Highly Accelerated EPI Evaluated for fMRI

Liyong Chen[1,2], An T Vu[1,2], Junqian Xu[3], Kamil Ugurbil[3], Essa Yacoub[3], and David Feinberg[1,2]

[1]*Advanced MRI Technologies, LLC, Sebastopol, CA, United States,* [2]*Helen Wills Neuroscience Institute, University of California, Berkeley, CA, United States,* [3]*CMRR, University of Minnesota, Minneapolis, MN, United States*

Introduction Multiplexed EPI, a type of simultaneous multi-slice imaging, utilizes multiband (MB) rf pulses and simultaneous image refocusing (SIR) to reduce the sampling TR of resting state and task fMRI [1-2]. Using *s* SIR refocusings and *m* images per MB excitation, the total number of images in each echo train is N=*s*×*m*. Here we evaluate different values of *s* and *m* with up to N=48 images per EPI echo train. Evaluations were quantified with temporal SNR (tSNR), BOLD CNR and movie-frame classification accuracy in fMRI studies.

Methods Subjects were scanned on a Siemens 3T Trio with a 32 channel coil. Parameters: resolution= 2.5 x 2.5 x 3 mm^3, TE=36 ms (for SIR *s*=2 the TEs are 36ms and 41ms; for SIR *s*=3, TEs 36ms, 41ms, 46 ms), whole brain coverage and controlled aliasing = FOV/4 shift [3]. RF duration was 5.2ms (for higher *m*, it is lengthened to up to 10ms due peak power limitations). The effects of *s* and *m* (*s*=1-3 and *m*=1-16) on tSNR (averaged across all voxels in slices acquired with TE=36ms) were evaluated on resting subjects while holding all other scan parameters constant at TR=500ms. Based on the tSNR results, accelerations were limited to N<=16 in subsequent BOLD evaluations. In visual stimulation studies, 5 subjects fixated while watching a 15s on 15s off 4Hz flickering checker board pattern 9 times per combination of *s* and *m*. In classification fMRI studies, recent developments enabled TE to be constant across SIR slices when *s*=2 [4]. Subjects fixated while watching a 36 second movie repeated 9 times per combination of *s* and *m* at near minimum TR. The information content of the resulting BOLD signals was measured using leave-one-repeat-out classification [5]. The number of possible frames for each N was 36 s / TR used.

Results Fig 1 shows increases in *s* and *m* factors generally decreased tSNR. However for constant N, *s*=2 generally has higher tSNR than *s*=1 especially for high total accelerations (N > 8). **Fig 2** shows better image quality with *s*2*m*8 than with *s*1*m*16. This is expected given g-values increase with *m* but not *s*. With s2, dropout is slightly worse due to longer echo train. **Fig 3** shows the comparison of the mean t-value and number of voxels with t>2.5 (p<0.01, uncorrected). **Fig 4** shows the number of time-points classified for acceleration factors 1 to 16 in the movie experiment. N=8-16 with *s*=2 (TR=300-600ms) gave the largest number of time points classified.

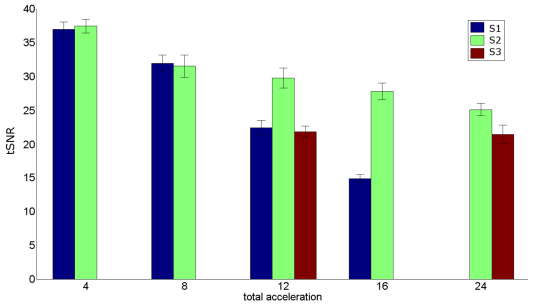

Fig 1. tSNR comparison of constant TR acquisitions after inter-subject analysis grouped by total acceleration factor.

