# Organization of neurophysiological and motion data for open and reproducible science

4th december 2025
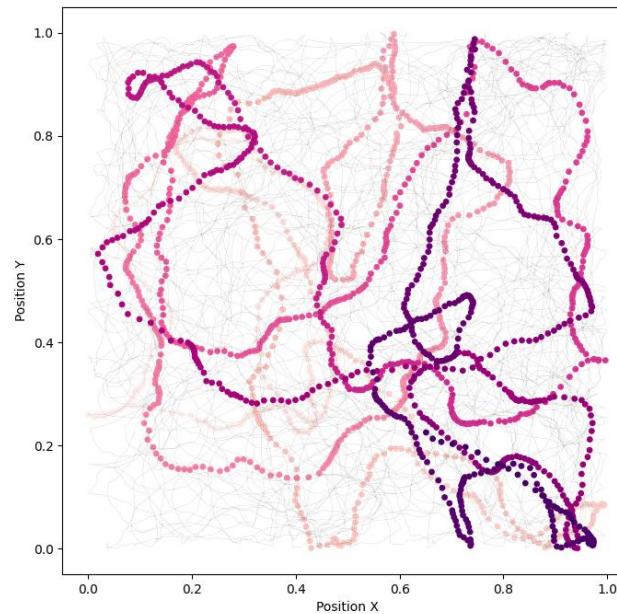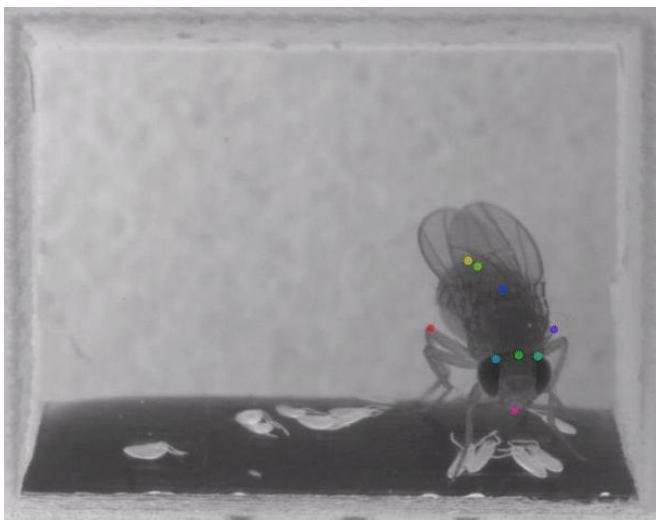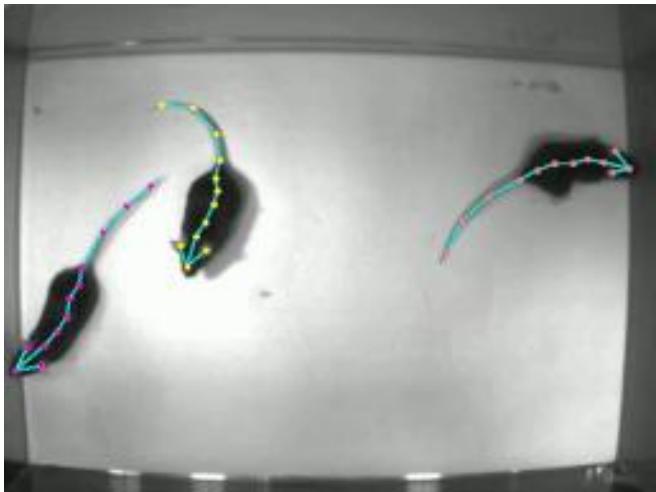
iMOVE - Lübeck

Julius Welzel

I-MOVE
2025

Animal Behavior Modeling in Neuroscience

Pose Tracking in videos

Biological Movement

Timeseries modeling of sensor data

Movement tracking in medicine

Encoding and decoding models

$P(x|K)$
Decoding model

$x(t)$

$K(t)$

World

Brain

$P(K|x)$
Encoding model

Segado ea., bioRxiv, 2025; Mathis ea., Cell, 2024
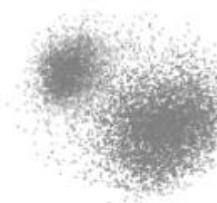
What we can learn from animal research

Position only   Direction only   Position + Direction
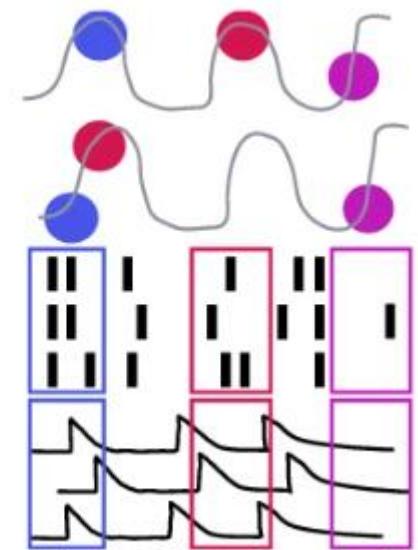
Behaviour labels
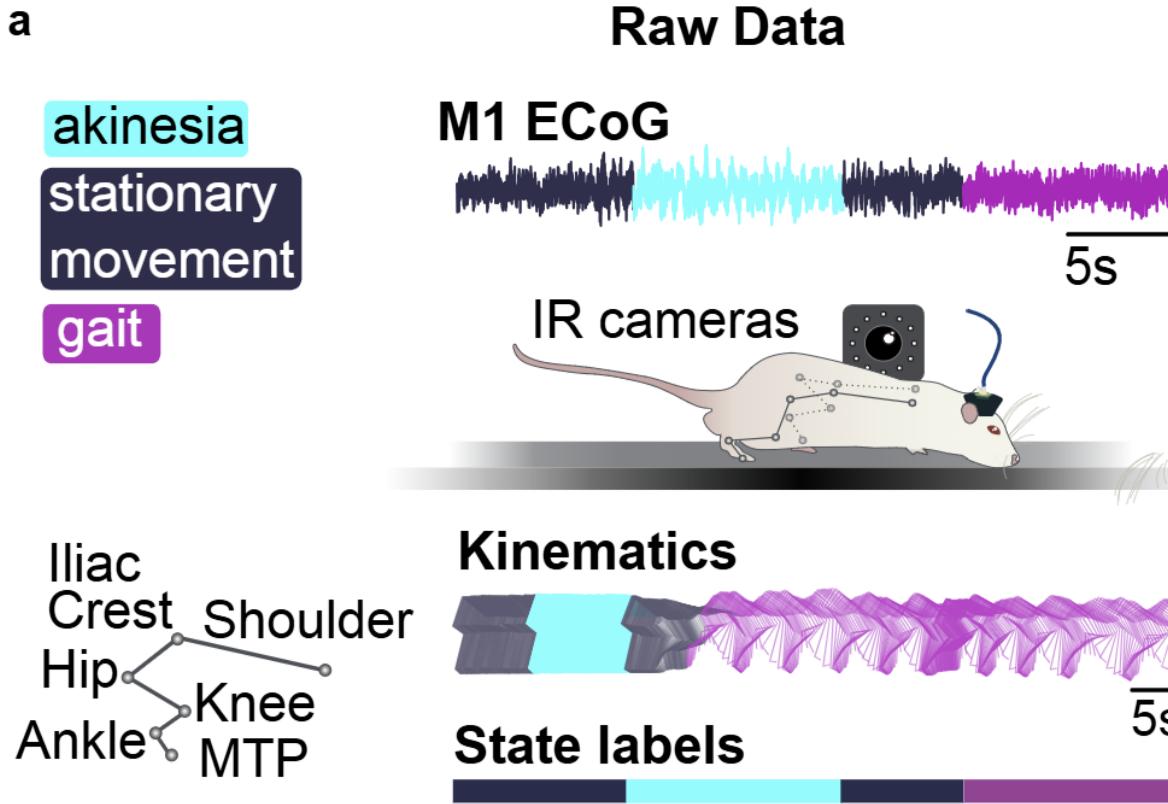
Time labels

