Multi-echo fMRI, fMRI meta-analysis, and BIDS

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BIDS
BRAIN IMAGING DATA STRUCTURE

The BIDS Schema

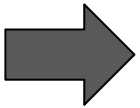
Magnetic Resonance Imaging

Common metadata fields

MR Data described in sections 8.3.x share the following RECOMMENDED metadata fields (stored in sidecar JSON files). MRI acquisition parameters are divided into several categories based on "A checklist for fMRI acquisition methods reporting in the literature" by Ben Inglis:

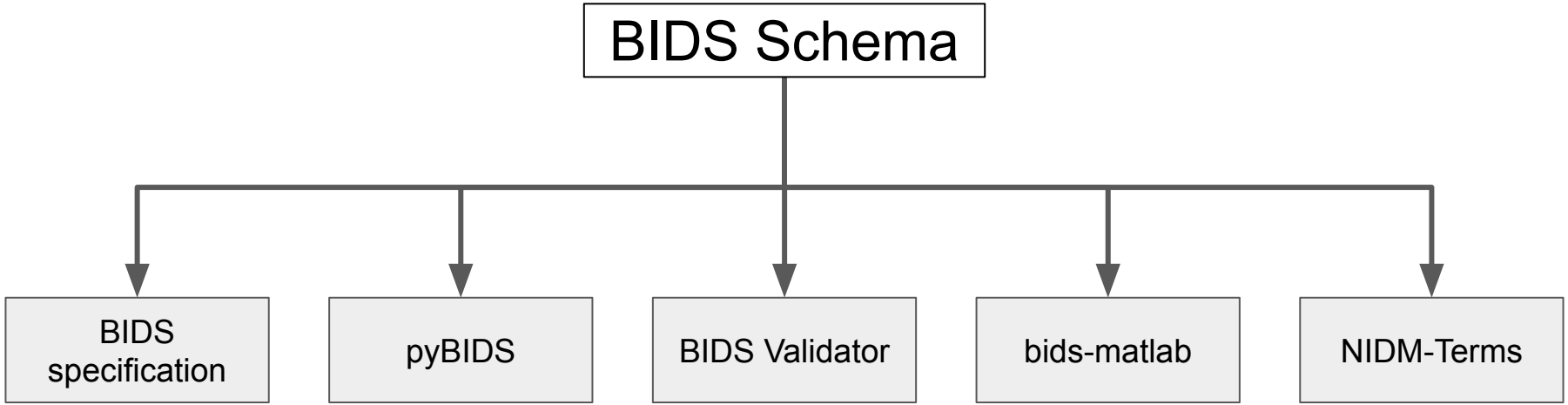
Scanner Hardware

Field name	Definition
Manufacturer	RECOMMENDED. Manufacturer of the equipment that produced the composite instances. Corresponds to DICOM Tag 0008, 0070 `Manufacturer`
ManufacturersModelName	RECOMMENDED. Manufacturer's model name of the equipment that produced the composite instances. Corresponds to DICOM Tag 0008, 1090 `Manufacturers Model Name`
DeviceSerialNumber	RECOMMENDED. The serial number of the equipment that produced the composite instances. Corresponds to DICOM Tag 0018, 1000 `DeviceSerialNumber`. A pseudonym can also be used to prevent the equipment from being identifiable, so long as each pseudonym is unique within the dataset

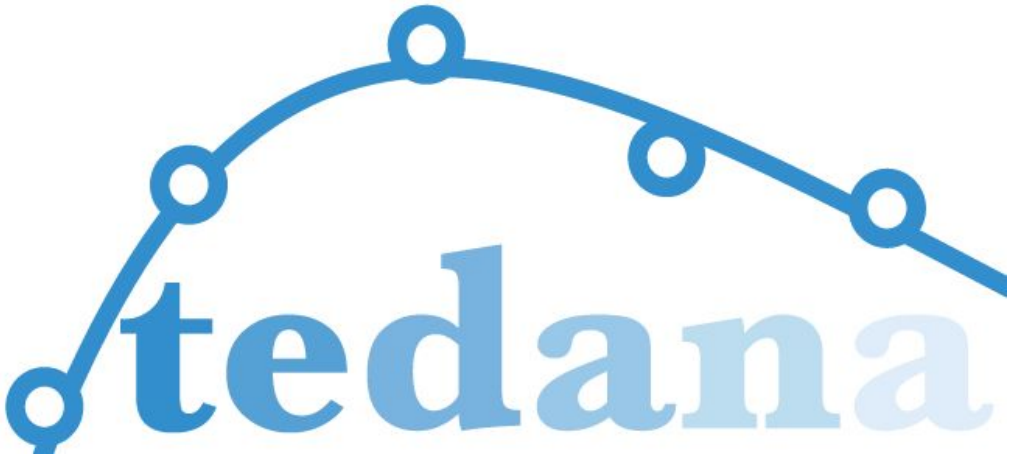


```yaml
Manufacturer:
  name: Manufacturer
  display_name: Manufacturer
  description: |
    Manufacturer of the equipment that produced the measurements.
  type: string
ManufacturersModelName:
  name: ManufacturersModelName
  display_name: Manufacturers Model Name
  description: |
    Manufacturer's model name of the equipment that produced the measurements.
  type: string
MatrixCoilMode:
  name: MatrixCoilMode
  display_name: Matrix Coil Mode
  description: |
    (If used)
    A method for reducing the number of independent channels by combining in
    analog the signals from multiple coil elements.
    There are typically different default modes when using un-accelerated or
    accelerated (for example, `"GRAPPA"`, `"SENSE"`) imaging.
  type: string
```

