Slice-by-slice prospective motion correction in EPI sequences

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Target Audience: Researchers using EPI based sequences (BOLD/diffusion) who are concerned with motion artifacts.

Purpose: Recent research has shown that head motion can cause spurious group differences in functional[1-3] as well as structural[4] connectivity analyses. These differences persist even in the presence of compensatory retrospective techniques (such as volume-based retrospective motion correction and regression of motion estimates). Both analysis techniques rely on MRI data acquired with an echo planar imaging (EPI) readout. This abstract examines slice-by-slice prospective hardware motion correction in EPI based sequences in order to mitigate such spurious group differences.

Methods:
A system designed for interventional-MRI tool tracking (Endoscout; Robin Medical, Baltimore MD) has been repurposed to track head motion. A sensor, which consists of 3 orthogonal pairs of parallel coils, is attached to the subject's head. The sensor′s position can be inferred by using the scanner′s gradients to create a time-varying magnetic field across the sensors which induces an electric potential in each coil. The system is programmed to detect three triangular gradient waves – one on each gradient axis – played with a slew rate of 60mT/m/ms and a total duration of 1.5ms. This sub-block can be inserted into a sequence and the resulting sensor position can be queried from the tracker's server. We have inserted these tracking blips into a diffusion sequence immediately after the EPI readout and query the server for the updated position before the slice selective excitation pulse (see Figure 1).

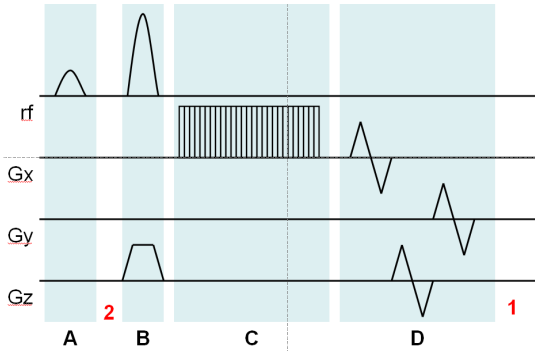

Figure 1: Timing diagram (not to scale) for an EPI readout augmented with Endoscout excitations. A: Non selective FatSat pulse, B: RF excitation, C: EPI readout, D: Endoscout excitation. After the endoscout excitation, we query the endoscout server (1) and update the imaging coordinates accordingly before the next excitation (2)

Results:
We have tested the diffusion sequence on a 3T Tim Trio (Siemens Healthcare, Erlangen, Germany) using the product 32-channel head matrix. The sensor was affixed to the subject's forehead using a headband. Two conditions were considered: one with the prospective motion correction applied, and one without. In both conditions, the subject was instructed to make a discrete movement once every 30s. Each diffusion sequence employed 6 directions with a b-value of 700. Each direction was acquired 8 times, and the average tSNR was computed on each direction independently, before being averaged together. All diffusion sequences had a 9910ms TR, 90° flip angle, 88ms TE, 64 slices, 1396 Hz/px bandwidth and an in-plane imaging matrix of 128x128. The mean tSNR was **10.4** in the prospective motion correction condition and **4.81** in the no correction condition. Sample tSNR maps are illustrated in Figure 2.

Discussion:
Slice-by-slice motion correction offers the potential to significantly mitigate spurious artifacts in structural and functional connectivity analysis, which could aid to further understand various neurological disorders. This potential is especially noteworthy in diffusion, where there currently are no commonly available techniques to prospectively compensate for motion. There are however, still several issues to overcome including ensuring the sensor is properly affixed to the patient so that it moves rigidly with the skull, filtering the sensor data to separate actual motion from sensor noise and mitigating sensor bias.

References
1. Power, J.D., et al., *Spurious but systematic correlations in functional connectivity MRI networks arise from subject motion*. Neuroimage, 2012. 59(3): p. 2142-54. **2.** Van Dijk, K.R., et al., *The influence of head motion on intrinsic functional connectivity MRI*. Neuroimage, 2012. 59(1): p. 431-8. **3.** Satterthwaite, T.D., et al., *Impact of in-scanner head motion on multiple measures of functional connectivity: relevance for studies of neurodevelopment in youth*. Neuroimage, 2012. 60(1): p. 623-32. **4.** Yendiki, A. et al., *Spurious group differences due to head motion in a diffusion MRI study*, Neuroimage, Accepted, 2013.

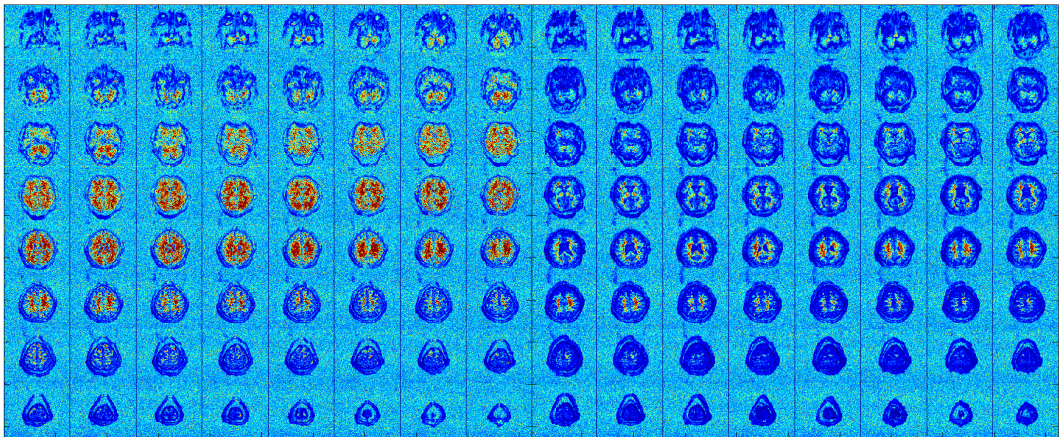

Figure 2: Sample tSNR maps computed from multiple acquisitions of a single diffusion direction. Left: With prospective motion correction, Right: Without

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