Neural data (N)

Mathis ea., Nature Neuroscience, 2018; Schneider ea., Nature, 2023
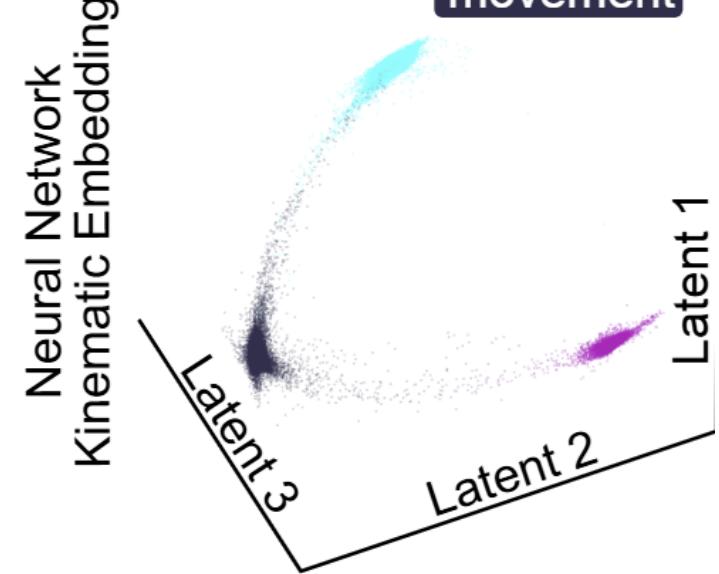
Neurobehavioral "phenotyping"
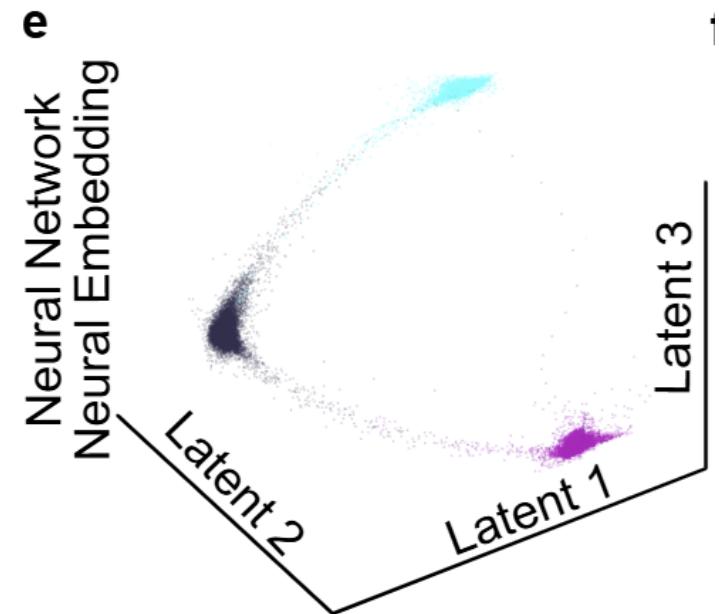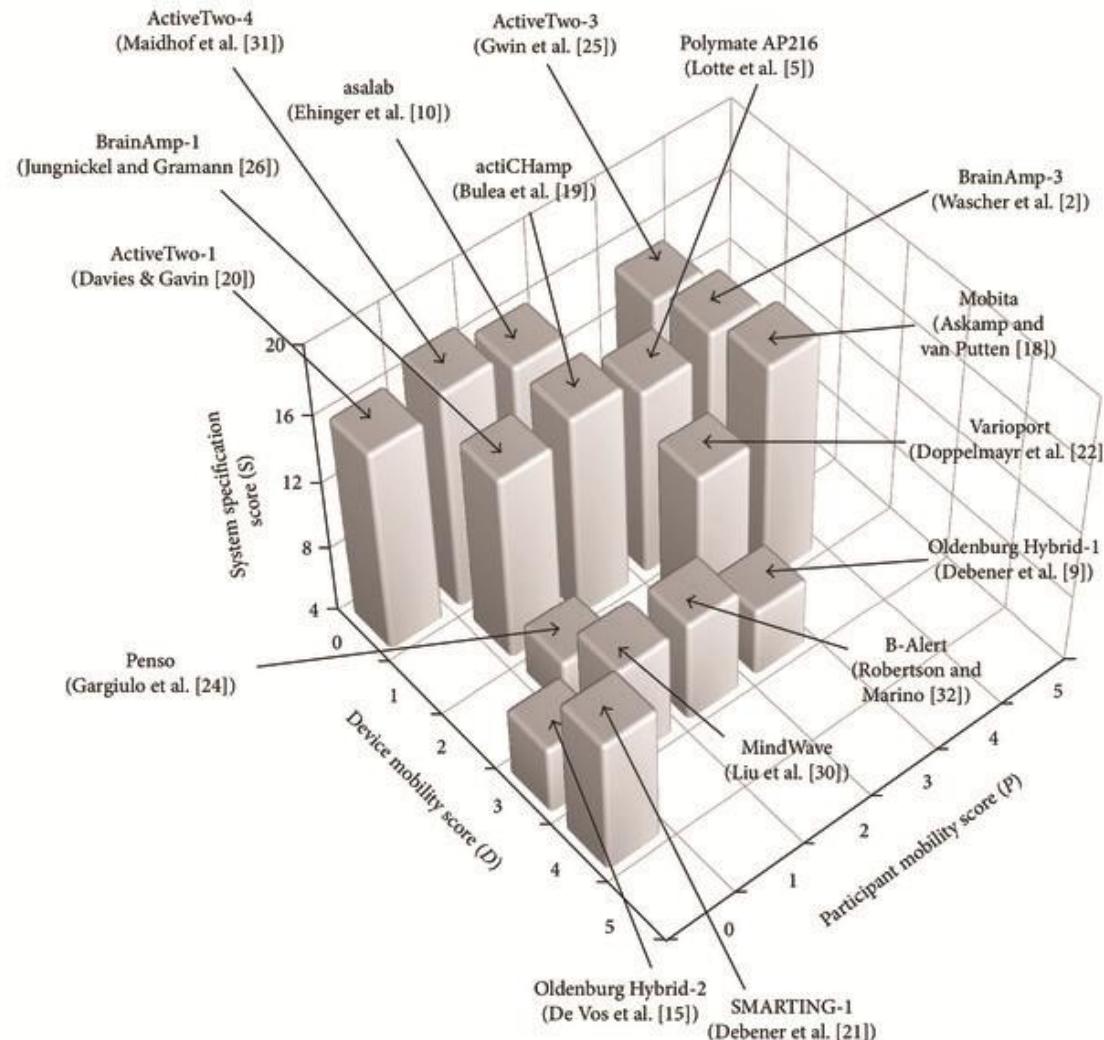
Levels of „mobile" brain recordings