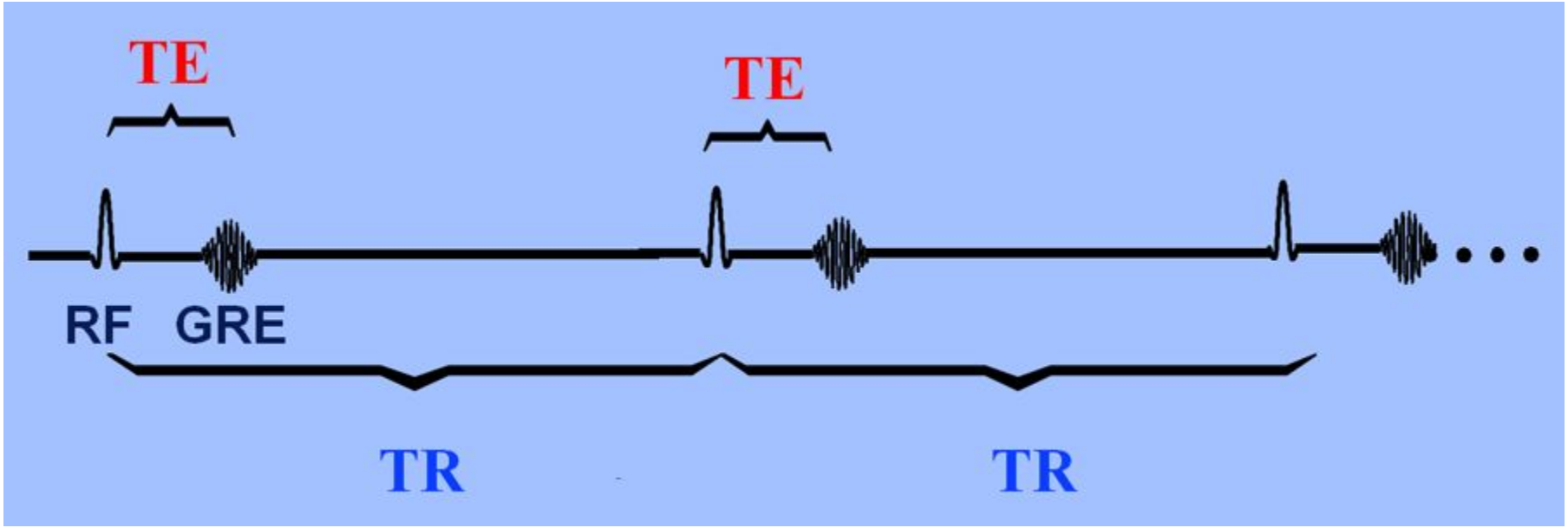
The schema will be used by several tools



