMENDED | string | The name of the institution in charge of the equipment that produced the composite instances. |
| [InstitutionAddress] | RECOMMENDED | string | The address of the institution in charge of the equipment that produced the composite instances. |
| [Manufacturer] | RECOMMENDED | string | Manufacturer of the eye-tracking system (e.g. "SR-Research", "Tobii", "SMI", "Gazepoint", "Pupil Labs", "Custom built", ... , "Other") |
| [ManufacturersModelName] | RECOMMENDED | string | Manufacturer's designation of the eye-tracker model (e.g. "Eye-link 1000"). See Appendix with preferred names |
| [SoftwareVersions] | RECOMMENDED | string | Manufacturer's designation of the data acquisition software. |
| [TaskDescription] | RECOMMENDED | string | Description of the task. |
| [Instructions] | RECOMMENDED | string | Text of the instructions given to participants before the experiment. If no instruction is given, write "none". |

| | | | |
|---|---|---|---|
| [CogAtlasID] | RECOMMENDED | string | URI of the corresponding Cognitive Atlas term that describes the task (for example, Resting State with eyes closed "http://www.cognitiveatlas.org/task/id/trm_54e69c642d89b"). |
| [CogPOID] | RECOMMENDED | string | URI of the corresponding CogPO term that describes the task (for example, Rest "http://wiki.cogpo.org/index.php?title=Rest"). |
| [DeviceSerialNumber] | RECOMMENDED | string | 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 ET fields MUST be present:

| | | | |
|---|---|---|---|
| SamplingFrequency | REQUIRED | number | Sampling frequency (in Hz) of all the data in the recording, regardless of their type (e.g., 1000). In case if multiple, varying or changing sampling frequencies were used state “multiple” and provide specifics in the *_events.tsv file. |
| SampleCoordinateUnit | REQUIRED | string | Unit of individual samples. E.g., in pixel or metric (mm, cm) units. |
| SampleCoordinateSystem | REQUIRED | string | Classical screen-based eye tracking data would be “gaze-on-screen”, but “eye-in-head” or “gaze-in-world” are also possible coordinate systems (e.g. in VR). |
| EnvironmentCoordinates | REQUIRED | object of objects or "n/a" | In the case of the classical gaze-on-screen coordinates, this can be for example: [["0,0", "top left"], ["1,1", "bottom right"]]. In VR this could take on, amongst others, spherical coordinates. |
| EventIdentifier | REQUIRED | string | The message sent to the eye tracker which disambiguates the belonging of the sample to a certain event, condition or group. This can be a unique trial identifier, or in the case of continuous presentation (e.g. video) the annotated event of interest. |

| | | | |
|---|---|---|---|
| RawSamples | REQUIRED | number | Indicate if raw samples were recorded (with "1") or not (with "0). |
| IncludedEyeMovementEvents | REQUIRED | object of objects or "n/a" | List of included events with message specifications. E.g., if fixation markers from the EyeLink are included add: [[Start of fixation: "SFIX"], [End of fixation: "EFIX"]]. If no events are included write "None". |
| DetectionAlgorithm | REQUIRED | string | Name the event detection algorithm. If no events are included write "None". If a detection algorithm is used, settings SHOULD be present at DetectionAlgorithmSettings. |

Specific ET fields SHOULD be present:

| | | | |
|---|---|---|---|
| [StartMessage] | RECOMMENDED | string | The message sent to the eye tracker to indicate the start of each trial. Could be the start of the presentation of an image, word, video, etc. |
| [EndMessage] | RECOMMENDED | string | The message sent to the eye tracker to indicate the end of each trial presentation. Could be the end of the presentation of an image, word, video, etc. |
| [KeyPressMessage] | RECOMMENDED | string | When the paradigm includes pressing a key, message identifying this should be included to the sidecar JSON file. |
| [CalibrationType] | RECOMMENDED | string | Description of the calibration procedure. E.g. the H3 for horizontal calibration at 3 positions or HV9 for horizontal and vertical calibration at 9 positions, or one point calibration. |
| [CalibrationPosition] | RECOMMENDED | number or array of numbers | Provide a list of X/Y/Z coordinates in cm on the screen/world or the visual angles of the calibration positions used. The Z coordinate reflects the calibration distance, e.g. distance to screen or distance to real-world/virtual objects. |
| [CalibrationUnit] | RECOMMENDED | string | Unit of CalibrationPosition. E.g., in pixel or metric (mm, cm) units. |