- Data collection
  (Hands-on session: Martin & Melanie)

- EEGManySteps
  (Poster 13: Klaus)

- Gait related EEG
  (Poster: 38 Lila)

Batson ea., BioMed, 2017
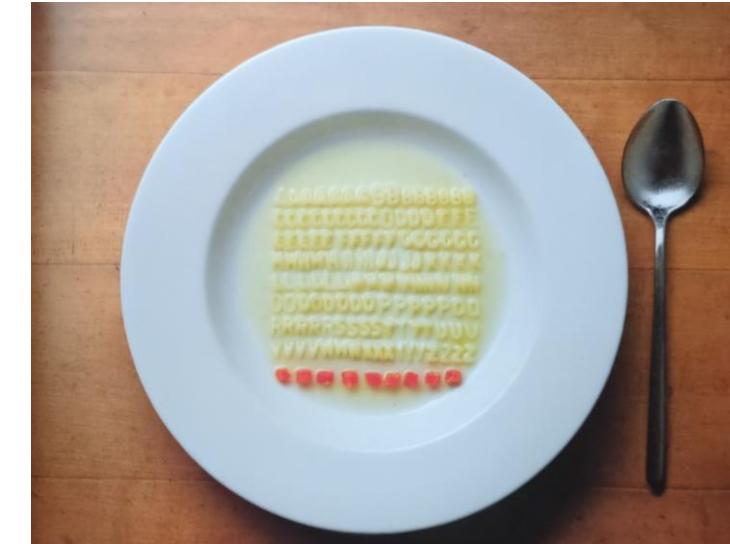
The Brain Imaging Data Structure (BIDS)

What is BIDS?

Dataset info

Motion

Aims of BIDS

The Structure (The Container)

- **Hierarchy:** Standardized `Subject → [Session] → modality` folders.

- **Predictable Naming:** Key-value pairs allow automated parsing.

- **Simple Formats:** Uses non-proprietary standards (.edf, .tsv).
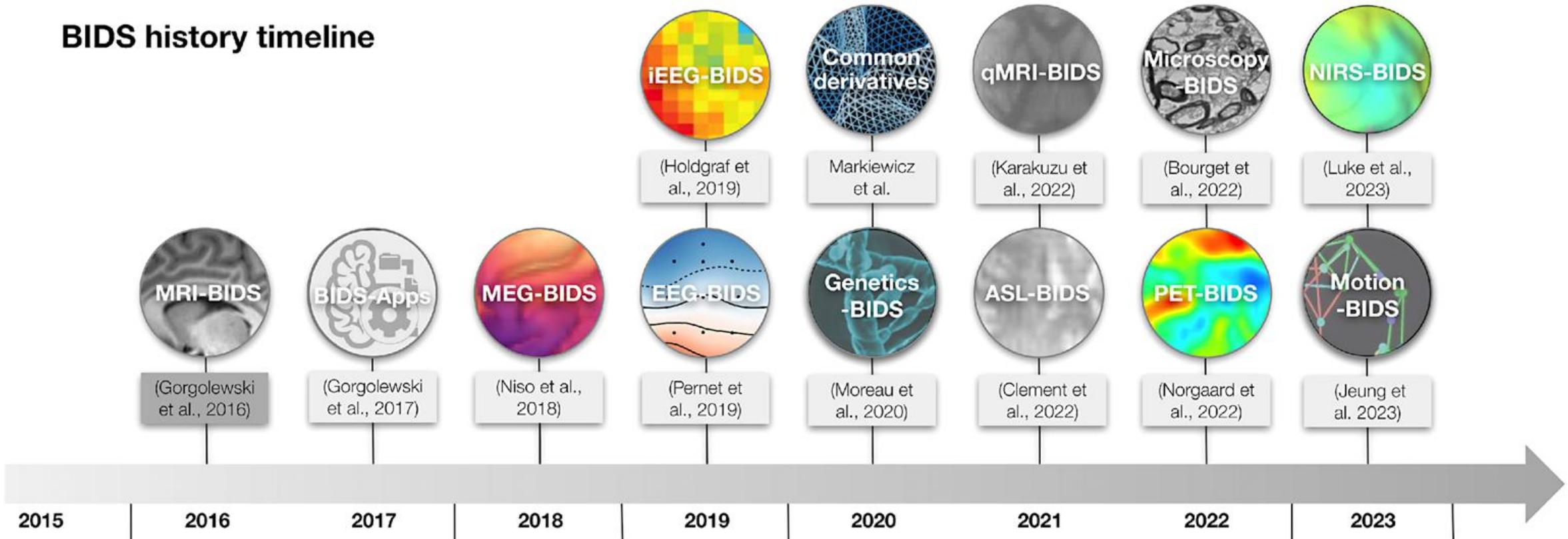
Metadata (The Context)

- **JSON Sidecars:** Every data file is paired with a .json file containing critical metadata details (e.g. sampling rate).

- **Machine-Readable:** Allows software (fMRIPrep, fieldtrip) to easily read data.