Tedana

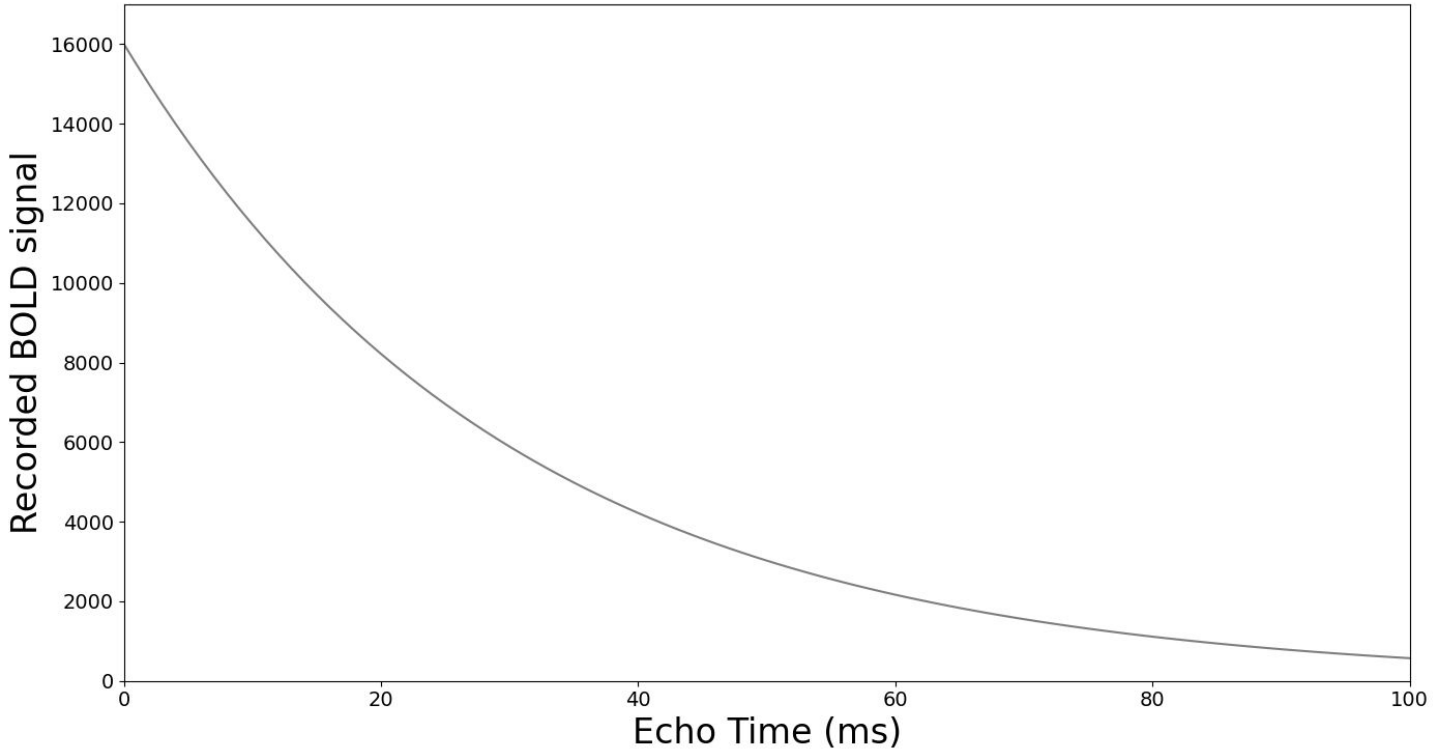


A simplified schematic of the EPI sequence

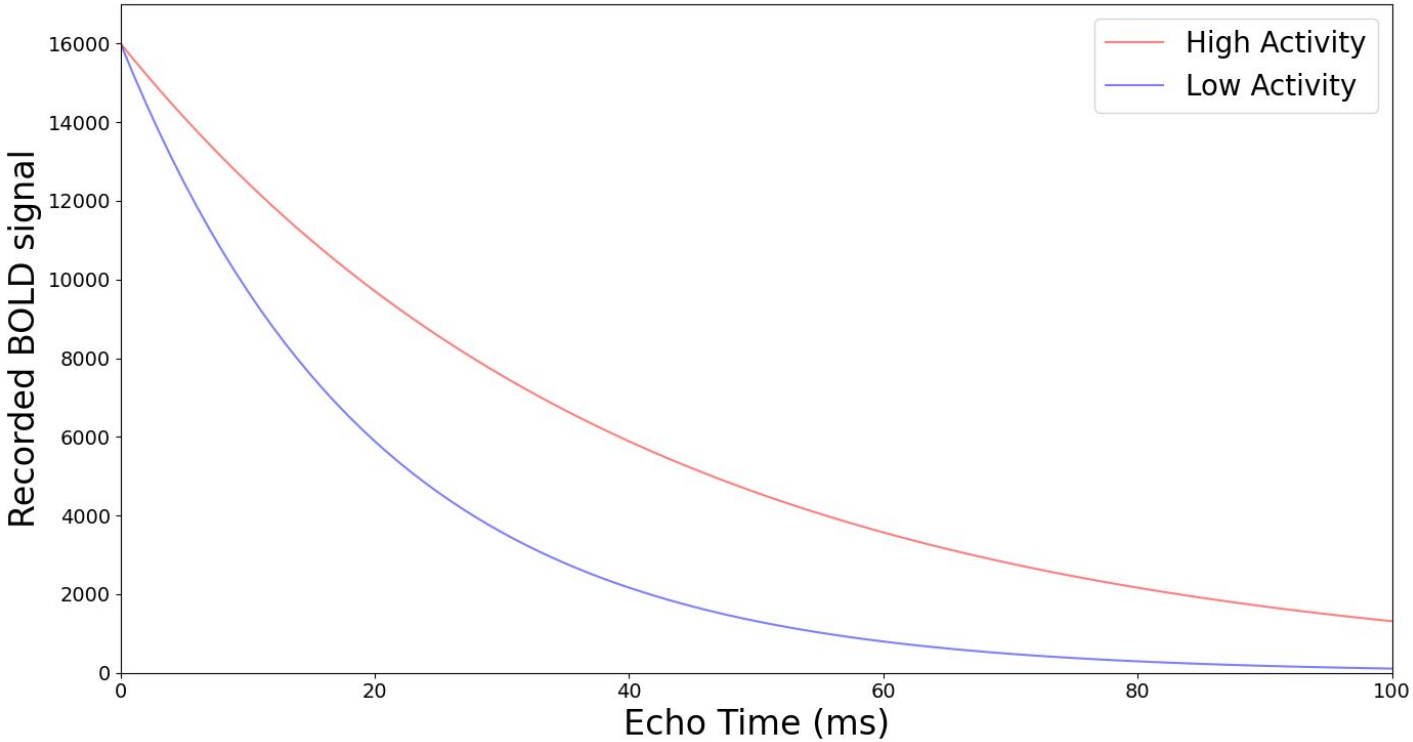