| | | | |
|---|---|---|---|
| [MaximalCalibrationError] | RECOMMENDED | number | Maximal calibration error in visual degree. |
| [AverageCalibrationError] | RECOMMENDED | number | Average calibration error in visual degree. |
| [CalibrationList] | RECOMMENDED | object of objects or "n/a" | List of lists including information for each calibration. This list includes the calibration type, recorded eye, maximal calibration error, average calibration error, and time relative to the first event of the event file. |
| [RecordedEye] | RECOMMENDED | string | Specification for which eye was tracked (Left, Right, Both) |
| [EyeCameraSettings] | RECOMMENDED | object of objects or "n/a" | A field to store any settings that influence the resolution and quality of the eye imagery. Autowhitebalance? Changes in sharpness? |
| [FeatureDetectionSettings] | RECOMMENDED | object of objects or "n/a" | A place to store arbitrary information related to feature detection E.g. Minimum/maximum pupil size. |
| [GazeMappingSettings] | RECOMMENDED | object of objects or "n/a" | A place to store arbitrary information related to gaze mapping. For example, if there was a threshold on pupil confidence required for gaze mapping, one could store that information here. |
| [DetectionAlgorithmSettings] | RECOMMENDED | object of objects or "n/a" | List of prametersettings used in the DetectionAlgorithm for eye movement events. |
| [RawDataFilters] | RECOMMENDED | string | Filter settings applied to eye-movement raw data. E.g. Eyelink trackers typically automatically filter the raw data. |
| [ScreenSize] | RECOMMENDED | string | Screen size inclusively the units, e.g., “47.2 x 29.5 cm” |
| [ScreenResolution] | RECOMMENDED | string | Screen resolution, e.g., “1680 x 1050 px” |

| | | | |
|---|---|---|---|
| [ScreenRefreshRate] | RECOMMENDED | string | Refresh rate of the monitor (when monitor used), in Hz<br>E.g., “150 Hz” |
| [AOIDefinition] | RECOMMENDED | object of objects or "n/a" | Define, what shape are the AOIs and what coordinates are used.<br>[“square”,[“x_start”, “x_stop”, “y_start”, “y_stop”]]<br>Other options: “custom”/”circle”/”triangle”,[[“x”,”y”],[“x”,”y”],[“x”,”y”],etc.] |
| [PupilPositionType] | RECOMMENDED | string | The type of position that is coded in the datafile; e.g., raw pupil position on screen; pupil-in-head; or pupil-in-world |
| [PupilFitMethod] | RECOMMENDED | string | The method employed for fitting the pupil, e.g. centre of mass or ellipse. |

### 3.3.2. Task events description table (*_events.tsv)

Task events are part of the general Brain Imaging Data Structure (BIDS) Specifications (section 8.5) .

