Growing Tedana: a grassroots-leveraged platform for processing multi-echo fMRI data

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INTRODUCTION

tedana

Open software to use and improve multi-echo methods

Community & resources for multi-echo fMRI

Multi-echo fMRI, data are collected at multiple echo times (TE) after each excitation pulse. This enables time series separation of BOLD effects of potential neural interest, from non-BOLD effects[1-7]. The acquisition cost of multi-echo is often minimal, and it improves data quality[8-19].

Over the past year, the tedana community has made many changes that improve how researchers can use the software and understand their results. We have also made improvements increase speed and stability and support continued methodologal innovation.

Additionally, we have built up resources, primarily through an interactive online book, to support the growing community of multi-echo fMRI users.

WAYS TO CONNECT

Multi-echo fMRI Book
https://me-ica.github.io/multi-echo-data-analysis

Multi-echo questions: https://neurostars.org with 'multi-echo' or 'tedana' tags

Subscribe to the tedana newsletter:
https://groups.google.com/g/tedana-newsletter

Join the conversation:
mattermost.brainhack.org/brainhack/channels/tedana

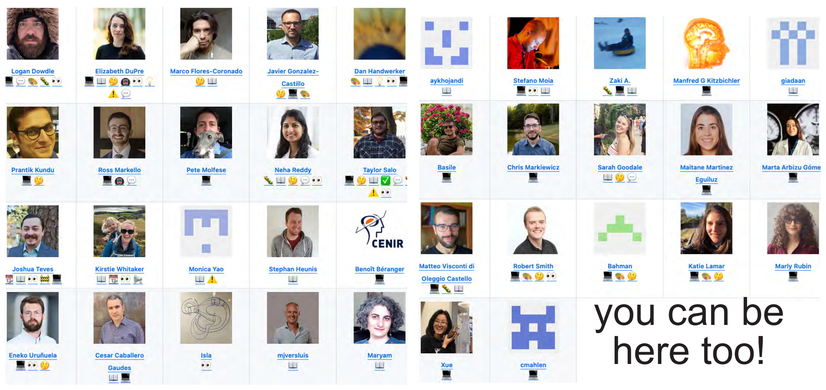
Recordings of multi-echo users meetings:
https://www.youtube.com/@tedana-devs

Openly available multi-echo fMRI datasets
https://me-ica.github.io/open-multi-echo-data/

Code and resources are open source.
Contribute at: https://github.com/ME-ICA/tedana

Multi-echo content including tedana interactive reports, a link to this poster & a form to add info to list of multi-echo fMRI studies:
me-ica.github.io/ohbm-2026-multiecho/tedana.html

CONTRIBUTORS



you can be here too!

REFERENCES

1. **DuPre, Salo et al., (2021) "TE-dependent analysis of multi-echo fMRI with tedana." J of Open Source Software**
2. Buur (2008) "Extraction of task-related activation from multi-echo bold fmri." IEEE Journal of Selected Topics in Signal Processing
3. Kundu (2012). "Differentiating BOLD and non-BOLD signals in fMRI time series using multi-echo EPI." NeuroImage
4. Kundu (2017). "Multi-echo fMRI: A review of applications in fMRI denoising and analysis of BOLD signals." NeuroImage
5. Poser (2006). "BOLD contrast sensitivity enhancement and artifact reduction with multiecho EPI: parallel-acquired inhomogeneity-desensitized fMRI." Magn Reson Med
6. Posse (1999). "Enhancement of BOLD-contrast sensitivity by single-shot multi-echo functional MR imaging." Magn Reson Med
7. Speck and Hennig, (1998) "Functional imaging by i0- and t2* -parameter mapping using multi-image epi." Magnetic Resonance in Medicine
8. Cohen (2021) "Using multiband multi-echo imaging to improve the robustness and repeatability of co-activation pattern analysis for dynamic functional connectivity." NeuroImage
9. DuPre (2016) "Multi-echo fmri replication sample of autobiographical memory, prospection and theory of mind reasoning tasks." Scientific data
10. Evans (2015) "Separating slow BOLD from non-BOLD baseline drifts using ME fMRI." Nimg
11. Gonzalez-Castillo (2016) "Evaluation of multi-echo ICA denoising for task based fMRI studies: Block designs, rapid event-related designs, and cardiac-gated fMRI." Neuroimage
12. Gonzalez-Castillo (2025) "A new fMRI quality metric using multi-echo information: Theory, validation and implications" bioRxiv
13. Heunis, (2021) "The effects of multi-echo fmri combination and rapid t2*-mapping on offline and real-time bold sensitivity." NeuroImage
14. Lynch (2020) "Rapid Precision Func Mapping of Individuals Using ME fMRI." Cell Reports
15. Kundu (2013) "Integrated strategy for improving functional connectivity mapping using multiecho fMRI." PNAS
16. Markello (2018) "Segregation of the human basal forebrain using resting state fMRI." Nimg
17. Steel (2022) "Evaluating the efficacy of ME ICA denoising on model-based fMRI." Neuroimage
18. Tahayori (2025) "Robust-tedana: An automated denoising pipeline for ME fMRI data." bioRxiv
19. Zhao (2024) "Leveraging multi-echo EPI to enhance BOLD sensitivity in task-based olfactory fMRI." Imaging Neurosci
20. Lamar-Bruno (2025). "Adapting the tedana multi-echo denoising pipeline for echo planar time-resolved imaging (EPTI)" ISMRM Annual Meeting

