Effect of Slice Selection Parameters on Motion Correction in fMRI using 2D Planar Imaging

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Background:

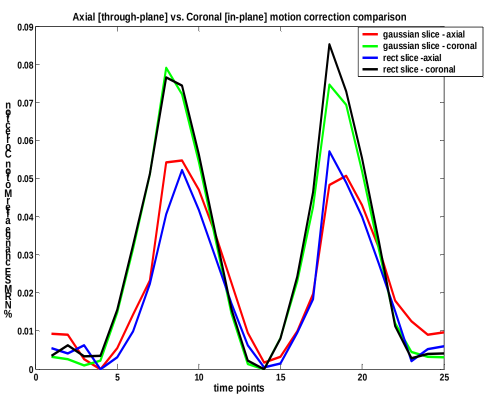
Head motion is a very significant source of error that degrades the accuracy and sensitivity of fMRI studies of the brain. Head movement introduces variability in activation data and causes erroneous activation, especially near the edges and sinuses. In addition, head motion also results in dynamic changes in R2* maps and aggravates signal loss and image distortions resulting from susceptibility artifacts [1]. These effects are more pronounced near the air-tissue interfaces in the brain. The effectiveness of motion correction algorithms is limited since they reslice the time-series data into the co-ordinate frame of the reference image without accounting for the susceptibility and other indirect sources of error. Furthermore, the reslicing process itself often introduces errors due to aliasing and interpolation artifacts in the slice select direction [2]. In this study, we have explored the effect of suggested optimal slice acquisition parameter [2] on quality of motion correction. Specifically, we looked at whether Gaussian slice profile with lower frequency content, higher sampling with zero-gap spacing or overlapping slices and in–plane vs. through plane acquisition have a significant effect on quality of motion correction by way of reducing aliasing and interpolation artifacts during reslicing.

Methods:

Datasets were acquired using a spherical, susceptibility phantom containing tissue mimicking material [3] and undergoing a computer-controlled, precise and repeatable through plane saw-tooth motion routine with maximum angular displacement of ~5 degrees. A constant volume was imaged using a 4mm center to center slice spacing and increasing slice thickness so that the overlap was 0%, 50% and 75% of the slice spacing. We acquired GRE forward spiral images using a rectangular slice profile (windowed sinc excitation pulse) and Gaussian profile with all other acquisition parameters identical for the two separate acquisitions. We also acquired another set of coronal (in plane motion) and axial (through plane [in slice select direction] motion) images with both rectangular and Gaussian slice profiles to compare in-plane versus through-plane motion correction quality. 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. Images were motion corrected using FSL [4], and the realigned images were subtracted from the reference image, the average of first three 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. Thus, the higher the change in NRMSE indicates more complete motion correction.

Results:

As evident from fig. 1, a comparison of completeness of motion correction using change in NRMSE post motion correction, the in-plane (coronal) acquired images show a significantly (~ 25%) greater NRMSE reduction, indicating more complete motion correction, compared to the dataset acquired with dominant component of motion in through-plane (axial). The quality of motion correction seem to correlate positively with slice overlap, with 75% slice overlap performing a more accurate motion compensation than 50% and 0% (0 slice gap) overlap respectively. The decrease in NRMSE post motion correction was ~22% higher for 75% overlap slices compared to zero-gap slice acquisitions (see fig 2). The use of Gaussian slice profile did seem to improve the quality of motion correction, although, the improvement was fairly small (see fig.3).



<u>Figure 1</u>: Comparison of in-plane vs. through- plane acquisition: inplane seems significantly better.

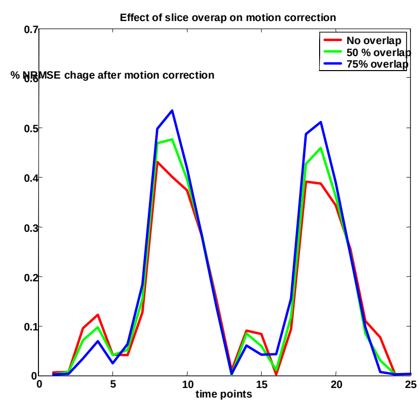


Figure 2: increasing slice sampling frequency improves motion correction

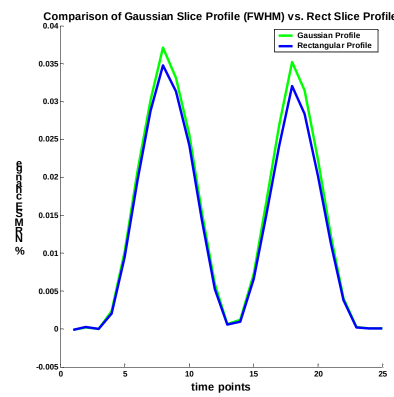


Figure 3: Gaussian slice profile performs better than rect profile in decreasing motion artifact.

Conclusion:

We found that motion correction is most effective when the dominant component of motion is "in-plane" compared to "through-plane". This is due to inherent under-sampling in the slice-select direction in most 2D planar acquisition, resulting in aliasing and interpolation errors during reslicing in through plane direction. If direction of motion is known apriori, one might be better off reorienting the acquisition plane. With increasingly overlapping slices i.e. increasing the sampling rate, the quality of motion correction improved significantly possibly due to decreasing contribution of aliased energy to interpolation error during reslicing. Gaussian slice profile with lower frequency content than the rectangular profile resulted in better motion correction.

References: [1] D. H. Wu, J. S. Lewin, and J. L. Duerk, J Magn Reson Imag. 7(2): p. 365 – 70, 1997. [2] D. C. Noll, F. E. Boada, and W. F. Eddy, MRM. 38:151-160, 1997. [3] J.C. Blechinger, E .L. Madsen and G. R. Frank, Med Phys, 15(4): p.629 – 36, 1988. [4] M. Jenkinson, et al. NeuroImage, 17(2): p.825—841, 2002.
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