# Effects of Acquisition Parameters and Reconstruction Methods on the Correction of Motion and Susceptibility Artifacts in fMRI

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## Background:

Signal loss due to intravoxel dephasing in T2* - weighted imaging and off-resonance image distortions are two major manifestations of magnetic susceptibility artifacts in functional MRI and are induced by air – tissue interfaces in the head, e.g., above the sphenoid paranasal sinus. Head motion can change the orientation of interfaces relative to $B_0$ and thus, the appearance of these distortions in raw T2*- weighted images [1]. Incorporation of methods that abate image distortions and intra-voxel dephasing significantly reduced the error between the reference image and movement corrected image in a static susceptibility phantom [2]. In this study, we examine the effect of acquisition parameters and reconstruction methods on motion correction in fMRI while the imaged phantom is continuously moving across the time series of images. Specifically, we examine whether spiral-in or spiral-in/out acquisitions, which are generally more robust to susceptibility artifacts [3], and whether image reconstruction with dynamically updated field maps can lead to improved motion correction in T2*-weighted (BOLD) imaging.

## Methods:

Data were acquired using a spherical, layered susceptibility phantom containing tissue mimicking material [4] and undergoing a computer-controlled, precise and repeatable through plane saw-tooth motion routine with maximum angular displacement of ~ $\pm$8 degrees. We acquired 51 2-mm slices using a gradient echo spiral pulse sequence (TE 27 ms, FOV=24 mm) using a single-shot spiral-in/spiral-out acquisition. Images were reconstructed using a conjugate phase image reconstruction using a static field map acquired at the start of each run to correct for off-resonance distortion effects. Spiral-in/spiral-out images were also reconstructed using an iterative method [5] using dynamically updated fieldmaps at every image in the time series. Images were motion corrected using FSL [6], and the realigned images were subtracted form the reference image, the average of $4^{th}$ & $5^{th}$ images in the time series. The error calculated was normalized by the average intensity of the reference images. The calculated normalized root mean squared error (NRMSE) was compared across the various acquisition parameters and reconstruction methods to determine which parameters and reconstruction methods would lead to the most accurate and complete motion corrected images.

## Results:

On average, the spiral-in /spiral-out images reconstructed with the iterative reconstruction method using dynamically updated field-map were most accurate and had the lowest NRMSE of all images before and after motion correction, followed by the spiral-in, spiral-in/spiral-out images, and the spiral-out images being the least accurate. A comparison of the pre and post motion corrected images also revealed that motion correction was most effective in the images reconstructed with the iterative method (33% error reduction) compared to CP spiral-out (28%) and CP spiral-in/out & spiral-in (~25%) respectively. For images reconstructed with CP reconstruction method, the NRMSE for spiral in and spiral in-out acquisitions were significantly lower than the spiral-out acquisition.

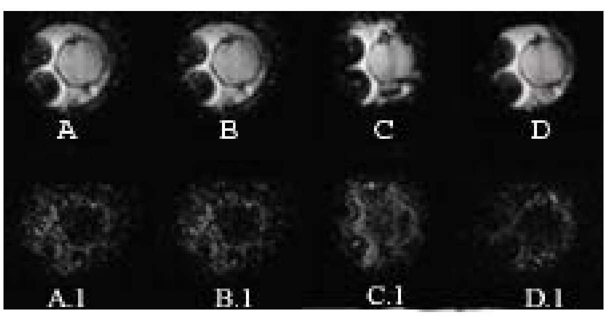
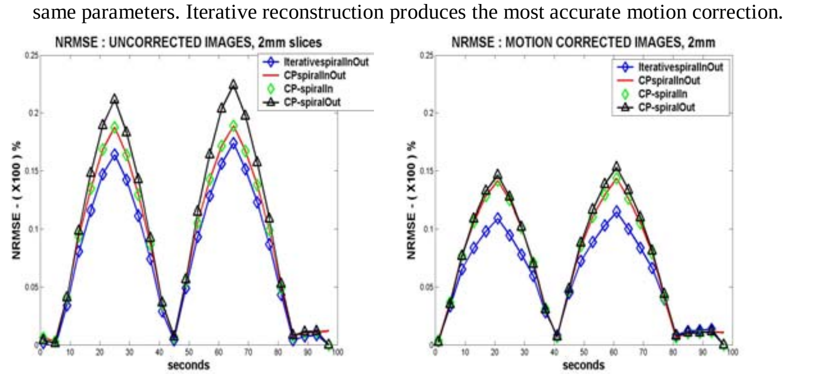



**Figure 1**: **A)**- spiral-in/CP recon **B)**- spiral-in/spiral-out/ CP **C)**- spiral-out, CP **D)**- spiral-in/spiral-out, Iterative method with dynamic fieldmap update. **A.1/B.1/C.1/ D.1**) – post motion correction error images, (**white- indicates more error**) of respective acquisitions.

**Figure 2**: (**left**) pre motion correction NRMSE error calculation for a saw-tooth motion routine and acquisition Parameters spiral-in, spiral-in/out, spiral-out using CP reconstruction and spiral-in/spiral-out using iterative reconstruction. (**right)** post motion correction with same parameters. Iterative reconstruction produces the most accurate motion correction.




** Error peaks correspond to the max. ($\pm$8) deg. rotational displacement from the reference.

## Conclusion:

We found that the use of acquisition parameters that are less sensitive to off-resonance and susceptibility artifacts, along with the incorporation of dynamic estimates of susceptibility-induced inhomogeneities in presence of motion during imaging, results in better motion corrected images. Acquisition methods that are more robust to susceptibility artifacts, namely, spiral-in and spiral in-out acquisitions produced more accurate motion corrected images. As expected, the iterative method using the dynamic field-map estimates resulted in more complete motion correction since these field-maps were able to account for motion induced dynamic changes in the local field inhomogeneity and off resonance effects due to motion.

**References**: [1] D. H. Wu, J. S. Lewin, and J. L. Duerk, J Magn Reson Imag. 7(2): p. 365 – 70, 1997. [2] K. K. Pandey, D. C. Noll and S. Peltier, Proc. of ISMRM $11^{th}$ Meeting, 1736, 2003. [3] G. H. Glover, C. S. Law, Magn Reson Med, 46:515-522, 2001. [4] J.C. Blechinger, E .L. Madsen and G. R. Frank, Med Phys, 15(4): p.629 – 36, 1988. [5] B. P. Sutton et al. Proc. of ISMRM $11^{th}$ Meeting, 479, 2003. [6] M. Jenkinson, et al. NeuroImage, 17(2): p.825—841, 2002.

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