Template:

```
sub-<label>/
   eyetrack/
      <matches>_eyetrack.asc
      <matches>_events.tsv
```

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

Specific ET fields MUST be present:

| | | | |
|---|---|---|---|
| eventIdentifier | REQUIRED | string | The accompanying message sent to the eye tracker which disambiguates the belonging of the sample to a certain event, condition or group. This can be a unique trial identifier, or in the case of continuous presentation (e.g. video) the annotated event of interest. The event identifiers should be identical to the list in the JSON file, to make the matching of the data with specific events easier. |

Specific ET fields SHOULD be present:

| | | | |
|---|---|---|---|
| aoi | RECOMMENDED | array of arrays of numbers | Specify coordinates of the AOIs according to the shapes defined with the field AOIDefinition in the JSON file. When the shape of the AOIs is a square, would an array of four AOIs look like e.g.: [[410,610,95,295],[630,830,95,295],[850,1050,95,295],[1070,1270,95,295]] |

# 4. Eye-Track-BIDS Example datasets

To access the Eye-Track-BIDS data samples detailed below, please follow these links:

- "Potsdam Sentence Corpus Dataset" https://github.com/greckla/Eye-Tracking-BIDS/tree/master/PSC_train/PSC_train_raw_data_BIDS
- "Reading Hyperlinks Dataset": https://github.com/greckla/Eye-Tracking-BIDS/tree/master/hyperlink/hyperlinks_raw_data_BIDS
- "Emotional Faces Dataset": https://github.com/greckla/Eye-Tracking-BIDS/tree/master/emotional_faces/freeviewfaces_raw_data_BIDS

## 4.1. Potsdam Sentence Corpus Dataset

Eye-tracking data, measured by a Eyelink CL, from 2 German language learners reading 36 sentences from the Potsdamer Sentence Corpus (Kliegl et al., 2004). They were measured on four occasions, in a randomized controlled design (i.e., before and after a control and experimental training). The sentences appeared after the calibration check on the fixation cross and disappeared as soon as a saccade crossed the invisible boundary on the right sight of the screen. The participants were asked to fixate the fixation cross and then read the sentences naturally as they would read a book or a newspaper. After they have read the sentence they should look to a fixation cross in the right down corner of the screen. With this action they automatically passed the boundary and the sentence disappeared. After some sentences a question sign appeared and the experimenter asked the participant a question about the content of the sentence to check if the participant understood it. The correctness of the answer was recorded by the experimenter by pressing the key "r" ("correct") or "f" ("false").

The BIDS conversion script is available here:

https://github.com/greckla/Eye-Tracking-BIDS/blob/master/PSC_train/from_asc_to_BIDS_asc.Rmd

## 4.2. Reading Hyperlinks Dataset

Eye-tracking data, measured by a Eyelink CL, from 8 subjects reading sentences with 320 embedded target words and invisible boundary manipulation. The task of participants was similar as in the Dataset in 4.1, silent reading with comprehension questions. The main interest of the study was to investigate word recognition processes of the target word under different conditions (e.g., was the word presented in blue or black). The invisible boundary manipulation allowed the investigation of parafoveal preview benefits in relation to the conditions of interest. Here, the predominant characteristics of Hyperlinks. For details see: https://doi.org/10.7717/peerj.2467

The BIDS conversion script is available here:
https://github.com/greckla/Eye-Tracking-BIDS/blob/master/hyperlink/from_asc_to_BIDS_asc.Rmd

## 4.3. Emotional Faces Dataset

Eye-tracking data, measured by a Eyelink CL, from 4 subjects viewing a grid of sixteen faces showing different emotions without any explicit task.
The procedure resembled that described by Lazarov and colleagues (2018). Grids of 4x4 stimulus matrices of 16 colour photographs of human faces displaying emotional expressions were presented. The photos were taken from the photo database FACES (Ebner et al., 2010).
The paradigm was divided into two tasks:

- Task 1 (happy + sad): 8 faces with happy and 8 faces with sad expression;
- Task 2 (happy/sad + neutral): 8 faces with happy or sad and 8 faces with neutral expression.

In both tasks, 64 stimulus matrices in 2 blocks of 32 matrices were presented. Participants were asked to just look at the photos. Each matrix was presented for 6s.

The BIDS conversion script is available here:
https://github.com/greckla/Eye-Tracking-BIDS/blob/master/emotional_faces/from_asc_to_BIDS_asc.Rmd