Combining Balanced Steady State Free Precession with Parallel Functional Imaging

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Introduction

Balanced steady state free precession (bSSFP) is a technique that has only recently has been applied to fMRI. It offers increased SNR and less sensitivity to the signal-dropout and distortion artifacts that can be suffered by gradient echo (GE) BOLD acquisitions in regions of non-uniform susceptibility such as the medial temporal lobe. bSSFP has been shown to be effective with functional imaging of the visual cortex [1,2]. The main drawback with bSSFP is its high sensitivity to B_0 inhomogeneities, resulting in "banding artifacts". Also, B_0 temporal instability, often referred to as "scanner drift", can degrade bSSFP functional images to a greater extent than with GE-BOLD. Meanwhile, parallel imaging improves the time resolution of functional imaging. This study compares passband bSSFP (pbSSFP) acquisitions with and without SENSE parallel imaging to investigate whether combining pbSSFP with SENSE is a viable option offering the advantages of each.

Methods

A standard flashing checkerboard paradigm was used in a block design. Each of 5 "on" blocks alternated with an "off" block, each taking 30 seconds. Each checkerboard image during an "on" block was displayed for 125 ms. Scanning was done with a Philips 3 T Intera, using the balanced fast field echo sequence to obtain 3D acquisitions. Before scanning started, a gradient-intense sequence was used on a phantom for at least 20 minutes to heat the gradient coils and reduce the scanner drift. Isotropic voxels of 2 mm were imaged, with a FOV of 240×240×60 mm^3. To ensure acquisition was in the passband, a flip angle of 30° was used, with TR=14 ms and TE=7 ms. Localised shimming of the visual area was done to minimise the B_0 inhomogeneities. For parallel imaging, a SENSE acceleration factor of 2.4 was used. This gave the parallel images a time resolution of 2.3 s/vol compared with the unaccelerated resolution of 5.1 s/vol. The total number of samples was comparable with both protocols, since the time saved from the reduced number of k-lines sampled with SENSE was used to measure more repetitions. Eight subjects were each stimulated with two runs of the paradigm – one using parallel imaging, the other not, with the protocol order randomized across subjects. Each run took 5 minutes. Analysis was done using FSL FEAT with 5 mm FWHM smoothing, $z>2.3$ and cluster correction $p<0.05$. A mask of the visual area was drawn manually from the anatomical images and this was applied to each subject to obtain region of interest statistics. Of the eight subjects, four were excluded – one felt discomfort, and three showed no activations with either protocol, possibly because of non-optimal shimming.

Results

Subject	Protocol	Mean z	Max z	# with z>2.3
1	Parallel	1.54	13.54	6261
	Standard	1.34	10.33	5371
2	Parallel	1.53	16.90	4966
	Standard	1.18	9.11	3370
3	Parallel	1.42	12.90	5183
	Standard	1.54	9.78	5892
4	Parallel	1.34	14.66	4190
	Standard	1.15	8.99	2634

Fig.1 shows that the bSSFP bands have been kept well away from the regions of interest, through the targeted shimming of this region. A summary of the z-score statistics for each subject in the selected region are tabulated above. Comparable images of the two protocols for the same subject are shown in Fig.1. The 95% confidence intervals for the difference of the means for these data are: *mean* (-0.09, 0.40); *max* (2.67, 7.23); *# voxels with z>2.3* (-1345, 3012).

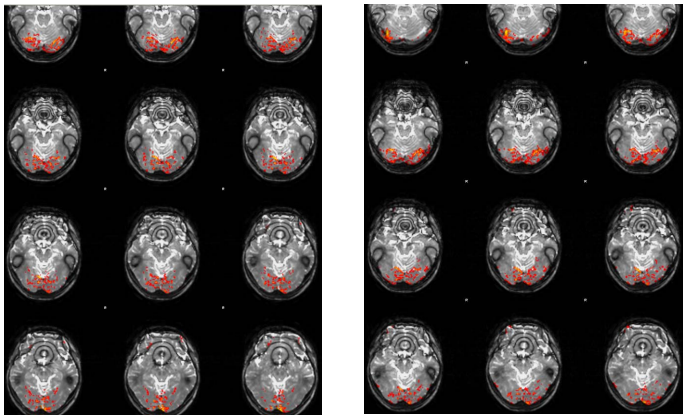

Fig. 1 Without SENSE With SENSE

Discussion

These results show quantitatively (Table) and qualitatively (Fig.1) that pbSSFP with SENSE is at least as sensitive as, and possibly more sensitive than, without SENSE. With all three measures of sensitivity – mean z, maximum z, and number of voxels above the threshold, the confidence interval for the difference of the means is strongly weighted towards the positive, indicating an increase in each case with SENSE. With the maximum z score, this increase is statistically significant. Such increased sensitivity could be explained if the temporal noise were dominated by physiological noise, and if the physiological noise were similar in the two acquisitions. Then, more functional CNR would be gained from the increased number of repetitions than would be lost from the reduced number of samples in each repetition, and an increase in the z-value of the SENSE protocol could be expected even in this block-design. That parallel imaging samples the response more densely might also contribute to improving its sensitivity. These results suggest there could be advantages in combining parallel imaging, with its decreased acquisition time, with pbSSFP, which has reduced susceptibility artifacts and 3D functional imaging. This could have important applications in event-related designs in high susceptibility gradient regions such as the medial temporal lobe.

References

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