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Validating multi-echo fMRI analysis methods across a range of acquisitions

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INTRODUCTION

To access an audio recording and transcript describing this poster, click here: https://github.com/ramyav97/multi-echo-fMRI-OHBM-2020.git

- Validation of multi-echo data analysis methods benefits from a dataset with predictable signal changes across multiple brain regions and acquisition options.
- We are collecting such a dataset to help validate and compare existing and new changes to processing methods.

METHODS

In order to check that our dataset was able to display robust contrasts in multiple subjects and preprocessing conditions, we processed our data in the following three ways:

1. Single echo: The second echo was used to look at brain activation in response to the task.

2. Optimally combined: A weighted average of the echoes was used to optimize T2* weighting. This has been shown to give a reliable boost in data quality.

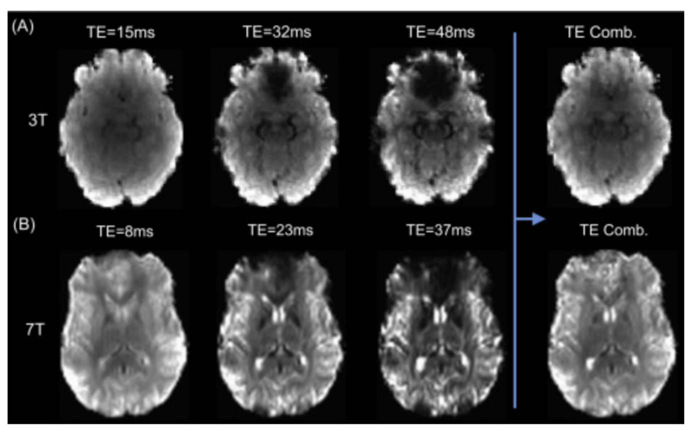

Figure 1. Generating an optimally combined image with a combination of echo images from a multi-echo experiment. (Figure from Kundu 2017)

3. Denoised: The data were denoised with the standard tedana.readthedocs.io pipeline. In this approach, ICA is performed to regress out components classified as noise.

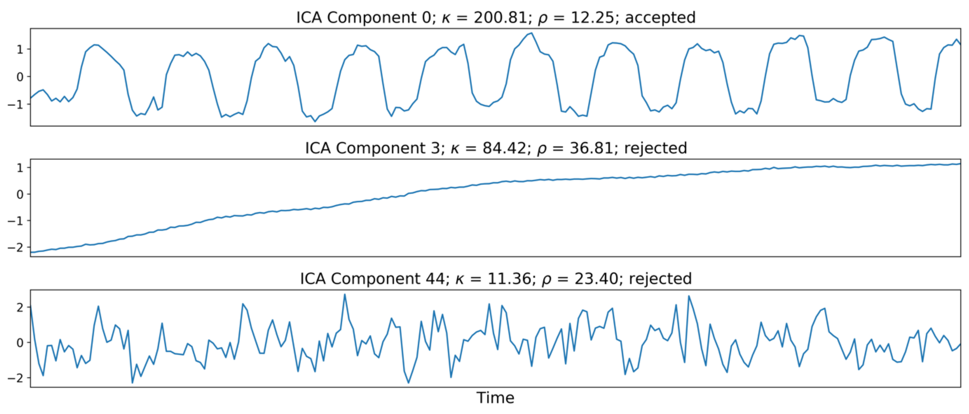

Figure 2. Applying TE-dependent ICA to separate data into components and then remove non-BOLD noise components. (Figure from tedana.readthedocs.io)

Data were processed in AFNI before denoising. Finally, we compared brain activation and task response across these three preprocessing streams in multiple subjects using a **group analysis**. We looked at significant ROIs for the two contrasts present in the task.

TASK DESIGN

13 healthy volunteers (3 males and 10 females, aged 22-48) performed a language localizer task.[3] They viewed 4-second groupings of 4 audio or visual stimuli and pressed a button if the same word or non-word appeared twice in each grouping. The visual stimuli were words or false font words. The audio stimuli were words or vocoded sounds derived from words. This task allows for a word-nonword contrast as well as a visual-audio contrast. These two contrasts mean a spatially diffuse number of brain regions will show measurable activation, and evaluation and validation of multi-echo methods will include a range of response magnitudes and drop out regions.