https://mriquestions.com/tr-and-te.html

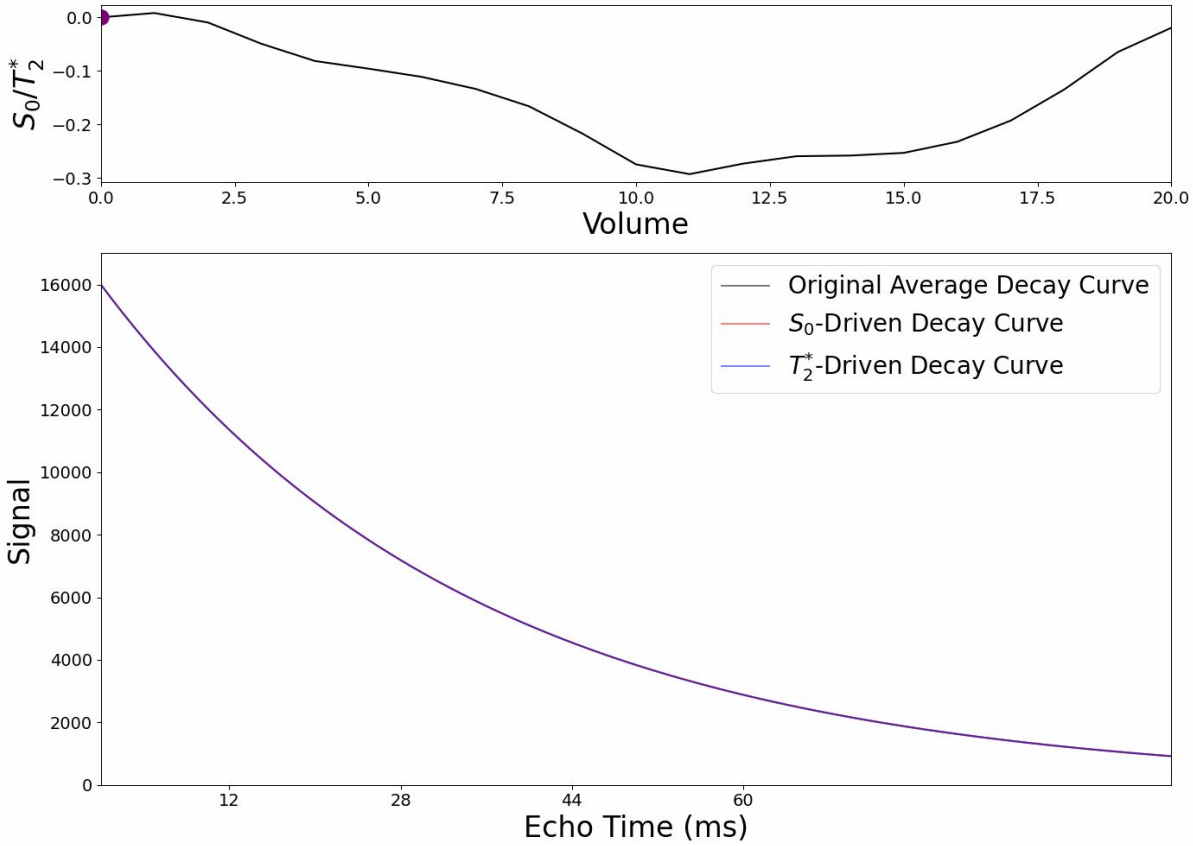
Functional MRI signal decays over time



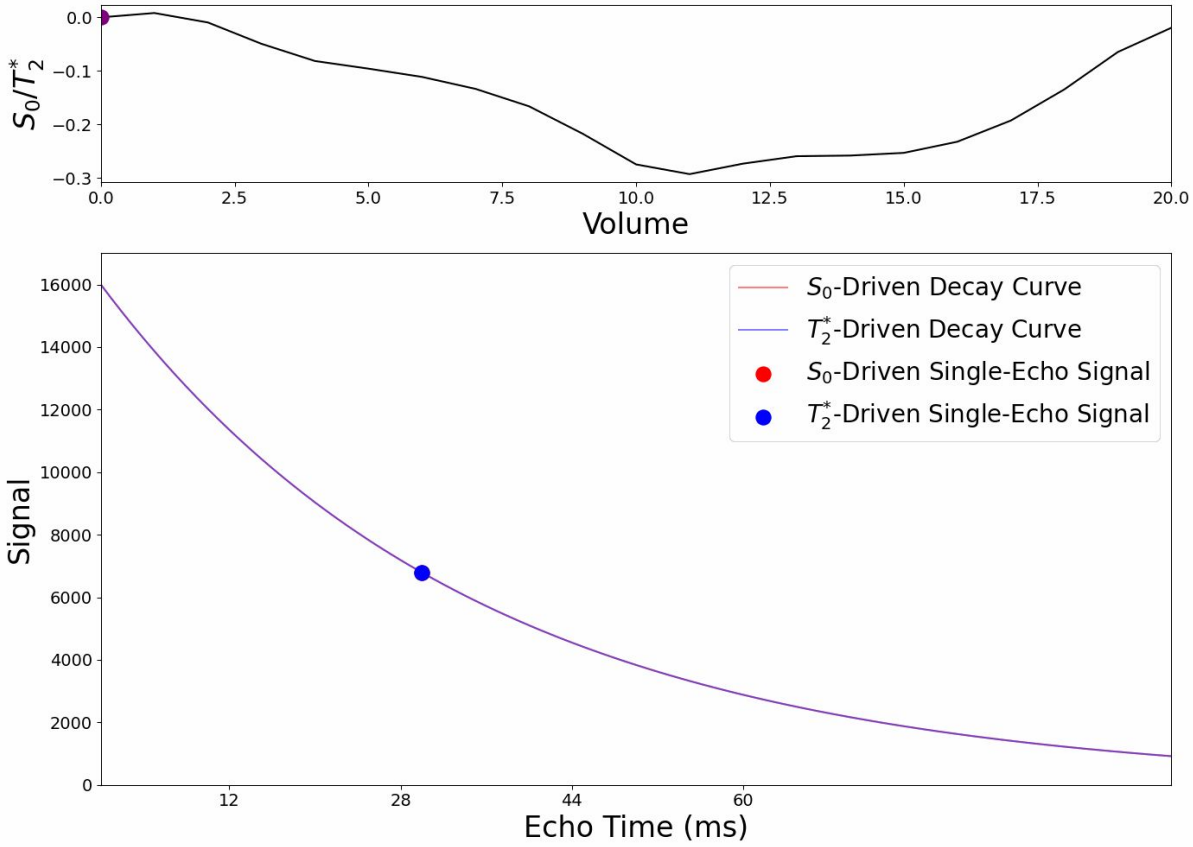
