Microelectrode electrophysiology: Extending the Brain Imaging Data Structure to intracellular and extracellular recordings in animal models

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ABSTRACT

The Brain Imaging Data Structure (BIDS) has facilitated data sharing and tool development in human neuroimaging. We present an extension for microelectrode electrophysiology recordings in animal models, addressing the unique requirements of intracellular and extracellular recordings. This extension introduces two new data types: 'icephys' for intracellular and 'ecephys' for extracellular recordings, supporting diverse recording modalities from patch-clamp to high-density silicon probes. Building on existing BIDS principles and prior electrophysiology extensions, we specify metadata for probes, electrodes, and channels, with particular attention to metadata required for spike sorting analysis. The extension adopts NWB (Neurodata Without Borders) and NIX (Neuroscience Information Exchange) as data formats, ensuring comprehensive metadata capture while maintaining compatibility with existing analysis ecosystems. We provide example datasets covering common use cases and demonstrate integration with established tools including [Which tools?]. This standardization enables reproducible analysis pipelines, facilitates data sharing through repositories like DANDI, G-Node and EBRAINS, and bridges scales from cellular to systems neuroscience.

Background & Summary

Microelectrode electrophysiology encompasses techniques for recording electrical activity from individual neurons to local field potentials, providing crucial insights into neural computation. Recent technological advances, including high-density silicon probes and standardized probe designs through the Neuropixels project, have dramatically increased data acquisition rates and experimental complexity.

While comprehensive data formats exist for neurophysiology (NWB; NIX), the field lacks standardized organization principles for datasets, metadata specifications, and directory structures. This fragmentation impedes data sharing, with surveys indicating [ADD SURVEY DATA] of researchers struggling to share or reuse electrophysiology data due to inconsistent formats and missing metadata.

BIDS has successfully standardized human neuroimaging data organization [cite], with over 850 datasets on OpenNeuro [cite] and adoption by major repositories. Prior BIDS extensions for human electrophysiology (EEG [cite], MEG [cite], iEEG [cite]) established patterns for organizing time-series neural data, while the Microscopy extension [cite] introduced critical metadata fields for animal data.

Microelectrode recordings present unique challenges: (1) electrode scales spanning orders of magnitude (sub-micron tips to millimeter arrays), (2) diverse probe geometries requiring specialized coordinate systems, (3) spike sorting as an essential preprocessing step requires specific metadata,

Here we present BEP032, extending BIDS to microelectrode electrophysiology, with a focus on animal models. This extension: [summarize key contributions]

Methods

Community Development Process

The development of BEP032 began in [DATE] through the INCF Working Group on Standardized Data Structures.

Scope and Design Principles

Inclusion Criteria

Design Decisions

The division between intracellular (icephys) and extracellular (ecephys) electrophysiology is based on the recording techniques and the resulting data characteristics. Icephys typically involves high-resolution recordings from individual neurons, requiring detailed metadata about the cell type, location, and experimental conditions. In contrast, ecephys captures broader population activity, necessitating metadata that describes the electrode array configuration, spatial sampling, and signal processing methods.

Data Format Specification
Supported Formats
Data Stream Linking
Directory Structure and File Organization
Data Type Specification
Required and Optional Files
Metadata Specifications
Inheritance Principle
Required Metadata Fields
Animal-Specific Metadata
Probe, Electrode, and Channel Specifications
Probes TSV Specification
ProbeInterface Integration
Electrodes TSV Specification
Channels TSV Specification
Coordinate Systems
Dual Coordinate Approach
Probe-Relative Coordinates
Surgical Coordinate Conventions
Brain Atlas Integration
Spike Sorting and Derivatives
Integration with Existing Tools
Conversion Tools
Analysis Pipelines

Data Records

Example datasets demonstrating the specification are available at [REPOSITORY].

Dataset 1: One icephys dataset
Dataset 2: One chronic ecephys dataset
Dataset 3: One acute ecephys experiment
Dataset 4: Neuropixels Multi-Region Recording

Technical Validation

Validator Compliance
Round-Trip Conversion
Cross-Tool Compatibility
File Size and Performance

Usage Notes

Converting Existing Data
Recommended Workflows
Integration with Other Modalities
Repository Submission

Code availability

BEP032tools [VERSION] provides validation and conversion utilities: [GITHUB LINK] Example conversion scripts are available at: [GITHUB LINK] The specification is maintained at: https://github.com/bids-standard/bids-specification

References

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Author Contributions

Competing Interests

The authors declare no competing interests.

Figures & Tables

Figure 1. Overview of the BIDS microelectrode electrophysiology extension. (a) Directory structure showing icephys and ecephys datatypes. (b) Metadata inheritance hierarchy. (c) Relationship between probes, electrodes, and channels. (d) Integration with analysis tools and repositories.

Figure 2. Directory structure and file organization for extracellular electrophysiology (`ecephys`) recordings. The schematic shows the hierarchical relationship between data files, metadata sidecars, and tabular specification files. Numbered labels indicate the correspondence between files in the directory tree and their content structure. The three-level hierarchy (probes, electrodes, channels) captures the physical recording setup, with probe-relative electrode coordinates and optional anatomical coordinates via the `space` entity.

Figure 3. Directory structure and file organization for intracellular electrophysiology (`icephys`) recordings. This example shows a patch-clamp dataset with brain slice samples. The `samples.tsv` file (at the dataset root) describes tissue samples, while the recording-specific files follow the same probe-electrode-channel hierarchy as extracellular recordings. Intracellular-specific metadata includes pipette solution, recording mode (current-clamp or voltage-clamp), and sample preparation details.

Table 1. Required and optional files for microelectrode electrophysiology recordings

Table 2. Required metadata fields and their descriptions

Table 3. Channel types for microelectrode recordings

Table 4. Example datasets demonstrating the specification