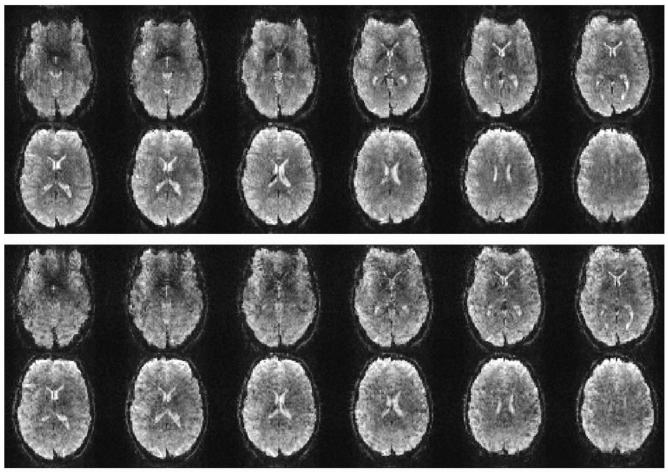

Fig 2. (**top**) s2m8 and (**bottom**) s1m16.

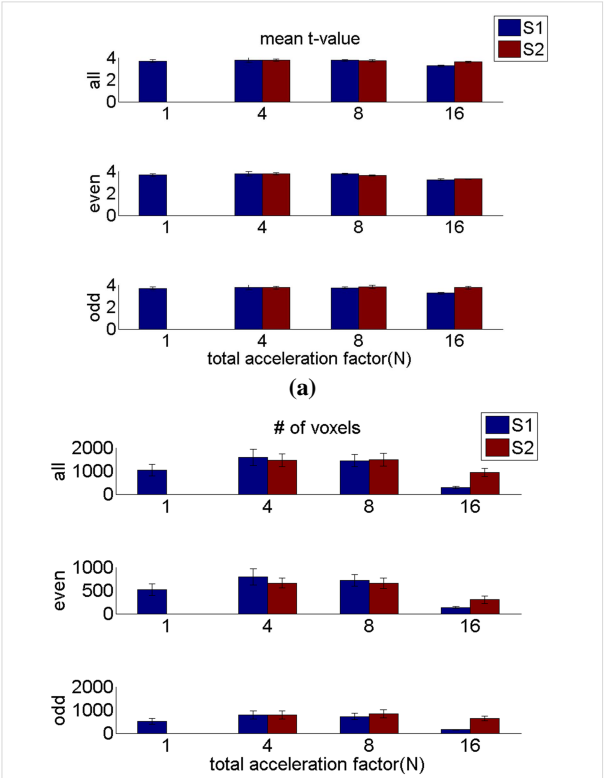

Fig 3. Mean t-value and number of voxels averaged across subjects in the visual stimulation experiment. **(a)** The mean t-value above the threshold of 2.5 for each acquisition. **(b)** The number voxels above threshold of 2.5 for each acceleration factor. SIR2 images have two TEs such that odd slices have longer TEs that results in higher BOLD contrast compared to even slices.

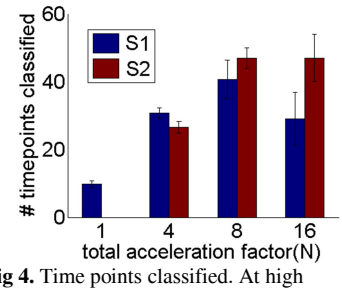

Fig 4. Time points classified. At high accelerations (N>=8), SIR 2 allows significantly more time points to be classified than with MB alone ($p < 0.05$).

Conclusion: For high accelerations, N>=8, multiplexed EPI with *s*=2 gave improvement over *s*=1 in terms of tSNR, BOLD CNR, and BOLD information content. TRs in the range of 600 – 300 ms resulted in the best performance in terms of single trial classification accuracy. These results suggest significant BOLD information exists at very high temporal frequencies and demonstrates the importance of highly accelerated EPI for fMRI and particularly for visual areas activated in this study. Future region specific evaluation of *s* and *m* are needed to address regional susceptibility differences. We expect the effects to be small given our recent implementation of ramp sampling for SIR used in this study.

References [1] Feinberg DA et al PLoS ONE, 2010.[2] Moeller S et al MRM 2010.[3] Setsompop K et al MRM 2012. [4] Vu AT et al ISMRM 2012. [5]Cox et al Neuroimage 2003, NIH-Human Connectome Project (U54MH091657), R44 NS073417, (first 2 authors made equal contribution)