BOLD activity is reflected in T2*



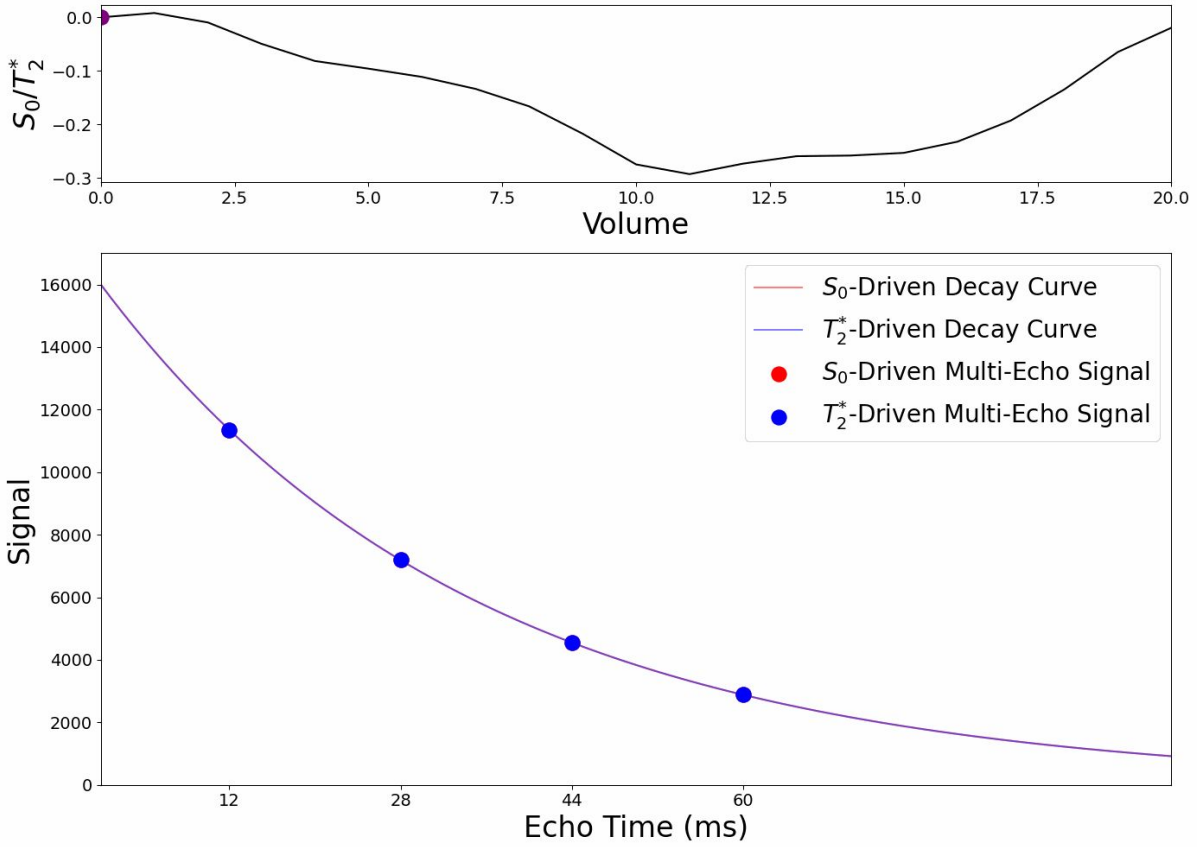
S0 and T2* fluctuations impact the signal decay differently



