FMRI at ultra high field (7T) with GRAPPA and SENSE

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Background: For functional imaging studies such as BOLD [1] the robust detection of very small temporal changes are essential for a successful representation of neural activation. The two common parallel imaging methods SENSE[2] and GRAPPA[3] are used routinely to achieve this goal. The acquired data are processed very differently and it is of interest to characterize what the differences are between the results from the two approaches.

Methods: Imaging experiments were performed on a 7 Tesla Magnet (Magnex Scientific, UK) equipped with Siemens Symphony/Harmony gradient amplifier (Erlangen, Germany) and a 16 channel head coil [4]. We utilized a multislice, multisegment Blipped Gradient Echo EPI sequence with TE = 20 ms and a flip angle of ~70 degrees in the center of slice (either 8 axial slices of 3 mm thickness or 5 axial slices of 5 mm thickness, Field of View (FOV) = 20 x 20 cm^2, matrix=128 x 128, nominal resolution in plane: 1.56 x $1.56mm^2$). fMRI data were obtained from normal volunteers performing a motor task (self paced finger tapping of right hand) employing 6 blocks alternating 30 sec. task and 30 sec. rest. The total duration was 6 minutes, giving 6 complete cycles. A 120 second acquisition during which the volunteers were asked not to engage in

activity was acquired as a baseline set. Each individual segment was reconstructed using both SENSE and GRAPPA. A total of 5 different time-series was generated with each method. Four of these were using a single segment repeatedly and one was the average of the 4 individual time-series - magnitude combined in image space. The auto-calibration signal lines (ACS) for GRAPPA were estimated from a single 4-segment acquisition at the end of each series. **Results and Discussion:** The relative temporal noise fluctuation σ_t from the baseline sets within an ROI in the center (with >1000 pixels) was calculated for GRAPPA when un-aliasing using an increasing number of ACS lines, and when using SENSE. The reconstructed static images were equal between SENSE and GRAPPA with 32 ACS lines. Averaged over 4 experiments and comparing a total of 19 slices, the noise in SENSE was 0.89±0.05 of that obtained using GRAPPA with a full set of ACS lines. Figure A shows how the noise decreases with increasing ACS lines. In the Primary Motor Cortex (PMC), where there is less than three fold aliasing, the average t-score of 130+ pixels was compared. SENSE exhibited an increase over GRAPPA of 1.08±0.05. Figure B shows the ratio of the average t-score from three different subjects each with multiple slices. The t-scores from SENSE have a pattern where the individual segments have higher t-scores than
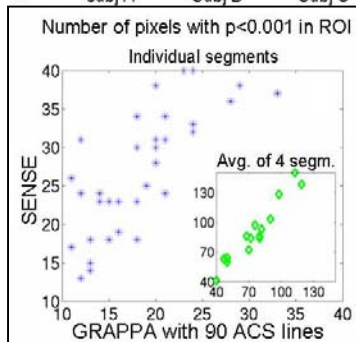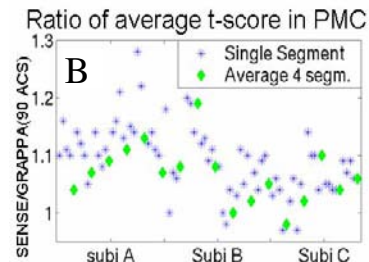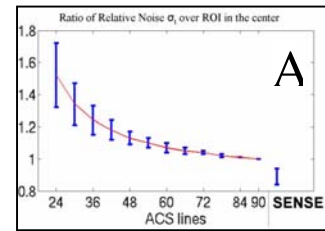
Fig A: Temporal noise as a function of ACS lines **Fig B:** The average t-score in the PMC of SENSE relative to GRAPPA reconstructed data. **Fig C:** Number of pixels with a p<0.001 from a SENSE versus a GRAPPA reconstruction.

GRAPPA, but when comparing the averaged GRAPPA and SENSE reconstructions the t-scores are less different. When comparing the number of pixels in the vicinity of the PMC that has a p-score of p<0.001, the averaged SENSE has 1.20±0.11 more activated pixels than GRAPPA (using 90 ACS), Figure C. This noise comparison indicates an issue inherent in a k-space reconstruction using limited calibration data (e.g. GRAPPA, PARS, GARSE, self-calibration) that the temporal noise suppression may be suboptimal. The data also indicates that there are different noise averaging processes taking place between SENSE and GRAPPA. The smaller increase in the number of pixels in the averaged GRAPPA vs. SENSE may be explained by GRAPPA having uncorrelated noise or by SENSE already having reached optimal SNR utilization so that averaging does not give a comparable improvement of σ_t or CNR.

References: [1] Ogawa Proc Natl Acad Sci U S A, 1992. [2] Pruessmann MRM 1999. [3] Griswold MRM 2002. [4] Adriany, MRM 2005 53(2) 434-45