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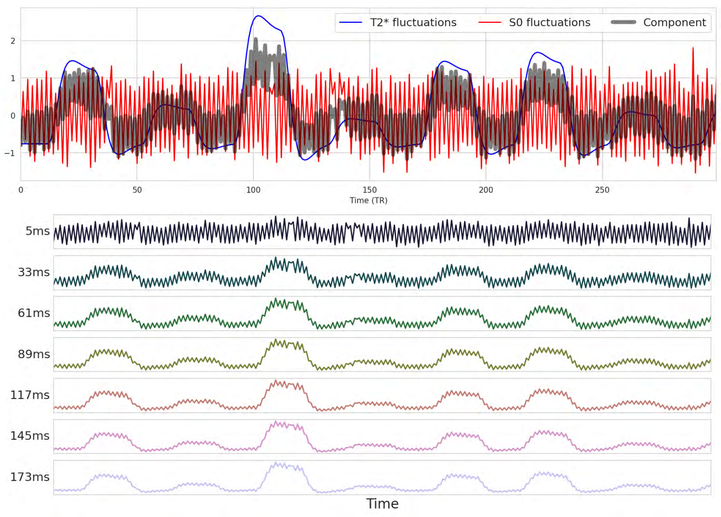
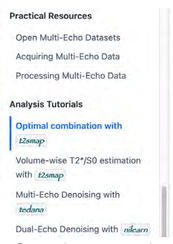
IMPROVED MULTI-ECHO FMRI RESOURCES





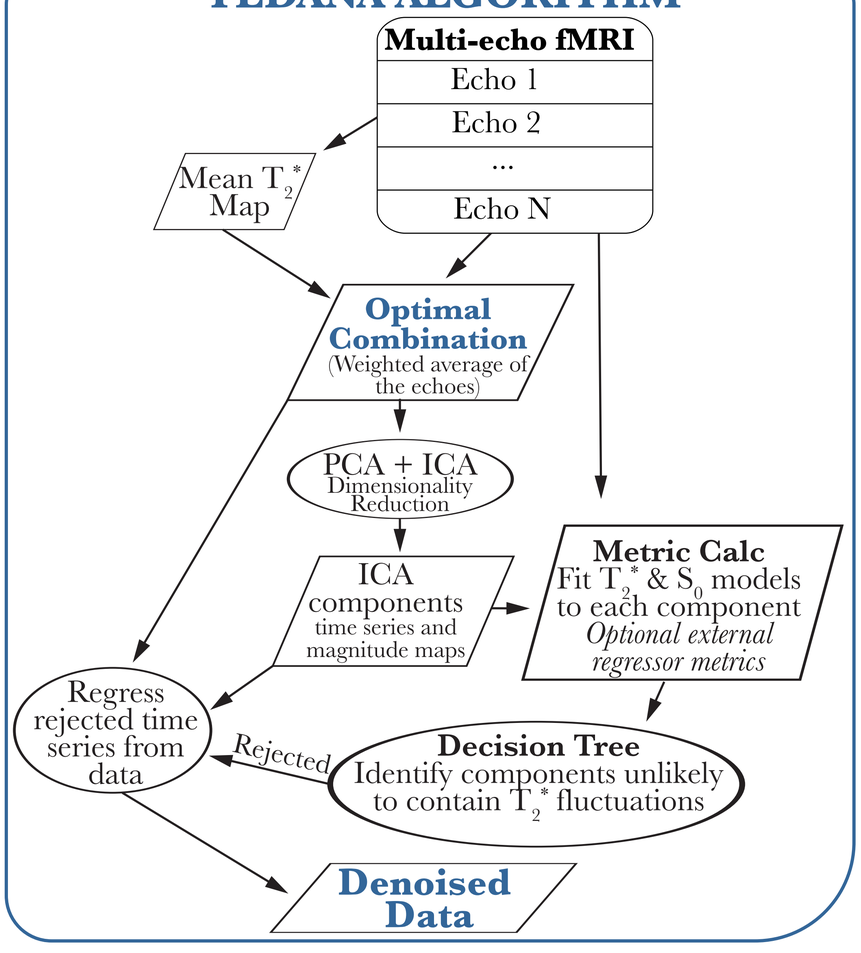
Our interactive multi-echo education book was redesigned to make it easier for more people to add content.
Contributions and requests for enhancements are welcome!

