

# Two is better than one (and many are better): Multi-echo fMRI methods and applications

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## Symposium

Multi-echo BOLD fMRI is an acquisition method that offers excellent reduction of both hardware noise and non-BOLD-weighted biological noise and artefacts. As neuroimaging research advances towards the study of individual differences, clinical diagnostics, and precision medicine, tools that can more accurately remove subject-specific signals-of-no-interest are becoming more urgently needed. Despite demonstrated and theoretical advantages of multi-echo fMRI, several issues have historically limited its widespread use. The recent addition of multi-echo capability to widely distributed sequences, including multi-band sequences, means multi-echo fMRI is now accessible to a much larger user base. Similarly, multi-echo-specific data analysis previously required custom preprocessing steps by researchers with advanced scripting skills. Now, multi-echo data can be easily pre-processed with widely used neuroimaging software including AFNI and fMRIPrep. Additionally, in the past two years, the tedana software community has become a place where an international, open community of researchers are working together to improve multi-echo-specific analysis methods and educational resources (<http://tedana.readthedocs.io>). As a result, the multi-echo fMRI community is rapidly growing, and the use of this technology is potentially on the cusp of widespread implementation and application. At the 2019 Annual Meeting of OHBM, 33 abstracts employed multi-echo fMRI, including a combination of methodological work as well as applications of existing multi-echo methods to study the brain. The OHBM Open Science Room has hosted a multi-echo fMRI discussion in 2018 and 2019, attracting both fMRI users and developers of at least seven distinct approaches to acquire or analyze multi-echo fMRI data. Note that the current proposal is fully independent from the previous multi echo symposium at OHBM with no overlapping speakers or organizers. Nearly all of the advances listed above happened after the last symposium and the current proposal emphasizes these recent advances, the open science community, and cognitive neuroscience applications..

**Presenter Diversity:** The speakers in this symposium include two women and two men, from four different labs, with geographical representation from three countries (e.g., USA, Spain, and Canada). The presenters also represent a range of research careers and stages, comprising an NIH staff scientist, graduate student, MRI engineer, and professor. All speakers are not currently participating in any other 2020 OHBM symposium proposal or educational course. Three speakers have never given a talk at an OHBM symposium.

## Objective

In this symposium, we will discuss the current state of multi-echo fMRI acquisition, analysis, and applications in cognitive neuroscience research and highlight the active open science community in this domain. We will provide attendees with an understanding of how multi-echo fMRI is currently being used in cutting-edge applications and when it might benefit their own research. Following this symposium, attendees will:

- Gain a critical and balanced understanding of the current research progress in multi-echo fMRI data acquisition and analysis, how multi-echo fMRI may benefit planned studies, and the potential of future work.
- Be informed about the active open science community efforts to provide rigorous and accessible analysis tools for multi-echo data, which showcases the potential of open source software projects to benefit the entire research community.

\* Learn about novel methods that take advantage of the physical model of multi-echo fMRI data to enhance data analyses and demonstrate its advantages relative to its single-echo counterparts in different tasks.

## Target Audience

Our target audience includes fMRI users who acquire data, particularly those who may not be aware of the recent advances and increased accessibility of multi-echo pulse sequences and analysis methods. Our proposed content will additionally appeal to methodology researchers who may be interested in developing better ways to use multi-echo data as well as OHBM members interested in the potential of community-driven, open-source software development for the neuroimaging domain.

## Presentations

### How to decide if multi-echo fMRI can improve your study?

This presentation will include an overview of multi-echo fMRI, including a historical review of the potential and limitations to date, as well as recent changes in pulse sequence availability and analysis methods that have addressed many of the earlier limitations. A critical examination of the remaining limitations will also be provided. A range of approaches to use multi-echo data for motion correction and denoising during preprocessing will be presented, along with data from several recent studies showing signal improvements.

### Presenter

*Daniel Handwerker, PhD*, National Institute of Mental Health  
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### tedana software and community

tedana is an open-source community-based project that started three years ago <http://tedana.readthedocs.io> to provide advanced denoising methods for multi-echo fMRI. Since then, over 17 researchers from almost as many institutions have contributed to the project. As a central place for developing and documenting advanced multi-echo denoising and analysis methods, tedana is an entry point for new multi-echo fMRI users who want to

appropriately acquire and analyze data. This presentation will discuss the denoising methods currently available in tedana, demonstrate how tedana methods can be integrated into standard fMRI processing pipelines, including AFNI and fMRIPrep, and highlight the community resources for helping researchers considering multi-echo fMRI to get started. This presentation will also describe the development of an open-science community focused on a specific technical area, and showcase pathways for new members to contribute both to the software and the multi-echo open science community.

### Presenter

*Elizabeth Dupre*, McGill University Montreal, QC  
Canada

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## Multi-echo beyond preprocessing

Most multi-echo fMRI tools have focused on combining echoes early in the processing pipeline to create a less noisy data set as an input for all typical fMRI analysis methods. Beyond preprocessing, analysis methods can also take advantage of the physiological mechanisms of the BOLD response that are observable with multi-echo acquisitions. Among such methods, multi-echo paradigm free mapping (ME-PFM) is a novel deconvolution method that enables blind detection of BOLD events within an fMRI time series without prior knowledge of their existence. Taking advantage of the dependence on the echo time of the BOLD response across multiple echoes, ME-PFM provides clear benefits over similar formulations with single echo data, nearly achieving similar results to conventional analyses that are aware of the timing of the responses. This talk will present its formulation, as well as examples of its use in the analysis of task-based fMRI data across different cognitive tasks and in resting state fMRI data to detect spontaneous brief events within functional networks. In addition to being a potentially valuable method on its own, ME-PFM points to completely novel ways to use multi-echo fMRI if the multi-echo information is integrated into later data analysis stages.

### Presenter

*Cesar Caballero-Gaudes, PhD*, Basque Center on Cognition, Brain, and Language San Sebastian, Gipuzkoa  
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## Multi-echo fMRI in practice

This presentation will provide a practical discussion of why and how researchers may choose to implement multi-echo research in their fMRI studies. From the perspective of an exemplar cognitive neuroscience laboratory, Dr. Laird will discuss how multi-echo fMRI was deemed to be useful for a new dense sampling study in her lab, what was involved in designing and collecting multi-echo fMRI, and what additional factors were considered when planning that study. Study data will be presented to demonstrate the benefits of using multi-echo fMRI and the excellent quality of results, along with recommendations for how other labs might approach adding multi-echo fMRI to their own research projects.

### Presenter

*Angela Laird, PhD*, Florida International University Miami, FL  
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