Effect of Respiration on Motion Correction in fMRI

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Introduction: Motion correction is critical for data analysis of fMRI time series. Most motion correction algorithms treat the head as a rigid body. Respiration of the subject, however, can alter the static magnetic field in the head and result in spurious head motions[1]. The magnitude of the spurious head motions is around 0.1 - 0.2 mm. For short TR, this spurious head motion can be taken care of by a motion correction algorithm. For long TR (e.g. TR> 2.5 s) and interleaved acquisition, the interleaved slices have large phase differences in respiration and therefore the effect can be cancelled. It is not clear how big the effect of respiration is on Motion Correction in fMRI. To characterize the effect of respiration on Motion Correction, we acquired highly sampled fMRI data using multi-band EPI[2] and then simulated different acquisition schemes. Our results show that interleaved acquisition leads to larger between volume variations than ascending acquisition, suggesting a hybrid acquisition scheme is preferred.

Methods: We applied two methods to explore the effect of respiration-induced slice shifts on motion correction. The first method synthesizes images with large effective TR from fast sampled images; while the second method compares the motion correction of segmented volumes between ascending acquisition and interleaved acquisition. For the first method, we acquired 590 volumes using the multiband EPI (TR = 675 ms, 33 slices, 64×64 matrix). Then we combined every four consecutive volumes to form a new volume with an effective TR = 2700 ms. Two combination schemes were employed when combining the slices: ascending (in time order) and interleaved composite (Fig. 1), resulting a total of 147 images for each composite scheme. We also extracted 147 images from the original dataset by skipping every three images. The skipped dataset has the same effective TR of 2700 ms but much less respiration effect because the respiration was limited to the shorter period of image acquisition. All the data sets were exported to SPM8 (Wellcome Department of Cognitive Neurology, London, UK) for motion correction and reslicing. For the second method, we acquired 160 volumes of image using normal EPI with both ascending and interleaved acquisition (TR = 3 s, 33 slices, SLT = 3 mm, gap = .4 mm). We divided the slices into three segments, slice 1-11 as bottom segment; slice 12-22 as central segment; and slice 23-33 as top segment. All the segmented time series, along with the whole volume time series, were exported to SPM8 for motion correction and reslicing.

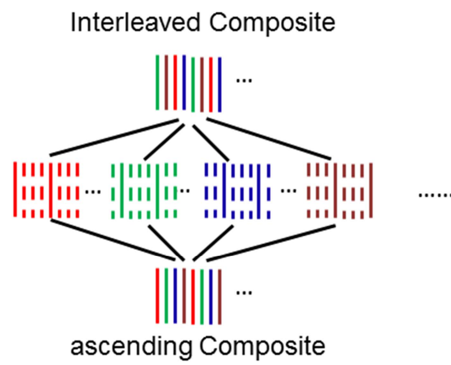

Fig. 1. Illustration of two combination schemes for method 1.

To characterize the noise, we took the difference between nearest volumes after motion correction and reslicing, and computed the standard deviation. The standard deviation was defined as 'noise' in this work, similar to the NEMA standard of noise quantification for MRI images. We avoided using temporal noise because the temporal noise is more affected by the intrinsic and slowly varying signal of the brain.

Result: After subtracting the noise obtained from the skipped dataset, the noise differences computed for the two combination schemes in method 1 are shown in Fig. 1. Although the difference of noise fluctuates across image indices, most of the values are above zero. Interleaved composition exhibits a higher difference than ascending acquisition, indicating that more cancellation of slice respiratory phases within an image volume tends to have higher noise after motion correction. Fig. 3 shows that for ascending acquisition there is an advantage in reducing noise by grouping slices into physically adjacent segments and doing motion correction separately. This is probably because the slices within each segment are acquired around the same time. As a result, the advantage diminishes for interleaved acquisition because slices within each segment are acquired TR/2 apart, which has little difference from the whole volume.

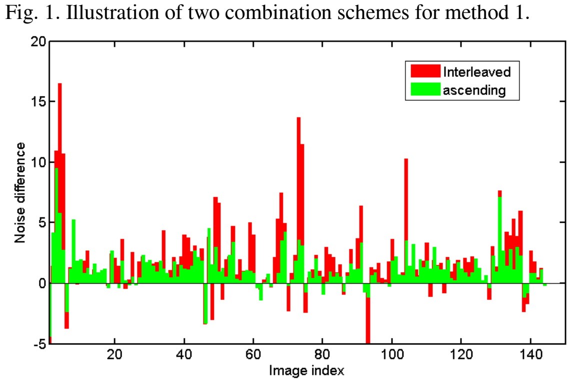

Fig. 2. Difference of noise (minus noise of skipped dataset) for interleaved and ascending combination schemes in method 1.

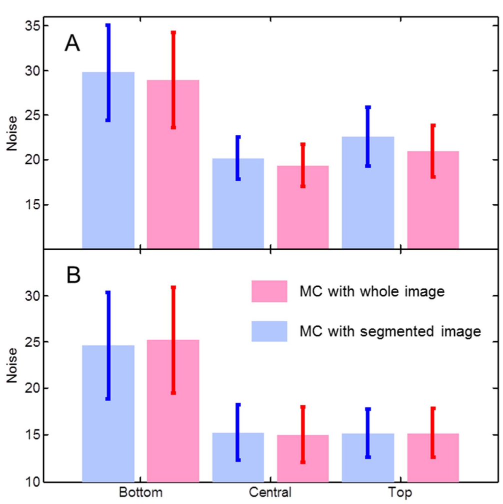

Fig. 3. Noise for three segments (bottom, central, top) from motion correction of whole images (light pink) and separate motion correction (light blue) for ascending acquisition (A) and interleaved acquisition (B).

Discussion: Our results from two different methods confirmed that respiratory noise can degrade motion correction. To reduce the respiratory noise in motion correction, an ascending-interleaved acquisition is preferred, i.e., there slices are segmented in sequential order while adopting an interleaved fashion in each segment.

References: 1. Raj D. et al., Phys Med Biol 2001;46:3331–40. 2. Moeller S. et al., Magn Reson Med 2010;63(5):1144-1153.

Acknowledgment: We thank Dr. Essa Yacoub for sharing the multiband EPI sequence.