Quantitative evaluation of Multi-channel fMRI at 7 Tesla with high 1–dimensional reduction factors

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Background: Functional imaging of the brain is a dynamic study that requires the detection of small signal changes in consecutively and rapidly acquired images. This task must be accomplished in the presence of unwanted signal fluctuations that occur due to physiological processes, instrumental instabilities, and subject motion. The most commonly used fMRI technique is based on the alterations of deoxyhemoglobin induced magnetic field gradients in the brain [1]. For this approach, high magnetic fields provide significant advantages, including higher contrast-to-noise ratio (CNR) and higher spatial accuracy of functional signals, e.g. [2]. To work with the shorter T_2^* multi segmentation acquisition are commonly used at the expense of temporal resolution. Alternatively, parallel imaging (PI) techniques can be employed by exchanging spatial SNR for higher temporal resolution. The impact on the CNR from a parallel acquisition is expected [2] to be dependent on the ratio between physiological and intrinsic noise, as given by Equation (1) with α=1, g the geometry factor and R the reduction factor. In comparison with existing neuro-physiological studies, additional benefits can be realized with the use of PI through the elimination of signal degradation due to segmented k-space acquisitions that is mandatory in high resolution and/or high field studies. Segmentation induced amplification of physiological fluctuations is modeled in this work with the parameter α>1 (Equation 1).

$$\frac{\text{t-score}^{SENSE,R}}{\text{t-score}^{fullFOV}} = \sqrt{\frac{(\alpha^2(\sigma_{Phys}^{SENSE}/\sigma_{Int})^2+1)}{((\sigma_{Phys}^{SENSE}/\sigma_{Int})^2+g^2R)}} \quad (1)$$

Methods: 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. Series of 4-segment/full FOV EPI images were acquired for all studies; the four segments together covered the full k-space and permitted the reconstruction of fMRI data without the use of parallel imaging. Each segment corresponded to a reduced field of view (FOV) acquisition that was used for SENSE [4] reconstruction with a reduction factor of 4. Maximum aliasing in the data were also 4. The 16 channel stripline coil [5] exhibited an average g-factor in the Primary Motor Cortex (PMC) of 1.2.

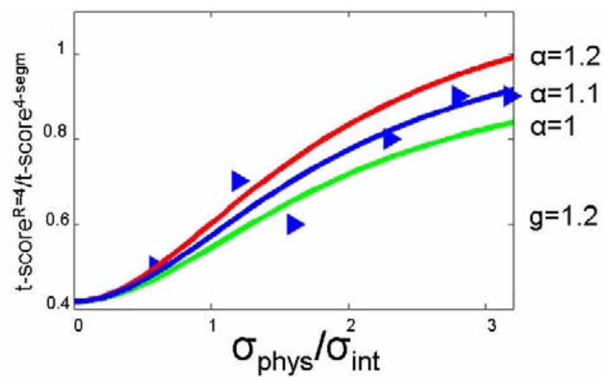

Fig 1: Reduction in statistical power for 1 segment relative to a full FOV 4 segment acquisition with 2 times the SNR.

Results and discussion

Using only ¼ of the data but reconstructed with parallel imaging, a reduction in the statistical significance of activation is expected. From an ROI in the PMC the t-score from 4-segmented acquisitions was compared with using just one of the four segments but un-aliased with SENSE. The change in statistical activation averaged over the four possible one-segment series was correlated with the physiological to intrinsic noise ratio (Fig.1). The obtained correlation is shown in figure one, where different α values are used to demonstrate the goodness of fit with the correlation predicted by (1), with α>1 providing the best result. These results demonstrate that the loss in spatial SNR from a parallel imaging reconstruction approach *consistently* does not result in an equal loss in CNR. Indeed the shorter studies that are possible with a multi-channel setup can even have better CNR than the longer multi-segmented studies. High resolution studies with larger thermal noise contribution benefits less from a parallel imaging acquisition, but the reduction in segmentation induced artifacts that is possible with a parallel imaging acquisitions is still a beneficial components for such studies.

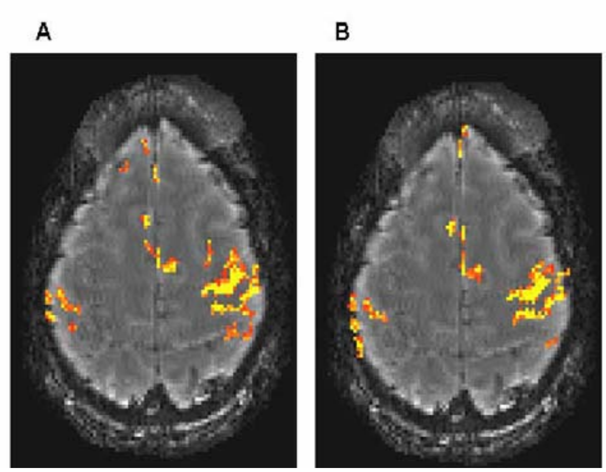

Fig2: A/ activation map from a SENSE time-series (R=4) using a quarter of the data from a 4-segment acquisition. B/ the activation map from the 4-segmented series. The 4-segment series has twice the SNR of the R=4 series.

References [1] *Ogawa* PNAS 1990, [2] *Yacoub* MRM 2003 [3]. *De Zwart J,* MRM. 2004 Jan;51(1):22-6. [4] KP. *Pruessmann and et al*. MRM, 42:952:962, 1999. [5] Adriany, MRM 2005 53(2) 434-45

Acknowledgement: Gregor Adriany, Peter Anderson, Johannes Ritter, Carl Snyder, John Strupp, Tommy Vaughan, Ute Goerke, Noam Harel, MIND Institute , KECK Foundation, NIH RR008079, NIH- R01 EB000895, NIH-R01 EB00473, NIH-PAR-02-010.