Figure 3. An example of the visual task conditions *(left:* visual-word and *right:* visual-nonword).

Each of the four conditions appeared 34 times over 22 minutes in a jittered event-related design.
Data were acquired on a GE MR750 3T MRI with a 2 sec TR
Acquisitions include:

- 3 echoes, in-slice accel=2, 3.3 mm^3 voxels, TE=10, 25, 40 ms
- 5 echoes, in-slice accel=3, 3.3 mm^3 voxels, TE=7.8, 18.4, 29, 39.6, 50.2 ms
- 3 echoes, in-slice accel=3, 2.75 x 2.75 x 3 mm^3 voxels, TE=9, 22, 35 ms (fewer volunteers & not presented here)

RESULTS

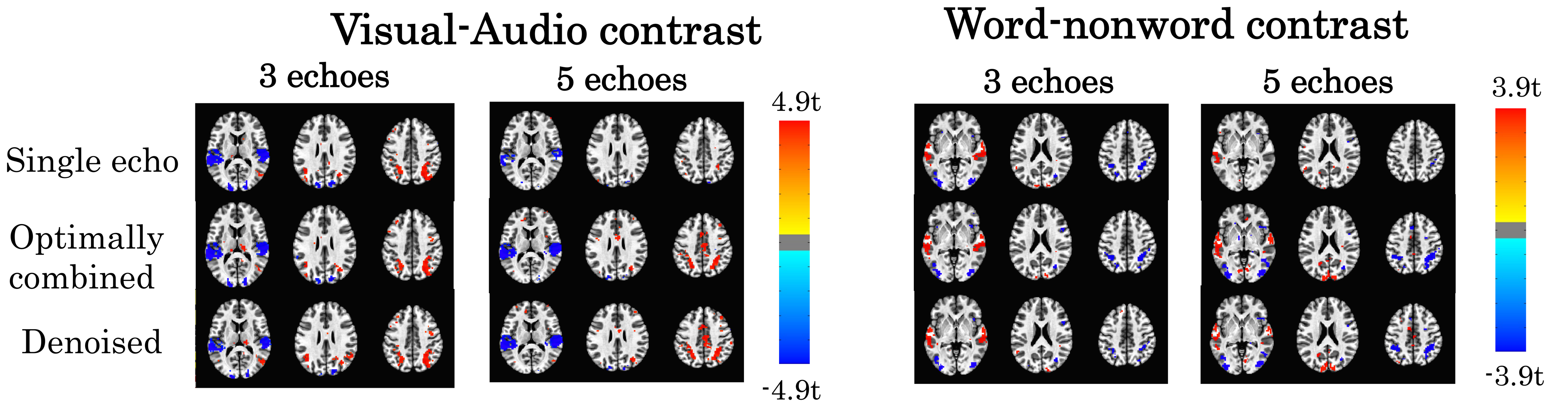

Figure 4. Group maps of visual-audio and word-nonword conditions visualized across preprocessing types

