Optimal SENSE factor for BOLD fMRI at 3T

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Introduction: Due to the relatively low bandwidth per point in the phase encoding direction, echo planar imaging (EPI) is susceptible to spatial distortion, an effect that is seen to increase in images of the brain acquired at higher magnetic field strengths. This can be problematic if accurate spatial information is required, such as the location of areas of functional activation measured using blood oxygen level dependent (BOLD) functional MRI (fMRI). The growth in 3 T MRI systems, giving an increase in SNR compared to traditional 1.5 T systems, means high field MR scanners are increasingly available to groups performing fMRI studies. The bandwidth per point in EPI can be increased by using parallel imaging techniques, such as sensitivity encoding (SENSE), resulting in a decrease in both spatial distortion and acquisition time. However, the effect of EP images acquired using SENSE on the post-processing required for fMRI analysis has only been studied by a few groups at 1.5 T [1-3] and only briefly at 3 T [4]. These results suggest that a SENSE reduction factor (R) of around 2 may be optimal for fMRI studies at both field strengths.

We have performed a thorough investigation of variation of SENSE factor on fMRI activation from a simple block motor task acquired using nine volunteers using a 3 T MRI scanner. Increasing the SENSE factor reduces the number of echoes in the EPI readout block, reducing the acquisition duration for each slice, which in turn reduces the time taken to acquire each volume through the brain. Hence, increasing R allows more volumes to be acquired in a fixed time, which will affect the fMRI statistics. In order to separate the effect of increasing R on reducing spatial distortion alone compared to both reducing distortion and increasing acquisition rate, two experiments were performed. Firstly, R was increased while keeping the volume repetition time (TR) and inter-slice time constant (defined by the acquisition with R=1). Secondly, for each increase in R, the volume repetition time was adjusted to the minimum time.

Method: MRI was performed using a Philips 3 T Intera with an eight element phased array head coil. For all experiments, a gradient echo MBEST EPI acquisition was used, with 64x64 matrix size, 36 contiguous slices, 3.25x3.25x3.00 mm voxel dimensions, echo time (TE) of 30 ms, and flip angle 90°. Motor task instructions were presented using the IFIS-SA system (MRI Devices). Each experiment lasted four minutes and the same paradigm (pressing index finger and thumb, block design with 18 seconds of motor activity and 18 second rest periods) was presented throughout. Experiments were performed with R=1, 1.4, 1.7, 2.0. 2.3, 2.6, 2.9, and 3.2, to cover the range of previously published optimal SENSE factors. For R>1, the acquisitions were run twice, once with a fixed TR of 2.9 s and once with the minimum TR available for that R. The order in which the acquisitions were run was randomised between subjects. A high resolution T_1-weighted 3D FLASH scan was also obtained for each subject on which the activation could be overlaid. Postprocessing and analysis was conducted with SPM2 (www.fil.ion.ucl.ac.uk: motion correction, EPI distortion unwarping, normalization to an isotropic 3x3x3 mm with single floating point precision, smoothing with 8mm FWHM kernel).

Results: Results from the experiments with constant TR show little difference between different SENSE factors. Figure 1 shows a typical fMRI result from the experiment involving reducing the TR with increasing R. In this case, BOLD activation increases slightly up to R=2.3 and a more rapid linear decrease is seen at higher SENSE factors.

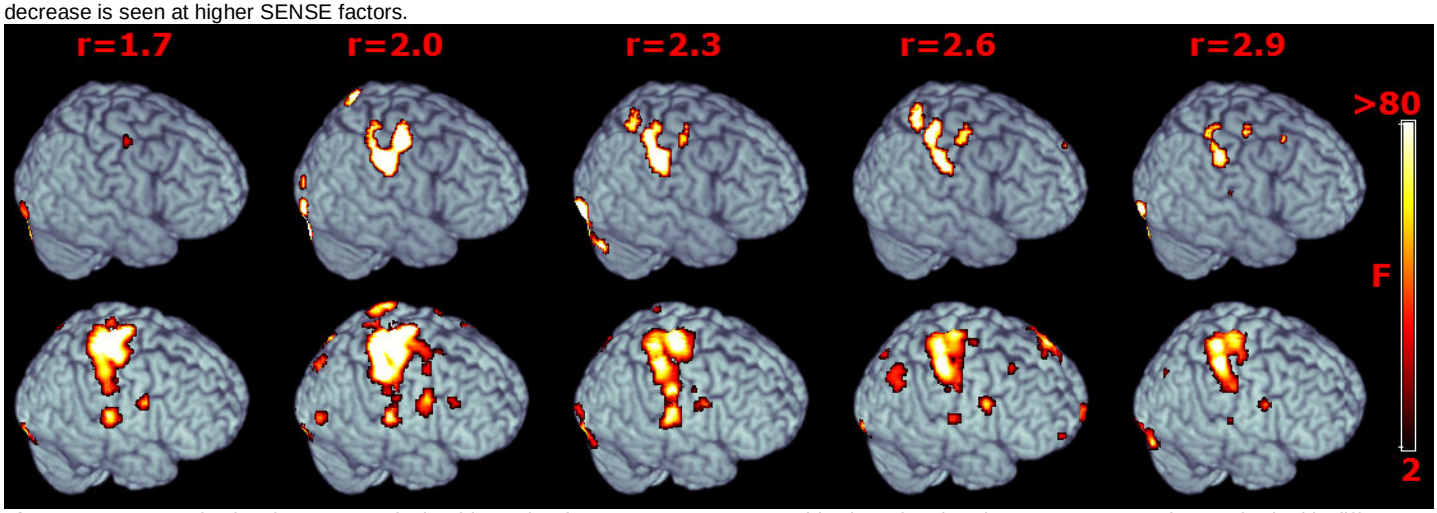

Figure 1. BOLD activation for a two typical subjects (each row represents one subject) performing the same motor task, acquired with different R values (1.7 to 2.9 shown in each column). Only activity within 12mm of cortical surface shown, renderings created using MRIcro (www.mricro.com)

Discussion: We have investigated the effect of varying SENSE factor on BOLD fMRI activation. Performing fMRI acquisitions with a fixed TR does not significantly affect the activation, suggesting that reducing the spatial distortion does not improve the BOLD response significantly for a 64x64 matrix at 3 T. This should be investigated at larger matrix sizes as in these cases spatial distortion might be expected to be more significant. The results from the minimum TR experiments suggest that the main advantage of using SENSE is to increase the number of volumes that can be measured in a fixed time. With a fixed TE around which the EPI readout is reduced with increasing R, the reduction in TR is more marked at lower SENSE factors. Our results suggest an optimum SENSE factor of just over 2 for fMRI studies at 3 T, in agreement with the results from other groups [4].

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