S0 and T2* fluctuations are indistinguishable with one echo



S0 and T2* fluctuations are apparent with multiple echoes

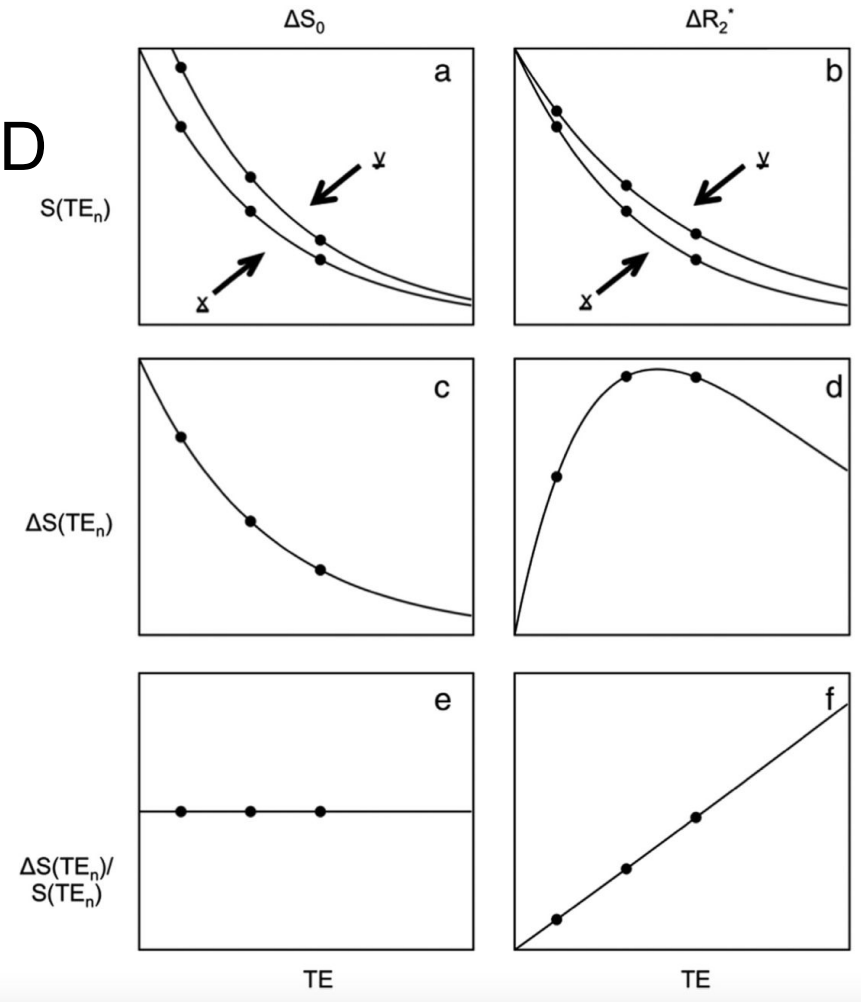


Separating BOLD from non-BOLD

fMRI signal fluctuations are a **mix** of BOLD and non-BOLD changes.

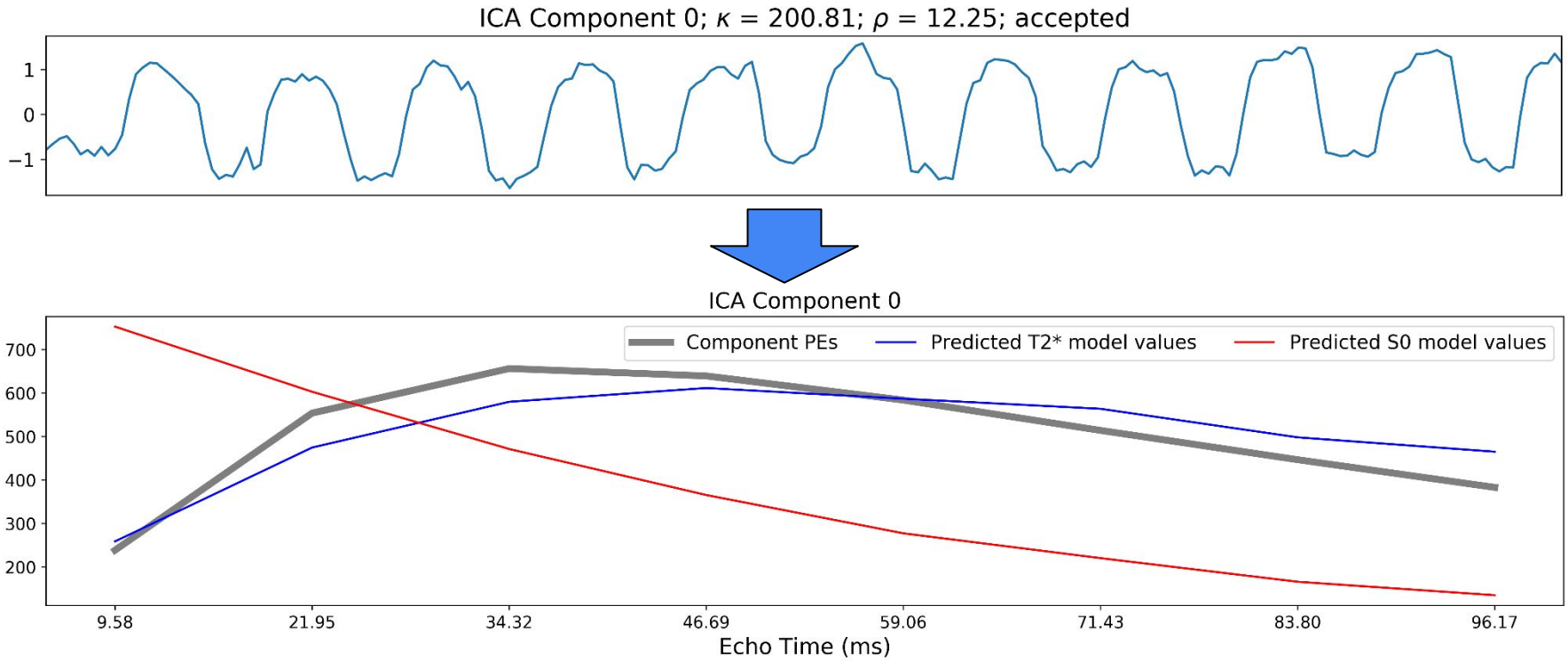
It is possible to estimate S0 and T2* for every TR, but there is too much noise.

