Physiological Noise Correction with Increasing Acceleration in SENSE-EPI

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Introduction: Accelerated Parallel Imaging techniques such as SENSE (1) show great promise in many areas of MRI, including BOLD-fMRI. A potential draw back for MRI techniques, especially fMRI is the loss of SNR with increasing acceleration factor (R). Krüger et al. (2) postulated that the variance in an EPI time series is the sum of the intrinsic variance and the physiological induced variance. For SENSE-EPI data de Zwart et al.(3) extended this description of the noise to Eq. 1 Where σ_t^2, σ_{ph}^2, and σ_i^2 are the temporal, physiological and intrinsic variances, respectively, and g is the SENSE geometry factor (1). Hu et al. proposed a retrospective method for reducing two principle components of the physiological noise. The respiratory and cardiac cycles are simultaneously monitored during the EPI acquisition, then a fitting procedure is used to remove modulations in the data caused by these sources (4). Eq. 1 indicates that as R, or g increases, σ_t^2, becomes more a function of σ_i^2 than σ_{ph}^2. This leads to the question of whether the retrospective correction of cardiac and respiratory noises is beneficial in SENSE data.

$$\sigma_t^2 = \sigma_{ph}^2 + Rg^2\sigma_i^2 \qquad [1]$$

Methods: To investigate the effect of retrospective physiological correction (RPC), EPI time series of four subjects were collected on a Varian Inova 4T (Varian Inc., Palo Alto CA.). A 4-channel dome-shaped "Duyn" array (Nova Medical Inc. Wakefield, MA) was used to collect the data. The accelerated images were reconstructed as described by Pruessmann et al. (1). Time series of 1000 volumes were collected with R= 1, 2, and 4. The full image matrix was 64x64 (20x20cm), with three 5mm slices. The R=1 data was 4-shot, the R=2 data was 2-shot, and the R=4 data was one shot. The shot to shot Tr was 53ms and Te/FA = 25ms/15° . In the R=1 and 2 cases, the slice segments were interleaved, in order to keep the T1 effects constant for all time series. For each time series, the variance of each pixel in the brain was calculated, both with and without RPC. Relative Variance maps were calculated using Eq. 2. In addition, an auditory fMRI experiment was collected on a separate subject. A four channel independent element array (Nova Medical Inc. Wakefield, MA) was used to collect R=1, 2, and 4 data sets with identical paradigms of 42, 5s, periods of human speech, separated by 15s periods of pink noise. 23 slice volumes were collected with volume Trs of 5.0, 2.5, and 1.25s respectively. The same segmentation was used as above, but without interleaving.

$$\mathrm{Re}\,lativeVariance(RV) = \frac{\sigma_{t,withRPC}^2}{\sigma_{t,withoutRPC}^2} \qquad [2]$$

Results and Discussion: Fig. 1 shows the RV maps for a sample slice from one subject. The dark grey spots in the R=1 RV map, indicate areas where RPC has significantly reduced the variance locally. This would be a reduction in the variance caused by the cardiac cycle in tissue close to a vessel. Since respiration modulation is a global effect, RPC corrections for respiration should yield an average RV of less than one. Table 1 shows that for the R=1 is well below 1. With increasing R, the amount of dark grey areas drop in Fig. 1, but are still visible in the R=2 case. Fig. 2 shows a plot of one readout line in the RV map (indicated by the arrows in Fig. 1). Three peaks well below 0.8 can be seen for the R=1. In the R=2 case, the peaks are still there, but reduced. In the R=4 case, for this line in the image, no improvement from the cardiac RPC can be seen. In Fig. 1 areas where RPC has helped in the R=4 case can be seen, but they are rare. Table 1 shows that across all subjects, there is no global improvement (respiratory correction) with RPC in the R=4 case, and only a small improvement in the R=2 case. All subjects showed significant local regions (cardiac) that were improved by RPC even with R=2. Figure 3 shows the results of the auditory experiment, for 1 slice through the auditory cortex, for R=1,2,&4. For R=1, there are clusters of activation recovered with RC (yellow pixels). For R=2, there are significant clusters of green pixels(excluded by RC) and scattered yellow pixels. For R=4, the overall number of activates voxels is substantially down, and there are only scattered voxels where RC had an effect.

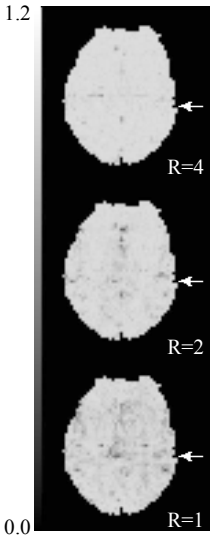


Fig.1. Example Relative Variance maps.

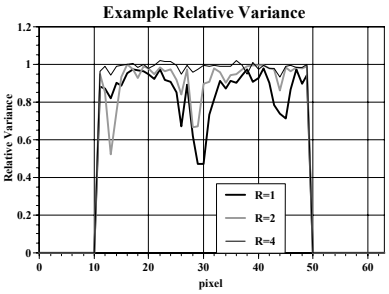
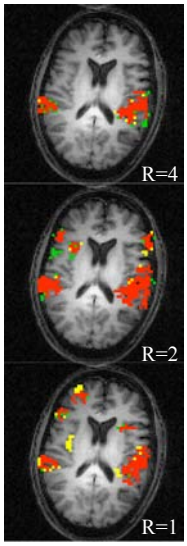


Fig.2. Comparison of single line from Relative Variance maps. The line is indicated by the arrow in Fig. 1.

Fig.3. fMRI results, yellow voxels, only significant after RC, green only before RC, red with or without RC.



Conclusions: We have shown that with increasing acceleration in sense-EPI, retrospective physiological correction becomes less effective. In the data presented here there is no apparent correlation between this loss of effectiveness, and the g-factor maps, however, depending on array configuration and slice orientation this may sometimes be the case.

Table 1
Average Relative Variance and g-factor

	Subject 1	Avg.(n=4)
R=1 Avg. RV	0.93	0.94
R=2 Avg. RV	0.97	0.96
R=4 Avg. RV	0.99	0.99
R=2 Avg. g	1.03	1.02
R=4 Avg. g	2.16	2.18

References:

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