Optimized physiological noise correction for 3D EPI time series

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Introduction 2D EPI is the most commonly used technique to detect signal fluctuation due to brain activity. 3D EPI usually exhibits higher image SNR than 2D EPI but is also more sensitive to physiological noise, which leads to a reduction in signal stability and therefore in BOLD sensitivity [1, 2]. As a result, the use of 3D EPI has so far been limited. A number of published techniques [3,4] effectively correct for physiological noise in 2D EPI time series, leading to increases in the temporal stability (tSNR) of the fMRI runs. In this work, we present a method adapted and optimized for physiological noise correction of 3D EPI time-series, which significantly increases the tSNR and improves 1.5 mm high resolution fMRI at 3T.

Methods **Image acquisition:** 2D and 3D EPI time-series were acquired on 3 subjects on a 3T Tim Trio whole-body system (Siemens Healthcare, Germany), operated with RF whole-body transmit and 32-channel receive coils. Parallel imaging with acceleration factor R=2 was used along the phase direction. A fully sampled volume and a noise volume were acquired prior to the image scans and used for the reconstruction of the undersampled images with a home-written implementation of SENSE [5]. The size of the reconstructed images was 128x128 in plane. Acquisition parameters: TE=33ms (3D)/36ms (2D), TR per partition/slice =80ms (3D)/85ms (2D), 36 (3D)/ 32 (2D) slices, image resolution: 1.5x1.5x1.5 mm^3. 100 volumes were acquired in each run and the total acquisition time was 5min 46s. **Physiological noise correction:** During scanning peripheral measurements of subject pulse and breathing were performed together with scanner slice synchronisation pulses. The cardiac pulse signal was measured using a pulse oximeter attached to the subject's finger. The respiratory signal, thoracic movement, was monitored using a pneumatic belt positioned around the abdomen close to the diaphragm. Physiological signal was processed using a Matlab toolbox described in [6]. Models for cardiac and respiratory phase and their aliased harmonics were based on RETROICOR [3] and a similar, earlier method [4]. Basis sets of sine and cosine Fourier series components extending to the 5th harmonic for the cardiac phase and 3rd harmonic for the respiratory phase were used to model the physiological fluctuations. The result was sampled at a reference slice in each image volume to give a set of values for each time point. The reference slice was set to the central slice of the imaging volume for the 2D EPI runs. For the 3D EPI runs, the optimal reference partition was determined by comparing the tSNR for all possible reference partitions.

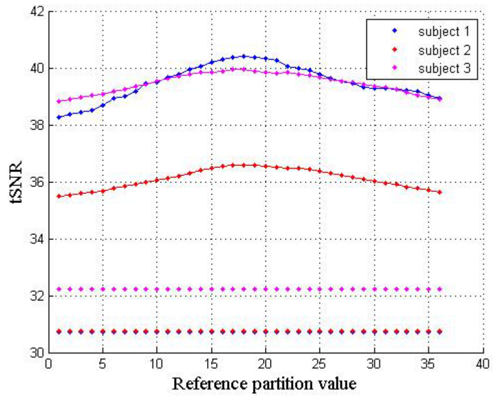

Figure 1. Changes in tSNR when different reference partitions are used in the physiological correction. Solid /dotted lines are corrected/uncorrected tSNR values (2 doted lines are overlapping at tSNR~31).

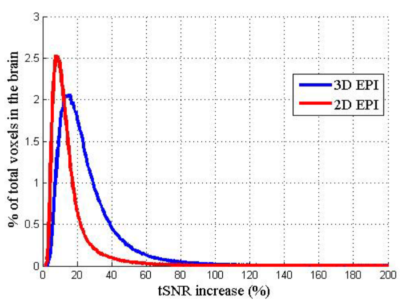

Figure 2. Improvements in tSNR values due to physiological correction.

Results Figure 1 represents brain averaged uncorrected (dotted lines) and corrected (solid lines) tSNR values from the 3D runs when different reference partitions are used in the physiological correction. tSNR values are maximum for the centre partition (#18) for all subjects. Figure 2 is a histogram of tSNR increase due to physiological noise correction averaged over all subjects. The voxel wise average improvement is 16% for the 2D EPI and 26% for the 3D EPI. Figures 3a) and 3b) represent tSNR maps before and after correction for a typical 3D EPI run. The improvement due to the physiological noise correction is shown in figure 3c). Figures 3 d-f) shows the equivalent as figures 3 a-c) for the 2D EPI sequence.

Conclusion The correction of physiological noise in fMRI time series leads to higher tSNR improvements for 3D EPI than for 2D EPI, particularly in cortical brain regions. Here we show that the corrected absolute tSNR values were ~25-90 for 3D EPI versus ~15-80 for 2D EPI, indicating that 3D EPI is a promising method for the study of brain activity at 1.5 mm resolution at 3T when an appropriate noise correction method is used.

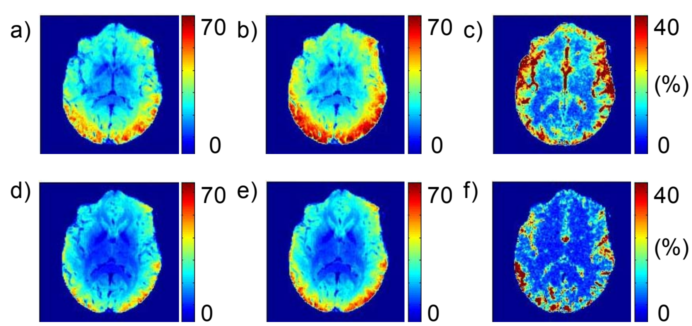

Figure 3. 3D EPI: uncorrected (a) and corrected (b) tSNR maps, (c) tSNR increase due to the physiological correction. d-f) same as a-c) for 2D EPI

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