- **Beyond "Brain" Imaging:** dataset, participant, events descriptions
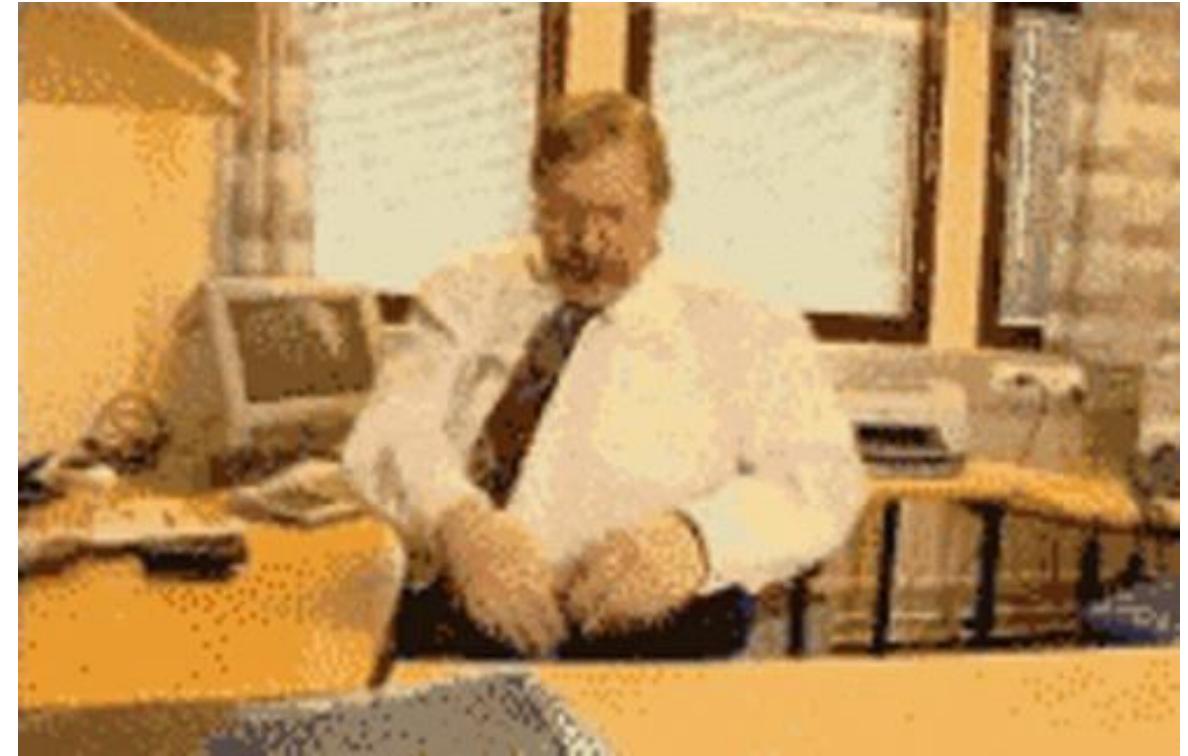
Remi Gau
Remi-Gau

Follow

I wanted to understand the brain, now I tell people how to name files, folders and variables.

https://bids-specification.readthedocs.io/en/stable/

The Past, Present, and Future of BIDS

BIDS history timeline

iEEG-BIDS (Holdgraf et al., 2019)
Common derivatives (Markiewicz et al.)
qMRI-BIDS (Karakuzu et al., 2022)
Microscopy BIDS (Bourget et al., 2022)
NIRS-BIDS (Luke et al., 2023)

MRI-BIDS (Gorgolewski et al., 2016)
BIDS-Apps (Gorgolewski et al., 2017)
MEG-BIDS (Niso et al., 2018)
EEG-BIDS (Pernet et al., 2019)
Genetics-BIDS (Moreau et al., 2020)
ASL-BIDS (Clement et al., 2022)
PET-BIDS (Norgaard et al., 2022)
Motion-BIDS (Jeung et al. 2023)

2015   2016   2017   2018   2019   2020   2021   2022   2023

Poldrack ea., Imaging Neuroscience, 2024

My favourite two
BIDS principles

Requirement levels

Level of requirement **for** files and **within** files:

1. **REQUIRED**
2. **RECOMMENDED**
3. **OPTIONAL**

```
├── README.md
├── dataset_description.json
├── participants.tsv
├── sub-001
│   ├── ses-01
│   │   ├── eeg/
│   │   └── motion/
│   └── ses-02
└── sub-002
```

participant_id	age	group
sub-001	34	C
sub-002	12	P
sub-003	33	M

Directories and file naming structure

- Data for each subject are organized in subdirectories labeled **"sub-<label>**

- Each subject contains subdirectories for different data (food) types

- For a data file that was collected from a given **subject**, the file name **MUST** begin with the string sub-<label> and **MUST** contain a task-<label>

```
├── README.md
├── dataset_description.json
├── participants.json
├── participants.tsv
└── sub-001
    └── eeg/
        └── sub-001_task-GoNoGo.eeg
```

Dataset info

EEG

```
├──  README.md

├──  dataset_description.json

├──  participants.json

├──  participants.tsv

└──  sub-001

    ├──  ses-01

    │    ├──  eeg/

    │    └──  motion/

    └──  ses-02

└──  sub-002
```

Modality agnostic data

dataset_description.json

```
├──── README.md

├──── dataset_description.json  ────────────▶

├──── participants.json

├──── participants.tsv

└──── sub-001
    ├──── ses-01
    └──── ses-02
└──── sub-002
```

{
"Name": "The mother of all experiments",
"BIDSVersion": "1.4.0",
"DatasetType": "raw",
"License": "CC0",
"Authors": ["Paul Broca", "Carl Wernicke"],
"Funding": [„NIH F37823MFH1"],
"EthicsApprovals": [„HRPO (Protocol AR0928"],
"DatasetDOI": "10.0.2.3/dfjj.10"
}

Participants.tsv/.json

```
├── README.md

├── dataset_description.json

├── participants.tsv

├── participants.json

└── sub-001
    ├── ses-01
    └── ses-02
└── sub-002
```
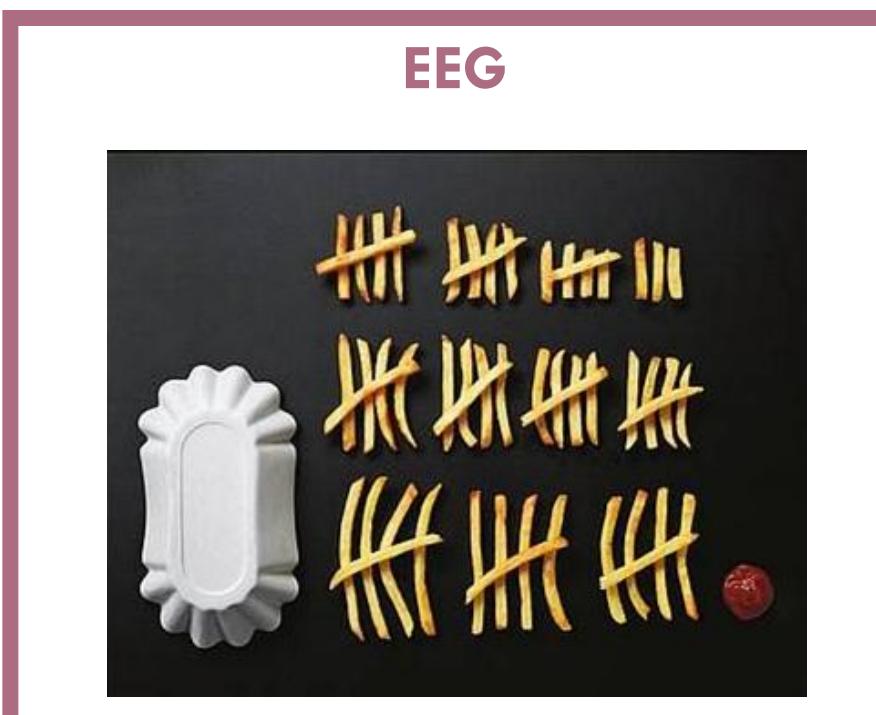
participants.tsv

participant_id	age	group
sub-001	34	C
sub-002	12	P
sub-003	33	M

participants.json

```
"age": {
    "Description": "age of the
    participant",  "Units": "years"
    },
„group": {
    "Description": „assigned group",
    "Levels": {
        „C": „control",
        „M": „medication",
        „P": „placebo",
        }
```

