Improved Activation Detection in fMRI Studies Using Acquisition and Reconstruction Methods Robust to Susceptibility and Motion Artifacts

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BACKGROUND: Head motion is a very significant source of error that degrades accuracy and sensitivity of fMRI studies by introducing variability in data and often causes erroneous activation. Head motion results in dynamic changes in R2* maps and alters signal loss and image distortions resulting from susceptibility artifacts [1]. These effects are most pronounced near the air-tissue interfaces in the brain. The effectiveness of motion correction algorithms is limited since they register the time-series data into the co-ordinates of the reference image without accounting for susceptibility and other indirect sources of error. It has been shown that use of methods robust to susceptibility and motion artifacts result in better quality of motion correction [2]. In this study, we show that acquisition and reconstruction methods that are more robust to susceptibility induced off-resonance artifacts, significantly improve the quality of activation detection in motion corrupted data set. More specifically, reverse spiral and combined reverse and forward spiral, and reconstruction method, iterative image reconstruction with dynamically updated field maps [3] were better able to preserve the fidelity of activation maps even in presence of significant head movement.

METHODS: Data was acquired during two separate runs, with and without head motion, while subject performed a visual-motor task involving 15 sec periods of alternating finger tapping and visual stimulation (see figure 1 for motion profiles). The data were acquired using single shot forward and reverse spiral and single shot forward spiral and TE=30ms/TR=1sec/15 slices, 6mm thick. The data were then reconstructed using 1) conjugate phase (CP) image reconstruction method with a static field map, 2) Iterative reconstruction with dynamically updated field maps [3]. Motion correction was carried out using MCFLIRT[4], and SPM[5] was used to determine functional task activation, using exactly same parameters across all acquisitions. A representative slice through the motor cortex is included for comparison across the acquisition and reconstruction methods. Similar results were also observed in the visual cortex region.

RESULTS: Head movement during first session was negligible compared to the second session containing rotations up to 4 degrees and translations up to 2mm (see figure 1). **Comparison of Acquisition methods:** activated regions were very similar for forward spiral (fig 2, **A**) and combined forward and reverse spiral (fig 2, **B**), with no motion. However, activation maps differed significantly in presence of motion as combined forward and reverse spiral images, after motion correction, (fig. 2, **D**) were better able to localize activation compared to forward spiral only acquisition (fig 2, **C**), where significant spurious activation was present. We also found that reverse spiral images were better able to localize activation maps after motion correction compared to forward spiral images. **Comparison of Reconstruction methods:** Iterative reconstruction with dynamically updated field maps significantly out performed CP reconstructed images with static field maps, both qualitatively and quantitatively, in correctly identifying activated regions even in presence of large head motion. As seen in figure 3, the activated regions are identical in session without (fig 3, **B**) and with motion (fig 3, **D**) for iterative reconstruction with updated field maps. The CP reconstruction shows smaller activation region even in absence of motion (fig 3, **A**) and several regions of spurious activation after motion correction (fig 3, **C**) of data with movement.

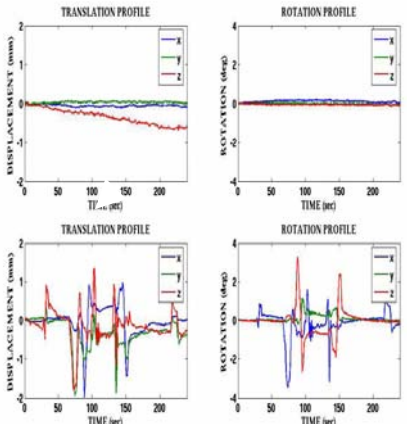

Figure 1: Translation and rotation profiles of time series with minimum motion (TOP) and significant motion (BOTTOM).

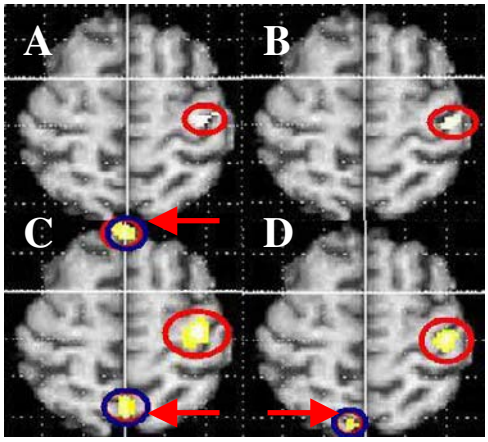

Figure 2: (A): forward spiral/ no motion, (B): forward & reverse spiral/ no motion, (C): forward spiral / motion, (D) forward & reverse spiral /motion. Forward spiral only resulted in spurious activation (C), compared to forward &reverse spiral acquisition (D).

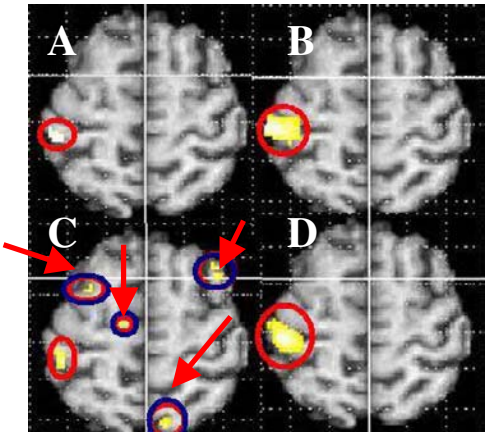

Figure 3: (A) CP recon,/no motion (B) Iter recon - updated field map/no motion, (C) CP recon / motion, (D) Iter recon /motion. Activation in (B) and (D) are almost identical, but CP recon shows false activation (C) in presence of large motion.

CONCLUSION: Susceptibility mismatch at tissue air interfaces cause artifacts that can be debilitating to fMRI study. Head movement aggravates the situation by dynamically altering the air-tissue interface, hence the artifacts. Acquisition methods, more robust to these susceptibility induced off-resonance contributions are better able to reduce the impact of these errors, both on quality and completeness of motion correction as well as fidelity of activation maps. In this study, we have shown that combined forward and reverse spiral, more robust to off-resonance contributions is better able to preserve and identify activated regions compared to forward spiral activation, which shows significant spurious activation. Similarly, iterative reconstruction with updated field maps is able to preserve activation maps even in presence of large motion compared to CP recon using static field map.

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