Inhomogeneity of signal intensity is a potential source for BOLD signal inaccuracy in ultra-high field fMRI

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TARGET AUDIENCE: Researchers of functional imaging of ultra-high field MRI

PURPOSE: Increased susceptibility effects associated with ultra-high field MRI, may be potentially beneficial for functional magnetic resonance imaging (fMRI). Enhanced BOLD effect allows greater sensitivity to subtle differences in activation level, and requires less trial repetitions of the functional task, allowing a potentially greater number of task paradigms. However, inhomogeneity of the main magnetic field (B_0), RF field (B_1), magnetic susceptibility effects and inhomogeneous coil sensitivity can be severe at ultra-high field MRI, with a detrimental effect on measured signal intensity across the image[1, 2], which may result in inaccurate BOLD signal values in affected areas. Therefore, in this work we applied signal inhomogeneity correction to fMRI data to assess the effect on measured BOLD activity.

METHOD: Nine healthy participants were included in this study (average age 33.47 ± 4.07, 4 females and 5 males). Written consent was acquired and ethical approval obtained from Iwate Medical University IRB. To assess brain function, each participant underwent a functional echo planar imaging (EPI) scan (TR: 6.1 sec, TE: 25.4 ms, FA: 90°, matrix size: 1.88×1.88×2 with 0.3 mm gap, FoV: 24 cm) and a T1 weighted structural scan using a 7 Tesla MRI scanner (Discovery MR950; GE healthcare, Milwaukee, WI) with 32-channel receive head coil. During functional scanning, a block-designed paradigm was used whereby participants observed unfamiliar faces[3] for 12.2 seconds and a fixation cross for 18.3 seconds, with 6 repetitions. All EPIs were processed with and without signal intensity correction (SPM8, http://www.fil.ion.ucl.ac.uk/spm/). Images were realigned and unwarped[4] and a mean image created. The bias field of the mean image was estimated using the 'New Segment' method implemented in SPM8 with 60 mm FWHM of Gaussian smoothness and applied to all realigned EPIs for the signal intensity correction. Corrected EPIs and non-corrected EPIs were normalized to MNI space and spatially smoothed with 5 mm FWHM using a standard fMRI analysis procedure. The two design matrixes (model using signal intensity corrected data: SIC and model using signal intensity not corrected data: NIC) were modelled in a general linear model at the single subject level analysis. Finally, corrected and non-corrected BOLD activation maps were compared.

RESULT: At the group level, the contrast images of SIC and NIC for each participant were entered into a pair wise t-test. As a result, both SIC and NIC showed similar activation patterns (Fig.1 regions coloured in red $p<0.05$ corrected for family wise error). However, in posterior visual cortex, a significantly higher activation was observed in NIC than SIC (Fig.1 regions coloured in yellow), whereas fusiform gyrus and anterior thalamus regions showed significantly higher activation in SIC than NIC (Fig.1 regions coloured in cyan. $p<0.001$ not corrected for multiple comparison).

DISCUSSION: Differences in BOLD signal between SIC and NIC demonstrates that in posterior visual cortex NIC overestimated BOLD signal (yellow), and in anterior thalamus areas NIC underestimated BOLD signal (cyan) due to inhomogeneous coil sensitivity. The fusiform gyrus also showed underestimated BOLD signal in NIC, which suggests susceptibility artefact from the ear canal can also affect BOLD signal detection. Thus, BOLD signal measured in the centre of the brain, and in areas where susceptibility artefact is increased such as paranasal sinus and the ear canal, will most likely be underestimated, and overestimated in areas closest to the surface coil.

CONCLUSION: fMRI studies at ultrahigh field should take account of signal inhomogeneity as a potential source for misrepresentation of brain activity levels. Pre-processing of ultra-high field fMRI data with SPM8 'New Segment' can help resolve underestimated and overestimated BOLD signal measurement by correction of signal inhomogeneity.

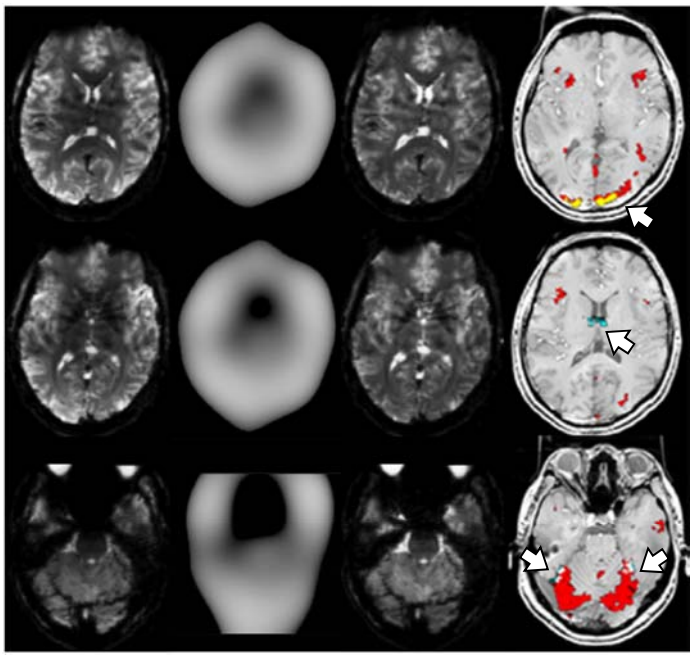

Fig. 1 Original EPI image (left), estimated bias field (second left), signal intensity corrected image (second right) and functional map from the group level analysis overlaid on T1 image. Both preprocessing methods show activated areas colored red. Significantly underestimated signal intensity data displayed in cyan and overestimated areas in yellow.

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