

# Multi-echo magnetic resonance inverse imaging improves the sensitivity of BOLD signal detection

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## INTRODUCTION

BOLD-contrast fMRI is a popular technique of non-invasive imaging approaches for investigating the signal changes related to neuronal activation. The echo time (TE) in fMRI acquisition is usually optimized to the T2\* value for high BOLD contrast [1]. Since T2\* is spatially dependent, echo-planar imaging (EPI) using one single TE may be only optimal to specific areas in the brain. EPI with multiple TEs [2, 3] can further improve BOLD signal sensitivity over multiple brain regions. Recently, we proposed the MR inverse imaging (InI) [4] to achieve fMRI with 100ms temporal sampling and whole-brain coverage using parallel acquisitions from channels of an RF coil array. In this study, we propose the multi-TE InI method to trade-off spatiotemporal resolution for higher BOLD signal sensitivity by acquiring data with multiple TEs. Specifically, we demonstrate EPI and multi-TE InI data with TE= 32 and 54 ms to reveal significantly activate brain areas using an audio-motor-visual task.

## METHODS

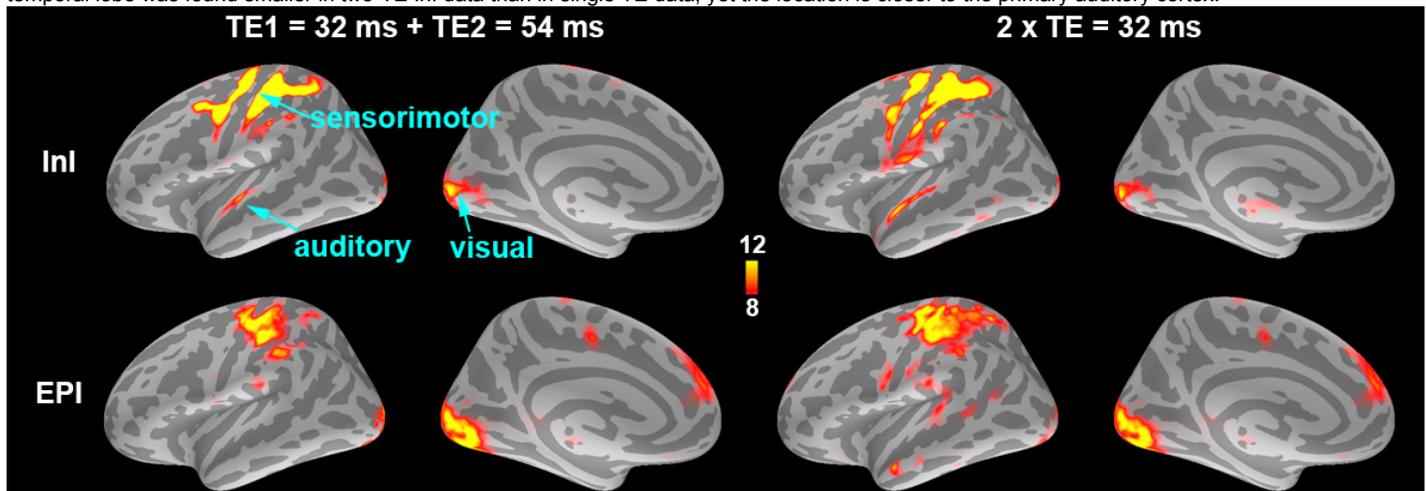
Eleven participants ( $n=11$ ) with informed consent were recruited to this study. The task was to press left or right hand response a button when the 1 kHz or 4 kHz auditory cues (sinusoids with 0.5 sec duration) was presented. Lateralized hemifield checkerboard reversals (8Hz, 500 ms duration) ipsilateral to the button pressing hand were presented to the subject at 500 ms after the button press. We expected to observe BOLD signal at auditory, sensorimotor, and visual cortices.

Multi-shot fully partition-encoded InI data were first acquired as the reference scan at a 3T MRI scanner (Tim Trio, SIEMENS, Erlangen, Germany) using a 32-channel head RF coil array. Accelerated InI coronal projection data were collected after volumetric RF excitation without partition encoding to achieve TR = 100 ms with whole brain coverage. The imaging parameters were: flip angle=30°, image matrix=64x64, 64 partitions, FOV=256<sup>3</sup>mm<sup>3</sup>. Two runs of InI data with TE = 32 ms and TE = 54 ms was collected. For comparison, multi-slice EPIs were also acquired (TR=2.5 s, flip angle=90°, bandwidth=2442 Hz/pixel, FOV=220x220x120 mm, image matrix=64x64x30). Two runs of EPI data with TE = 32ms and TE = 54 ms were collected. Both InI and EPI runs are 4 minutes long.

InI and EPI data were first analyzed by the General Linear Model with finite impulse response (FIR) bases to estimate hemodynamic responses with an effective TR of 100 ms. Coefficients of the FIR bases in the InI acquisitions were then reconstructed to yield volumetric distribution of hemodynamic responses using a minimum-norm constraint. Individual subject's hemodynamic responses were analyzed in a second-level random effect analysis to derive dynamic  $t$  statistics maps.

## RESULTS

The figure below shows the group-level  $t$  statistics map using InI and EPI data with single TE = 32 ms and two TEs at 32 ms and 54 ms at 6.7 s after the onset of the auditory cues for right hand responses. This is the time instant when the auditory, sensorimotor, and visual cortices were most significantly activated. At the same critical threshold, only InI data revealed significant auditory cortex activation. However, the visual cortex activation was stronger in EPI than InI. Comparing between acquisitions using single TE and two TE's, we found that EPI has similar activation in visual and sensorimotor cortex, while single TE EPI data suggested some activations in the temporal lobe outside the primary auditory cortex. For InI data, the size of the activated visual cortex is slightly larger in two-TE acquisitions. Sensorimotor activation was similar between single TE and two-TE InI data. The size of the activated temporal lobe was found smaller in two-TE InI data than in single TE data, yet the location is closer to the primary auditory cortex.



## DISCUSSION

Using the same amount of data, we demonstrated the feasibility of multi-TE InI to improve the sensitivity of detecting distributed activated brain areas by showing a larger activated brain area and more accurate localization. The preliminary results corroborated with previous EPI studies. Practically, the optimal TEs should be tailored to the local T2\*. This requires a pilot study to estimate activated brain areas and their local T2\* values. Previously, we have demonstrated the benefit of trading-off InI's temporal sampling for a higher sensitivity using temporally smoothed InI data [5]. This study suggested that the BOLD-signal sensitivity can be further improved by collecting data with different TEs during acquisitions. Practically this can be done by acquiring data of TEs across runs, since fMRI typically requires repetitive measurements to ensure sufficient SNR. We expect that this multi-TE InI can be combined with InI acquisitions of different projections [6] in order to improve the spatial resolution and BOLD signal sensitivity simultaneously.

## REFERENCES

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