The alternative is determine how BOLD-like a signal is.



Kundu et al. (2017)

Multi-echo ICA can remove S0-driven signals



Tedana performs several processes

T2*/S0 Estimation

- Multiple methods for estimating T2* and S0 from ME-EPI data.

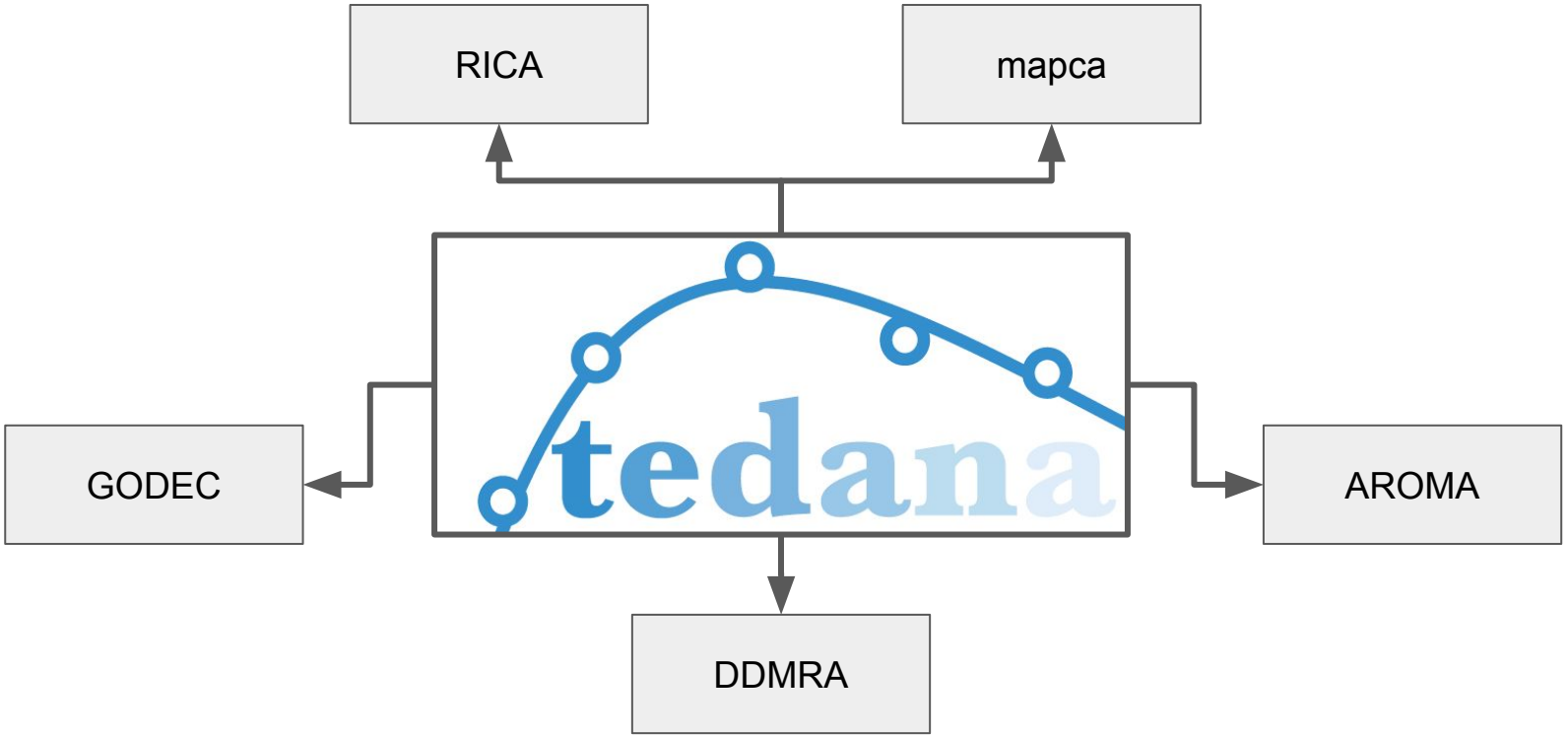
Optimal Combination

- Multiple methods for combining data across echoes.
- Optimal combination increases SNR and coverage.