Dataset info

EEG


```
├── README.md
├── dataset_description.json
├── participants.json
├── participants.tsv
└── sub-001
    ├── ses-01
    │   ├── eeg/
    │   └── motion/
    └── ses-02
└── sub-002
```
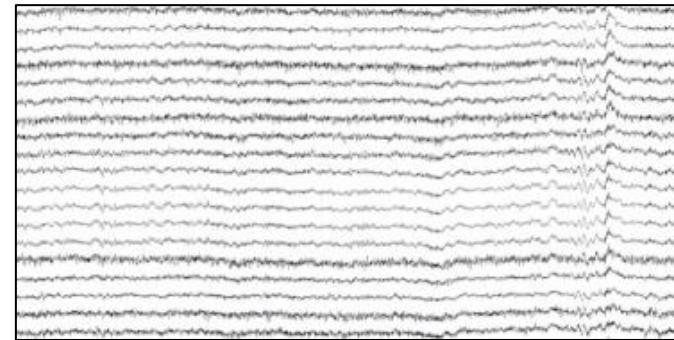
Modality specific data

Overview | eeg

```
{
    "TaskName": "TASKNAME",
    "SamplingFrequency": 1000,
    "SoftwareFilters": "n/a",
    "EEGChannelCount": 4,
    "EOGChannelCount": 1,
    "EEGReference": "placed on Cz",
    "PowerLineFrequency": 50

}
```

```
└── sub-001
    └── ses-01
        └── eeg/
            ├── sub-001_ses-01_task-<label>_eeg.<extension>
            ├── sub-001_ses-01_task-<label>_eeg.json
            ├── sub-001_ses-01_task-<label>_channels.tsv
            ├── sub-001_ses-01_task-<label>_electrodes.tsv
            ├── sub-001_ses-01_task-<label>_electrodes.tsv
```

name	type	units	status	status_description
CP5	EEG	microV	good	n/a
FC5	EEG	microV	bad	high freq noise
FC1	EEG	microV	good	n/a
C3	EEG	microV	good	n/a
VEOG	EOG	microV	good	n/a

```
{
    "EEGCoordinateSystem": "T1w",
    "EEGCoordinateUnits": "mm",
    "AnatomicalLandmarkCoordinates": {
        "LPA": [−0.067, 1.736e−09, −3.844e−09],
        "NAS": [−4.11e−09, 0.091, −4.541e−10],
        "RPA": [0.064, −6.435e−09, −4.566e−09]
    },
    "AnatomicalLandmarkCoordinateSystem": "T1w",
    "AnatomicalLandmarkCoordinateUnits": "mm",
    "IntendedFor": "sub−01_T1w.nii.gz"

}
```

name	x	y	z	impedance
CP5	−0.77	−0.30	0.57	8
FC5	−0.77	0.30	0.57	12
FC1	−0.29	0.31	0.91	2
C3	−0.59	0.00	0.81	5
VEOG	n/a	n/a	n/a	n/a

Pernet ea., Scientific Data, 2019

Metadata | eeg.json

REQUIRED

TaskName, SamplingFrequency,
PowerlineFrequency, EEGReference,
SoftwareFilters

RECOMMENDED

TaskDescription, Manufacturer,
EEGChannelCount,
EOGChannelCount, …

OPTIONAL

-

```
{
    TaskName: Seeing stuff,
    SamplingFrequency: 2400,
    Manufacturer: Brain Products,
    ManufacturersModelName: BrainAmp DC,
    EEGChannelCount: 87,
    EOGChannelCount: 2,
    TriggerChannelCount: 1,
    PowerLineFrequency: 50,
    EEGPlacementScheme: 10-20,
    EEGReference: single electrode placed on FCz,
    SoftwareFilters: {
            Anti-aliasing filter: {
                        half-amplitude cutoff (Hz):
                        500,
                        Roll-off:  6dB/Octave
                        }

}
```

Metadata | channels.tsv

REQUIRED

name, type, units

RECOMMENDED

-

OPTIONAL

description, sampling_frequency

name	type	units	description	reference	status	status_description
VEOG	VEOG	uV	left eye	VEOG-, VEOG+	good	n/a
FDI	EMG	uV	left first dorsal interosseous	FDI-, FDI+	good	n/a
Cz	EEG	uV	n/a	REF	bad	high frequency noise
UADC001	MISC	n/a	envelope of audio signal	n/a	good	n/a
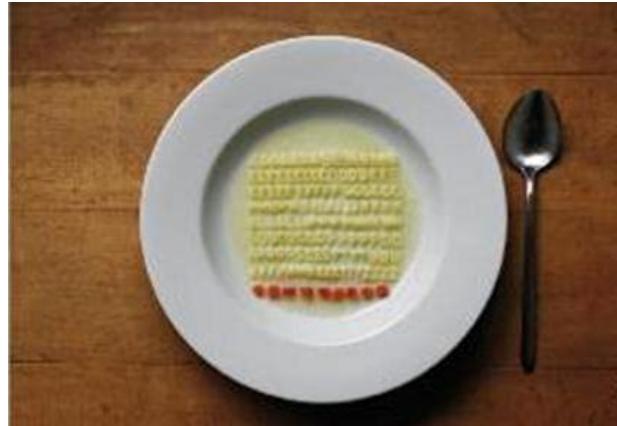
Metadata | electrodes.tsv

name	x	y	z	type	material	color
VEOG+	n/a	n/a	n/a	cup	Ag/AgCl	blue
VEOG-	n/a	n/a	n/a	cup	Ag/AgCl	white
FDI+	n/a	n/a	n/a	cup	Ag/AgCl	red
FDI-	n/a	n/a	n/a	cup	Ag/AgCl	red
GND	-0.07	0.00	-0.070	clip-on	Ag/AgCl	pink
Cz	0.00	0.07	0.06	cup	Ag/AgCl	yellow
REF	-0.07	-0.02	-0.01	cup	Ag/AgCl	grey

Column name	Requirement Level	Data type	Description
name	REQUIRED	string	Name of the electrode contact point. Values in `name` MUST be unique. This column must appear **first** in the file.
x	REQUIRED	number	Recorded position along the x-axis. This column must appear **second** in the file.
y	REQUIRED	number	Recorded position along the y-axis. This column must appear **third** in the file.
z	REQUIRED	number or `"n/a"`	Recorded position along the z-axis. This column must appear **fourth** in the file.
type	RECOMMENDED	string	Type of the electrode (for example, cup, ring, clip-on, wire, needle). This column may appear anywhere in the file.
material	RECOMMENDED	string	Material of the electrode (for example, `Tin`, `Ag/AgCl`, `Gold`). This column may appear anywhere in the file.
impedance	RECOMMENDED	number	Impedance of the electrode, units MUST be in `kOhm`. This column may appear anywhere in the file.
Additional Columns	OPTIONAL	n/a	Additional columns are allowed if they are defined in the associated metadata file.