Currently includes:

- An overview of MRI physics and processing underlying multi-echo fMRI
- Practical advice for acquiring multi-echo data
- Links to other multi-echo fMRI resources
- Executable pipelines for multi-echo processing methods

TEDANA SOFTWARE

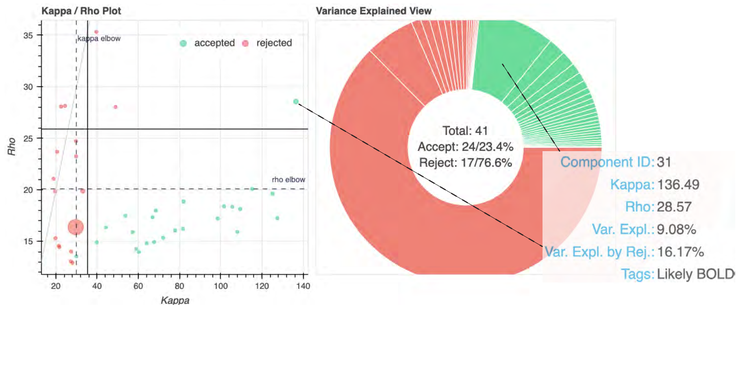
TEDANA ALGORITHM



Improvements during the past year

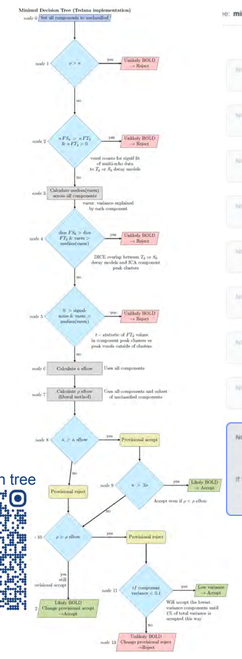
- Faster due to better parallelization of code
- Less memory by operating only on voxels in masks
- Added dummy scan parameter to make execution easier
- Works with EPTI sequences which have many more echoes that are not independent from each other.[20]
- User-created decision trees that identify components to reject can be added to figshare and run in tedana with just the tree name (doi.org/10.6084/m9.figshare.25251433)
- ica_reclassify can use custom tags, which makes it easier to combine tedana with other ICA denoising methods
- Switched to uv for package management, simplifying dependency management
- Changes to 96 files with 10.3K lines of code added and 2.3K lines removed

Tedana Report With Additional Information



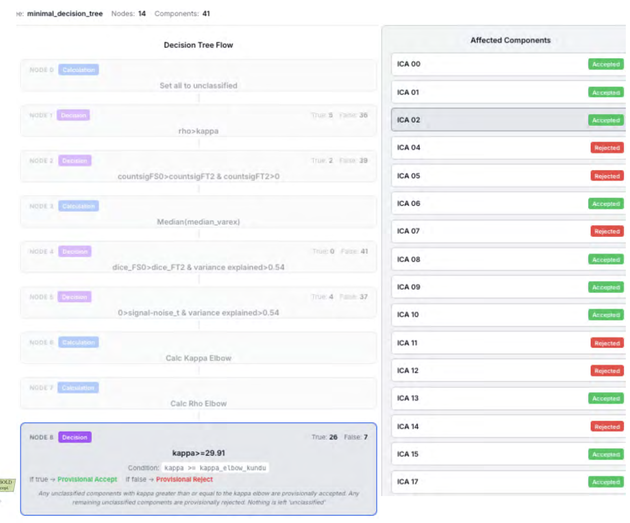
RICA Interactive Report

Decision Tree



DOI for decision tree

RICA Decision Tree Report



Several improvements focused on giving users more information and easier access to information to better understand the denoising process. In tedana interactive html report, we added measures for the total variance explained by accepted & rejected components. We also added how much variance explained in each accepted component was shared by rejected components. This is useful to see how much signal is common between accepted and rejected components. Users can now use arrow keys to cycle between components in the report.

For several years, we had a separate web-server-based program, RICA that allowed people to review results and manually change component classifications. The webserver can now be run with a simple command. It also visualizes information that was stored in text files. This includes key metrics for each component and what steps in the decision tree accepted or rejected each component.

CHALLENGES & ONGOING WORK

- We want to identify components that cleanly separate BOLD from non-BOLD information. Are there better ways?
  - Improving the estimation of the number of components and how data are decomposed (poster 746)
  - Improving the component selection process (poster 644)
- What can we improve if we have better temporal resolution for echos?
  - Improving methods that use EPTI data (poster 741)
- Vascular blood oxygenation fluctuations are T2* weighted. How do we best combine respiration and cardiac measures to remove these noise sources?
- How do we quantify improved noise removal?
  - Development of a pBOLD metric[12] (poster 2481)

HOW TO CONTRIBUTE

- Share challenges & feature requests
- Request educational material
- Contribute educational material
- Contribute to the code and methods
- There is always a risk that new methods are over-tuned to specific data parameters. If you have multi-echo data, help test methods on a wider variety of real data and share what works and what can be improved.