ICA-Based Denoising

- Decomposition with ICA, followed by identification of BOLD/non-BOLD components based on signal decay characteristics.

Tedana has spawned several related projects



NiMARE

NiMARE:
Neuroimaging Meta-Analysis
Research Environment

Meta-Analysis of fMRI Data

Individual fMRI studies are typically underpowered, or use a single task.
Meta-analysis is necessary for measuring consensus across the field.

Optimally, meta-analysts would have access to **statistical maps** from individual studies, for image-based meta-analysis.

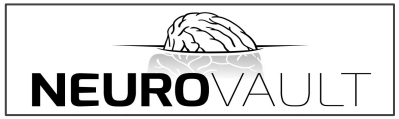
Most fMRI papers only report **coordinates** of peaks within significant clusters.

Many meta-analysis tools exist

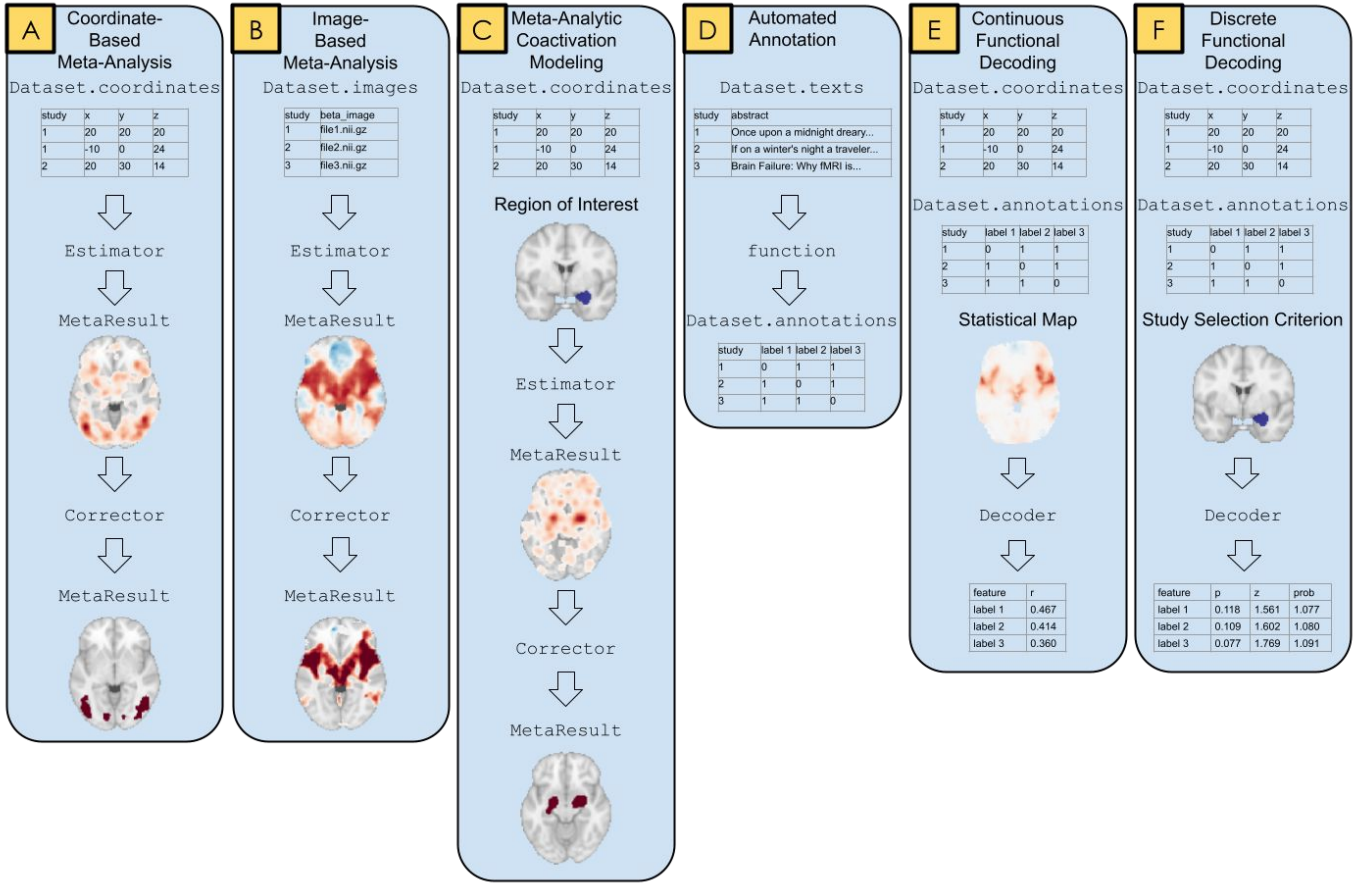
Most tools are GUI-based, closed-source, or written in languages neuroimagers don't know (e.g., C).

Most tools only implement one set of algorithms.

NiMARE implements a wide range of algorithms in a popular language (Python), with a common interface.



NiMARE supports a wide range of analyses using meta-analytic data



NiMARE is a part of a growing meta-analytic ecosystem