Dataset info

Motion

```
├── README.md
├── dataset_description.json
├── participants.json
├── participants.tsv
└── sub-001
    ├── ses-01
    │   ├── eeg/
    │   └── motion/
    └── ses-02
└── sub-002
```

Modality specific data

Files | motion

```
└── sub-001/
    └── ses-01/
        ├── eeg/
...
        └── motion/
            ├── sub-001_ses-01_task-<label>_tracksys-<label>_motion.tsv
            ├── sub-001_ses-01_task-<label>_tracksys-<label>_motion.json
            └── sub-001_ses-01_task-<label>_channels.tsv
```

0,2634511	0,092295	0,0086682	0,9305117	0,690106	0,8098815
0,694520	0,1918243	0,8437273	0,3975710	0,885496	0,8952724
0,0766395	0,2587211	0,5434792	0,2822837	0,2789791	0,2326254
0,5779993	0,0456141	0,0490745	0,9408899	0,1533421	0,6683652
0,054556	0,7915927	0,5871733	0,4669577	0,9754468	0,0480541
0,966024	0,1962834	0,7114406	0,3389448	0,7194495	0,4384892
0,984172	0,5079461	0,1180168	0,7966978	0,1753768	0,4886533
0,9883907	0,1557346	0,8002013	0,6334882	0,7526906	0,8529441
...	...	...	...	...	...

```
{
"SamplingFrequency": 60,
"SamplingFrequencyEffective": 60.19,
"TaskName": "BIDS Motion fictive example",
"TrackingSystemName": "imu1",
"TaskDescription": "walking and talking",
"MotionChannelCount": 6,
„SubjectArtefactDescription": "n/a",
"TrackedPointsCount" : 2,
"ACCELChannelCount": 3,
„GYROChannelCount": 3,
"Manufacturer": "BWSensing",
"ManufacturersModelName": "BW-imu600",
}
```

name	component	type	tracked_point	units	placement
imu1_rf_acc_x	x	ACCEL	rf	m/s^2	right_foot
imu1_rf_acc_y	y	ACCEL	rf	m/s^2	right _foot
imu1_rf_acc_z	z	ACCEL	rf	m/ s^2	right _foot
imu1_rf_gyro_x	x	GYRO	rf	rad/s	right _foot
imu1_rf_gyro_y	y	GYRO	rf	rad/s	right _foot
imu1_rf_gyro_z	z	GYRO	rf	rad/s	right _foot

https://bids-specification.readthedocs.io/en/stable/modality-specific-files/motion.html

Metadata | motion.json

REQUIRED

TaskName, SamplingFrequency

RECOMMENDED

TaskDescription, RecordingDuration,
MotionChannelCount, <type>ChannelCount,
SoftwareFilters, …

OPTIONAL

Manufacuturer, RecordingSoftware, …

```
{
"TaskName": "BIDS Motion fictive example",
"SamplingFrequency": 60,
"TrackingSystemName": "IMU Right Hand",
"TaskDescription": "walking and talking",
"InstitutionAddress": "Fictive address",
"InstitutionName": "Fictive Institution",
"MotionChannelCount": 18,
"RecordingDuration": 4667.641106,
"SubjectArtefactDescription": "n/a",
"TrackedPointsCount" : 2,
"ACCELChannelCount": 6,
"GYROChannelCount": 6,
"MAGNChannelCount": 6,
"Manufacturer": "BWSensing",
"ManufacturersModelName": "BW-IMU600",
}
```

Metadata | channels.tsv

REQUIRED

name, component, type, tracked_point, units

RECOMMENDED

placement, reference_frame

OPTIONAL

status, status_description, sampling_frequency

Restricted keyword list for channel type

Restricted keyword list for column `type` in alphabetic order. No

Keyword	Description
ACCEL	Accelerometer channel, one channel for each spatial axis. `*_channels.tsv` file (x, y, or z).
ANGACCEL	Angular acceleration channel, one channel for each spatia the `*_channels.tsv` file (x, y, or z).
GYRO	Gyrometer channel, one channel for each spatial axis. Colu `*_channels.tsv` file (x, y, or z).
JNTANG	Joint angle channel between two fixed axis belonging to t proximal and distal bodypart in deg.

name	component	type	tracked_point	units	reference_frame
t1_acc_x	x	ACCEL	LeftFoot	m/s^2	global
t1_acc_y	y	ACCEL	LeftFoot	m/s^2	global
t1_acc_z	z	ACCEL	LeftFoot	m/s^2	global
t1_gyro_x	x	GYRO	LeftFoot	rad/s	global
t1_gyro_y	y	GYRO	LeftFoot	rad/s	global
t1_gyro_z	z	GYRO	LeftFoot	rad/s	global
…					

Overview | motion

0,26345511   0,092292015   0,008668652   0,930514317   0,690193606   0,809881135
0,694520294   0,191824943   0,843726573   0,397571025   0,88542996   0,895276224
0,076633595   0,258720111   0,547534792   0,282283781   0,27890791   0,232620594
0,577995093   0,045616941   0,04903375   0,940889749   0,153318421   0,668360752
0,054555716   0,791513927   0,587116733   0,466957774   0,975446368   0,048053341
0,966026984   0,196283834   0,711044406   0,338944328   0,719445195   0,438488392
0,98417512   0,507944361   0,1180168   0,796692478   0,175376468   0,488659533
0,98839607   0,155737146   0,800206213   0,633481382   0,752698206   0,852943441
...   .

{
    "SamplingFrequency": 60,
    "SamplingFrequencyEffective": 60.19,
    "TaskName": "BIDS Motion fictive example",
    "TrackingSystemName": "imu1",
    "TaskDescription": "walking and talking",
    "MotionChannelCount": 6,
    "RecordingDuration": 10.05,
    "SubjectArtefactDescription": "n/a",
    "TrackedPointsCount" : 2,
    "ACCELChannelCount": 3,
    "GYROChannelCount": 3,
    "Manufacturer": "BWSensing",
    "ManufacturersModelName": "BW-imu600",
}

README
dataset_description.json
participants.tsv
participants.json
sub-001
    motion
        sub-001[_ses-01]_task-<label>_tracksys-<label>_motion.tsv
        sub-001[_ses-01]_task-<label>_tracksys-<label>_motion.json
        sub-001[_ses-01]_task-<label>_tracksys-<label>_events.tsv
        sub-001[_ses-01]_task-<label>_tracksys-<label>_events.json
        sub-001[_ses-01]_task-<label>_tracksys-<label>_channels.tsv
sub-002
    motion
        sub-002[_ses-01]_task-<label>_tracksys-<label>_motion.tsv
        ...