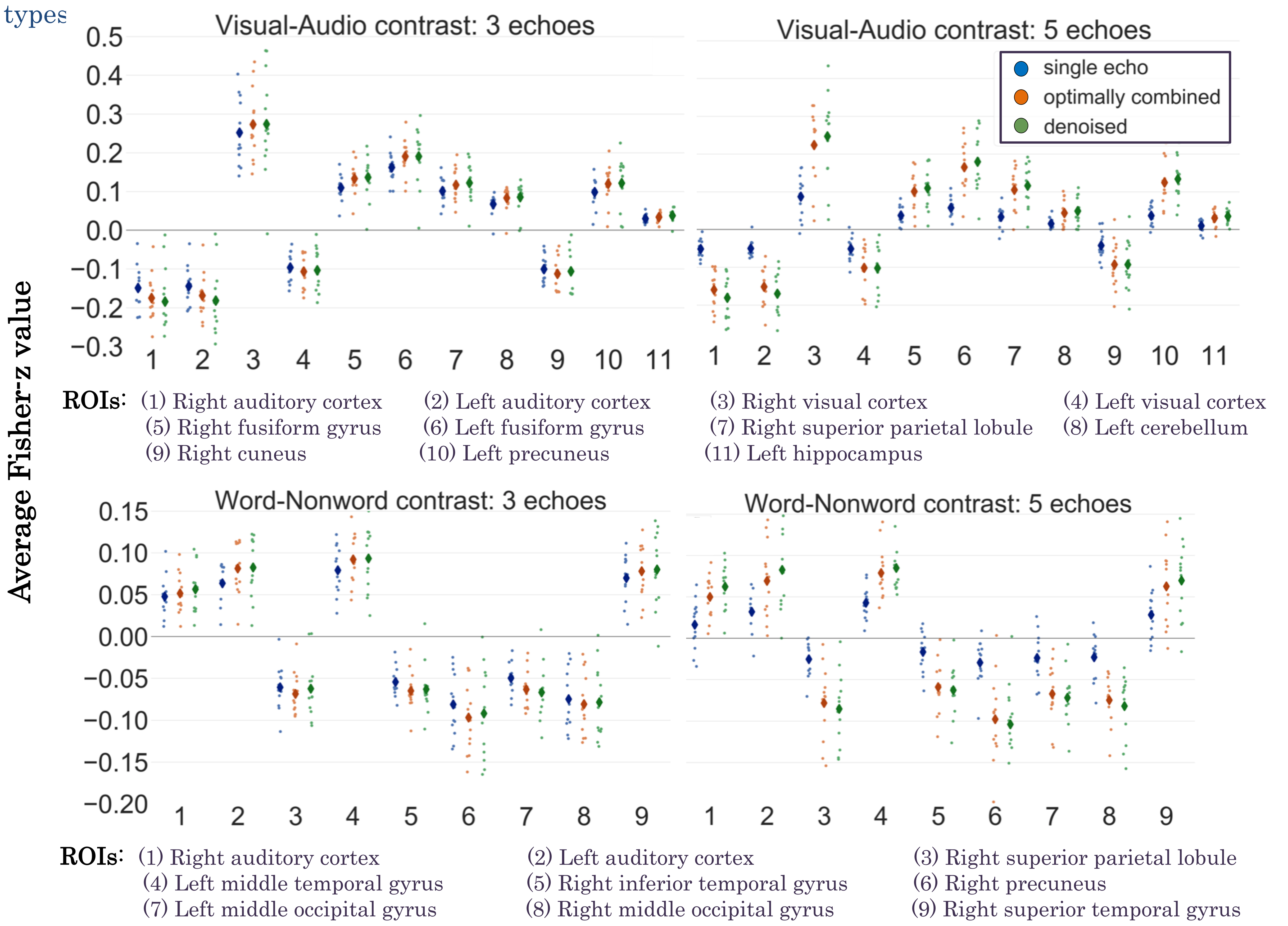

Figure 5. These dot plots show average Fisher-Z values in significant ROIs (>10 voxels) in the group maps. Effect magnitudes vary across ROIs, and consistent effect directions with all preprocessing choices. As expected, values tend to be slightly larger after optimal combination and denoising.

CONCLUSIONS

- The task generates robust and consistent contrasts with distinct acquisition parameters
- These can be used to validate and compare different preprocessing streams, like those being developed in tedana

FUTURE STEPS

- Continue evaluations of current analysis pipelines using these data
- Fully document and share these data
- Make these an option in the tedana integration and testing process

REFERENCES

1. Kundu P, Voon V, Balchandani P, Lombardo MV, Poser BA, Bandettini PA. Multi-echo fMRI: A review of applications in fMRI denoising and analysis of BOLD signals. *Neuroimage*. 2017;154:59-80. doi:10.1016/j.neuroimage.2017.03.033
2. "The Tedana Pipeline¶." *Tedana*, 2017, tedana.readthedocs.io/en/latest/approach.html#multi-echo-data.
3. Malins JG, Gumkowski N, Buis B, et al. Dough, tough, cough, rough: A "fast" fMRI localizer of component processes in reading. *Neuropsychologia*. 2016;91:394-406. doi:10.1016/j.neuropsychologia.2016.08.027

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