fMRI at 7 Tesla with a Parallel Imaging reduction factor of four: A comparison of SENSE reconstruction methods.

Steen Moeller, Pierre-Francois Van de Moortele, Kamil Ugurbil

Center for Magnetic Resonance Research, University of Minnesota, USA

INTRODUCTION:

For high field strengths shorter T2* and distortion along the phase encoding direction due to ΔB0, necessitates the use of multi-segmented EPI. The need for multi-segment EPI can be circumvented with Parallel Imaging techniques to maintain the same spatial resolution, but sacrificing reduction of the SNR. For temporal imaging such a fMRI studies reduction factors of 2-3 are commonly applied. It is known that the reduction in temporal SNR is lower than the reduction in spatial SNR. Initially this was shown at 3T in [1], and more recently quantified in [2] for a reduction factor of 2. The degradation of images and/or temporal stability is used as selection criteria for what degree parallel Imaging can be applied successfully. The potential of parallel imaging is greater at higher field strength, since the coil sensitivities used to substitute gradient encoding are known to be less regular [3].

In a finger-tapping study, changes in statistical response and temporal signal profiles for one-dimensional reduction factor of 4 at 7 Tesla using a 16 channel head coil are investigated. A method (S-SENSE) for tracking small changes in the sensitivity profiles is evaluated and compared with T-SENSE [4], and a standard SENSE approach without updating the sensitivity profile.

METHODS:

Volunteers (with IRB approval) were asked to perform a self-passed finger tapping task employing 6 blocks alternating 30 sec. finger tapping of right hand and 30 sec. rest. The total duration was 6 minutes, giving 6 complete cycles. Multi slice 4-segment EPI sequences where acquired with a TR of 1.5 sec. (6 sec. for 4 segm.) and an in-plane resolution of 2 mm. The 4-segmented EPI sequence was considered the gold standard and SENSE were applied using only one segment from each 4-segmented image.

Three different SENSE based reconstruction techniques were used for un-aliasing the temporal series with 1-segment Reduced FOV;

- SENSE with no temporal update of the sensitivity profiles
- T-SENSE using a sliding window for temporal updating of the sensitivity profiles
- S-SENSE using a consistency method for updating the sensitivity profiles, such that the same segment from the 4-segmented EPI sequence can be used.

$$\min_{S_i}\left(\underbrace{\left\|(\vec{S}^{ref}-\vec{S}_i)\vec{P}^{unal}\right\|^2}_{\text{FOV fit}}+\lambda\underbrace{\left\|\vec{P}^{RFOV}-\left(\vec{S}_i\right)\left(\vec{P}^{unal}\right)\right\|^2}_{\text{RFOV fit}}\right)$$

To compare the statistical score in activation detection, <u>each</u> segment of the 4-segment series was un-aliased, and then the segments were averaged. Areas selected for evaluation were those for which the 4-segmented EPI sequence demonstrates response. Using both t-scores (using the plateaus of a box-car function) and cross-correlation (with a hemodynamic response functions) detailed comparison were evaluated.

RESULTS AND DISCUSSION:

The mean g-factor for a reduction factor of 4 with this coil is 1.4, and the statistical power for the un-aliased series should be reduced accordingly. The t-score for the segmented EPI is equal or slightly less than the averaged un-aliased EPI series, as shown in figure 1 (right), and is for the used ROI very similar for the different reconstruction methods. The t-score for an individual 1-segment un-aliased series is therefore equal or larger than 50% of the t-score from a 4-segmented EPI sequence. The impact of segmentation is not evaluated, and is the most likely source for the high SNR in the un-aliased series.

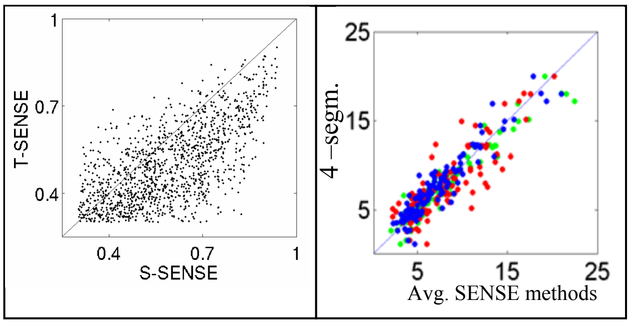

Figure 1: Left/ Comparision of crosscorrelation coefficients for two different temporal parallel imaging methods in an ROI with high t-scores. Right/ a comparison of t-scores from the 4-segmented series with the three different SENSE based Reconstruction methods.

Better overall temporal stability was observed when using the same segment repeatedly, indicated with higher cross-correlation values as in figure 1 (left). This difference can be reduced by introducing filtering with the T-SENSE method as proposed in [5] – but complicates a comparison. Also, it was observed that updating the sensitivity increases the t-scores as compared with not updating the sensitivity profiles.

REFERENCES:

[1] X. Golay MRM 2000 Jun;43(6):779-86.
[2] JA. de Zwart et al. MRM. 2004 Jan;51(1):22-6.
[3] F. Wiesinger et al. ISMRM 2002; p 191.
[4] P. Kellman. MRM. 2001 May;45(5):846-52.
[5] B. Madore et al. MRM. 2002;48(3):493-501.

ACKNOWLEDGEMENT:

MIND institute, Keck Foundation, NIH RR08079