onset	duration	trial_type
2.45	0.1	heel_strike
3.81	0.1	heel_strike
4.95	0.1	heel_strike
6.11	0.1	heel_strike
7.24	0.1	heel_strike

name	type	units	srate	tracked_point	component	placement
imu1_rf_acc_x	ACCEL	m/s^2	222	rf	x	right_foot
imu1_rf_acc_y	ACCEL	m/s^2	222	rf	y	right _foot
imu1_rf_acc_z	ACCEL	m/s^2	222	rf	z	right _foot
imu1_rf_gyro_x	GYRO	rad/s	222	rf	x	right _foot
imu1_rf_gyro_y	GYRO	rad/s	222	rf	y	right _foot
imu1_rf_gyro_z	GYRO	rad/s	222	rf	z	right _foot

BIDS Starterpack

Website

[https://bids-specification.readthedocs.io/en/stable/]

Tutorials

[MNE, fieldtrip, EEGLab]

Validator

[https://bids-standard.github.io/bids-validator/]

Community

[https://juliuswelzel.github.io/igor_bids_consultation/

IGOR BIDS consultations hour   Meetings   Materials

On this page
It's a match!
What is the IGOR BIDS Consultation Hour?
What can I expect?
How can I participate?
Upcoming Session:

IGOR BIDS consultations hour

It's a match!

What is the IGOR BIDS Consultation Hour?

We're are happy to offer the IGOR BIDS Consultation Hour, a monthly forum designed to help researchers like you navigate the Brain Imaging Data Structure (BIDS) format. During these sessions, you can connect with experienced BIDS users to get individualized feedback and solutions for your specific BIDS data conversion challenges.
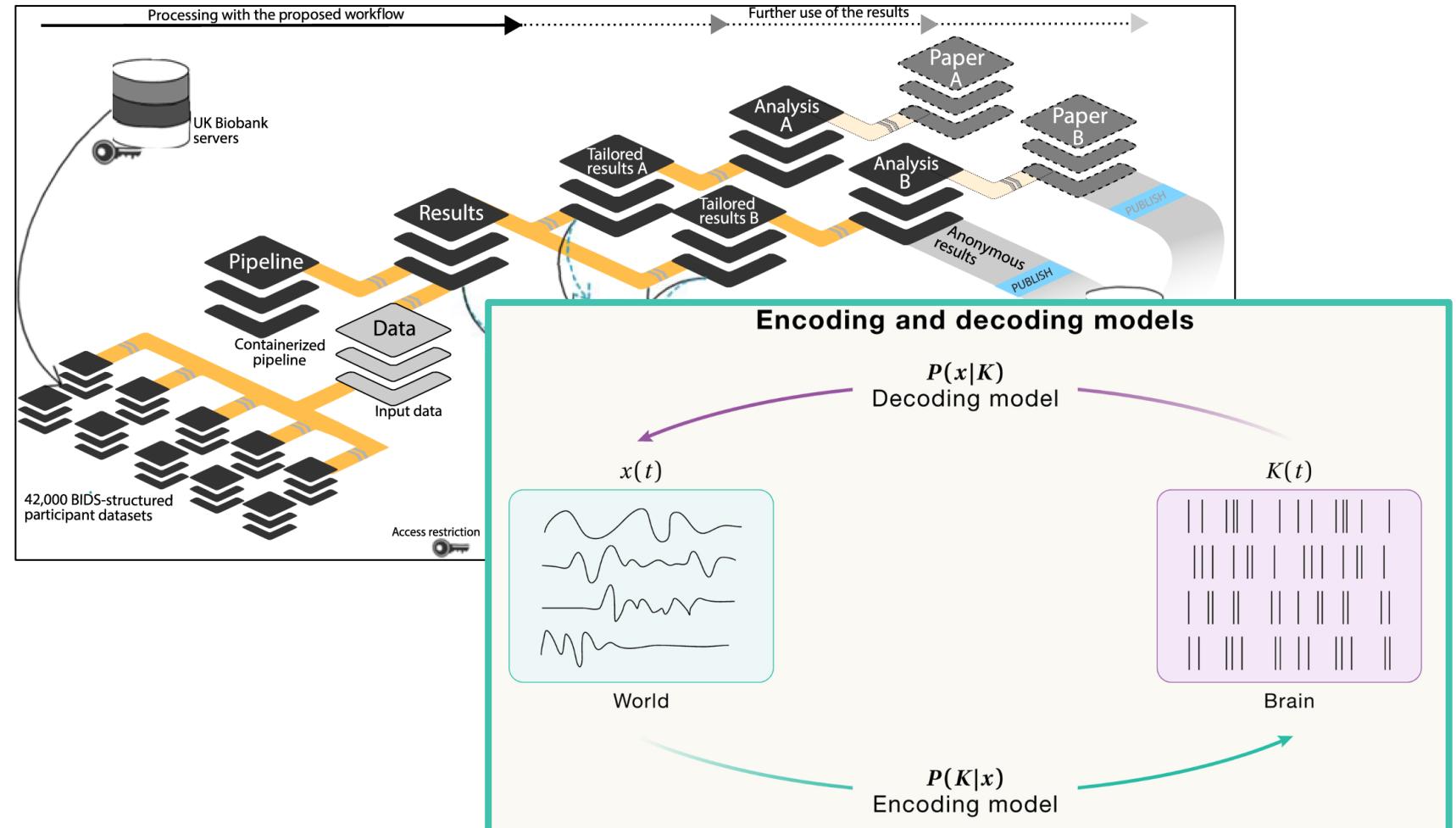
What can I expect?

- **Personalized guidance**: Our experienced researchers, Julius (EEG & motion data expertise) and Lennart (MRI expertise), will be available to answer your questions and provide tailored advice on converting your datasets to the BIDS format.

- **Open forum**: Feel free to bring any BIDS-related questions you have, big or small. We're here to help you overcome conversion hurdles and ensure your data adheres to BIDS best practices.

