Enhanced Sensitivity of Multi-Echo Resting-State fMRI on a cognitive-normal aging cohort using a Compact Head-Only 3T Scanner

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PURPOSE

- Multi-echo(ME)-fMRI improves BOLD sensitivity compared with single-echo acquisitions by increasing temporal signal-to-noise ratio (tSNR) and sampling multiple echoes in one repetition time.
- ME-fMRI particularly benefits from the head-only compact 3T (C3T) scanner's high-slew-rate gradients (700 T/m/s) [1], which shortens echo spacing that offsets the extra readout time required for ME and reduces geometric distortion [2].
- This study compared the performance of ME-fMRI acquired on a C3T scanner with a conventional whole-body 3T scanner in a large cognitive normal aging group study using resting-state fMRI.

METHODS

STUDY POPULATION

Two age-matched healthy volunteer groups were recruited with written informed consent: one scanned on the C3T scanner (n=45, age=72.36±9.90 years), and the other on a GE Premier whole-body 3T scanner (WB3T) (n=48, age=75.15±9.77 years).

DATA ACQUISITION

- ME-fMRI data were acquired using scanner-specific protocols as the gradients allow (C3T: TR=940ms; TEs=10.6/28.6/46.6ms; WB3T: TR=1350ms; TEs=16.7/43.4/70.1ms), with matched spatial resolution (2.4mm isotropic; 52 slices).
- T1-weighted anatomical images (1mm-isotropic) were also acquired.

DATA PROCESSING

- Pre-processing was performed using AFNI [3] and FreeSurfer.
- TSNR was calculated within gray matter (GM).
- Fractional amplitude of low-frequency fluctuations (fALFF) was analyzed using CONN [4], and second-level analyses assessed correlations between fALFF and age.
- Statistical significance was assessed using voxel-wise threshold of *p-uncorrected*<0.005 and cluster-level *p-FDR*<0.05.
- Group differences in fALFF between scanners were also assessed using second-level GLM-based analysis contrasting C3T versus WB3T while controlling for age [5].
- Statistical significance was assessed using voxel-wise threshold of *p-FDR*<0.001 and cluster size>100 voxels.
- All subjects scanned on both the C3T and WB3T scanners were included in a second-level analysis with scanner type and age as covariates.

RESULTS

FIGURE 1 showed no significant difference in age between participants scanned on the C3T and WB3T.

FIGURE 2 demonstrated a significant increase in gray matter tSNR for ME-fMRI acquired on C3T compared with WB3T, reflecting improved fMRI signal detection with C3T.

Brain maps display clusters showing significant correlations between fALFF and age for participants scanned on C3T (**FIGURE 3**) and WB3T (**FIGURE 4**) scanners. A greater number and spatial extent of significant clusters were observed in the C3T data than the WB3T data, indicating increased sensitivity to age-related fALFF effects with the C3T scanner.

In the second level test, subject-level fALFF maps were first computed, followed by group-level analysis using a general linear model (fALFF ~ Age + Scanner). Scanner effects were tested using the contrast C3T > WB3T while controlling for age. **FIGURE 5** shows that significantly higher fALFF for C3T relative to WB3T was observed bilaterally in posterior visual cortical regions, including the lateral occipital, occipito-temporal, and ventral occipital cortices.

FIGURE 1. No significant difference in age was observed between participants scanned on C3T and WB3T.

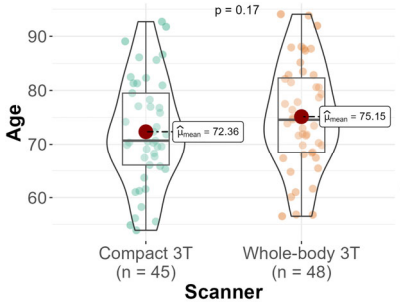
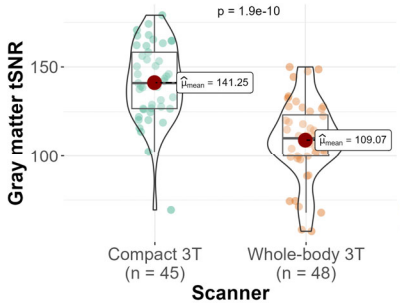


FIGURE 2. Significant increase in gray matter tSNR for ME-fMRI acquired on the C3T relative to the WB3T.



RESULTS (CONTINUED)

FIGURE 3. Clusters showing significant correlations between fALFF and age for participants scanned on the C3T. Voxel-wise threshold of p-uncorrected < 0.005; cluster-level p-FDR < 0.05.

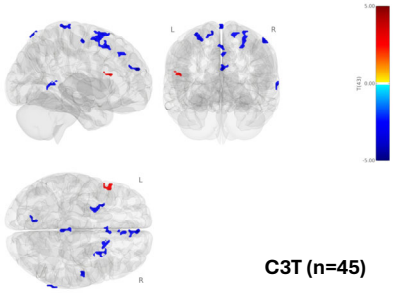


FIGURE 4. Clusters showing significant correlations between fALFF and age for participants scanned on the WB3T. Voxel-wise threshold of p-uncorrected < 0.005; cluster-level p-FDR < 0.05.

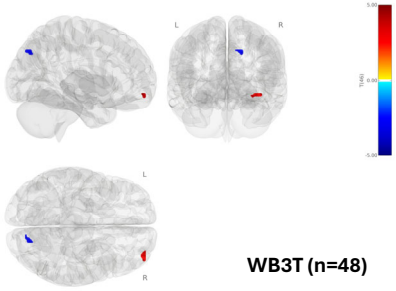
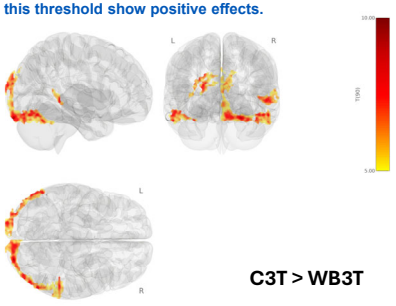


FIGURE 5. Significantly higher fALFF for C3T relative to WB3T was observed in the occipital lobe. Voxel-wise threshold of p-FDR < 0.001; Cluster size > 100 voxels. All clusters meeting this threshold show positive effects.



DISCUSSION

- GM tSNR was significantly higher for ME-fMRI acquired on the C3T compared with the WB3T.
- C3T data demonstrated greater sensitivity to age-related fALFF effects, revealing more extensive significant clusters than WB3T.
- Significantly higher fALFF for C3T relative to WB3T was observed in bilateral occipital and occipito-temporal cortical regions..

CONCLUSIONS

- This study demonstrates that ME-fMRI acquired on a head-only C3T scanner with high slew rate gradients yielded superior gray matter tSNR and increased sensitivity to age-related fractional amplitude of low-frequency fluctuations fALFF effects than a conventional whole-body 3T system.
- The findings highlight the performance advantage of C3T hardware for high-quality ME-fMRI and support its utility for more sensitive functional neuroimaging studies.

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