- **Recurring sessions**: The IGOR BIDS Consultation Hour takes place on the 4th Friday of each month at 12:00 PM (noon) CET.
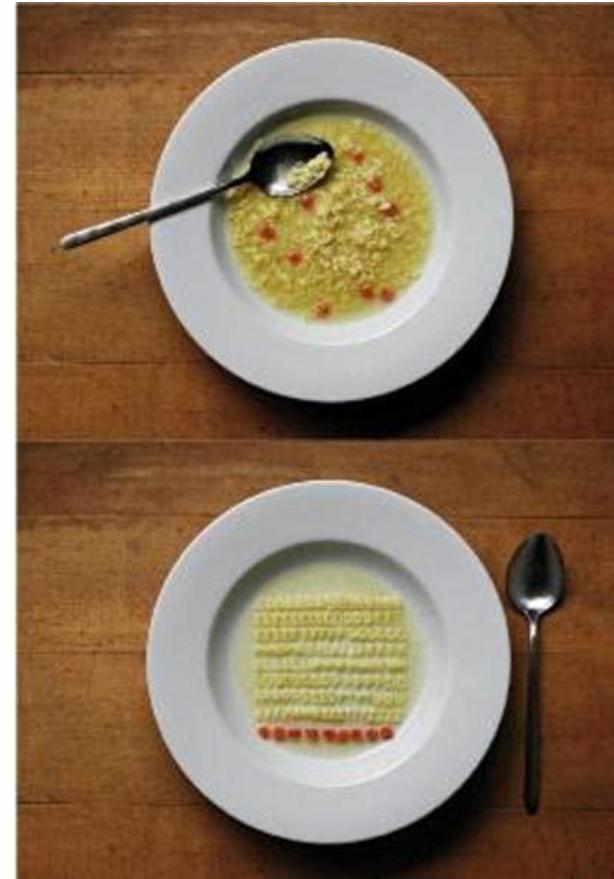
Read BIDS datasets   Convert MNE sample data to BIDS format   Interactive data inspection and bad channel selection   Convert EEG data to BIDS format

BIDS in the bigger picture
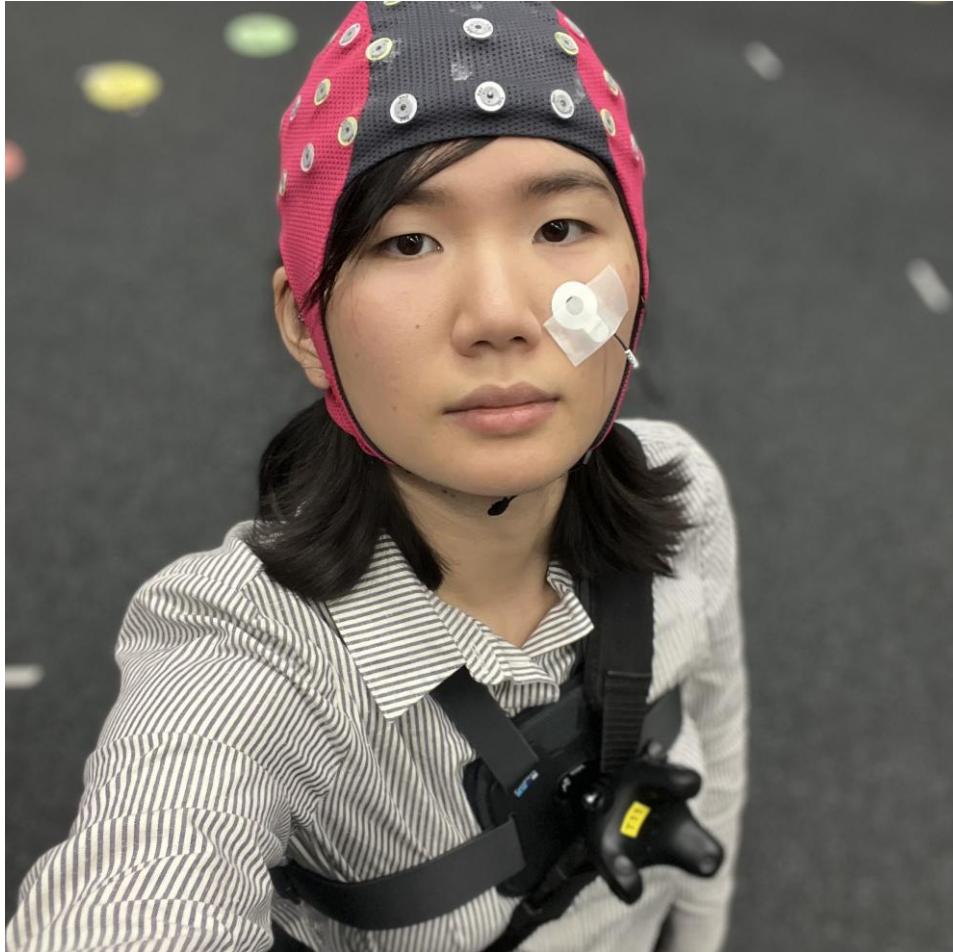
- Building a sustainable research environment

- Connect rich context information with neural recordings

Wagner ea., Scientific Data, 2022; Mathis ea., Cell, 2024

Conclusions

Thanks

Sein Jeung & Team
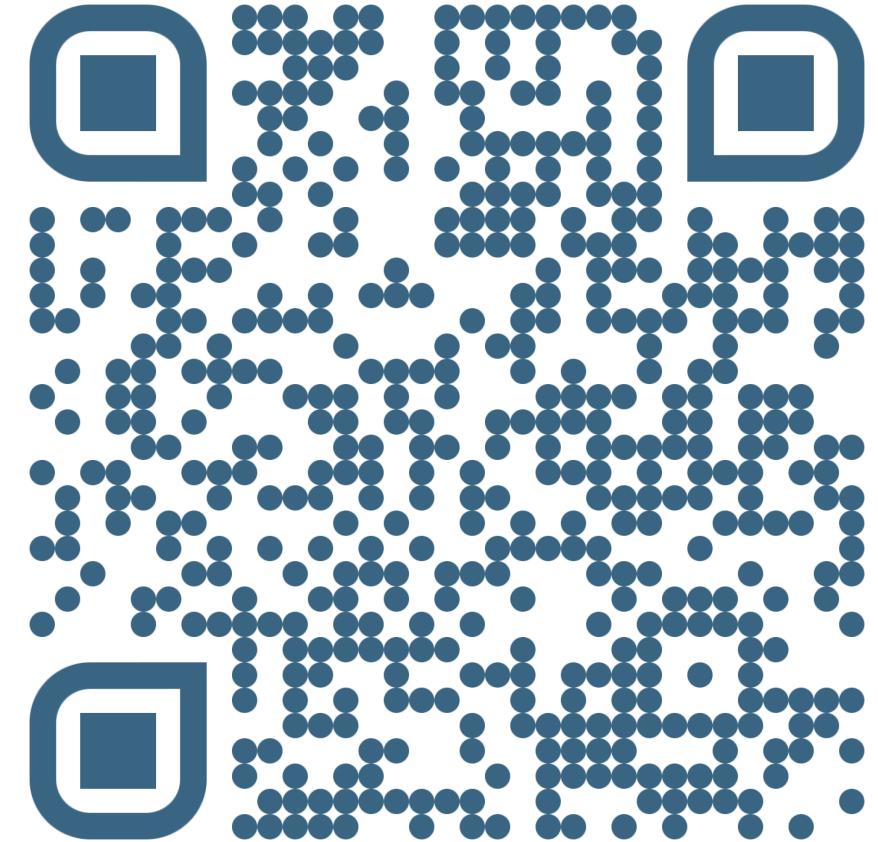
BIDS
BRAIN IMAGING DATA STRUCTURE

Lara Papin

Hands-On session

https://juliuswelzel.github.io/motion_bids_materials_jw

How to combine EEG and motion data?

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