MULTIBAND ECHO-SHIFTED (MESH) EPI FOR IMPROVED ACQUISITION EFFICIENCY OF T2* WEIGHTED EPI

David G Norris[1,2], Jenni Schulz[1], and Rasim Boyacioglu[1]
[1]*Donders Institute for Brain, Cognition, and Behaviour, Radboud University, Nijmegen, Netherlands,* [2]*Erwin L Hahn Institute, University Duisberg-Essen, Essen, Germany*

Target audience: MR physicists

Purpose

Multiband (MB) or simultaneous multislice (sms) imaging has greatly accelerated the acquisition of functional EPI data (1). However the sequence still contains some dead-time owing to the insertion of a delay necessary for the development of the required BOLD contrast. In the case of short echo trains and longer TEs this loss of efficiency can be significant. It was previously demonstrated that this loss of efficiency could be reduced by applying principles of echo shifting (2,3) however in previous applications of this technique either the echo train was too long for effective use with fMRI (4), or it was combined with the non-standard technique of inverse imaging (5). In this abstract we explore the application of multi-band echo-shifted (MESH) EPI as a potential tool for fMRI. To do this we utilise in plane acceleration in order to reduce the ETL to a minimum, combined with multi-band imaging to accelerate the acquisition along the slice direction.

Methods

Data were acquired using a 3T TimTrio system (Siemens Healthcare, Erlangen, Germany) equipped with a 32 channel head coil. Echo-shifting was implemented as shown in figure 1. After excitation the magnetisation is dephased by an additional gradient moment of nJP where n is the number of echoes shifted, and JP is the strength of the jump gradient. A GRAPPA factor of 3, and a multiband factor of 3 were used, with the MB pulses generated in the standard fashion. An isotropic voxel volume of 3.5mm was used on a 64x64 acquisition matrix and an acquisition bandwidth of 2520 Hz/pixel. Reconstruction of MB data was performed offline in Matlab using a SENSE/GRAPPA reconstruction (6). 12 multibanded slices were acquired giving a TR of 224 ms for whole brain coverage, and a TE of 12ms for n= 0 (i.e. reference data), and TE=30ms for n=1. The flip angle was set to 30. In order to minimise the inter-slice TR no fat saturation was performed. With this protocol the echo time can be incremented in steps of 18ms starting at 12ms without increasing the volume TR.

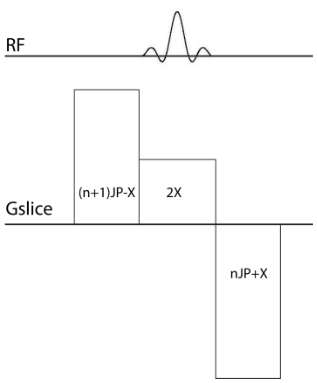

Figure 1. Echo shifting scheme: 2X is the total gradient moment for slice selection. The slice rephase gradient is reinforced by a moment nJP where n is the number of echoes shifted.

Results & Discussion

Figure 2 shows the TE 30ms data obtained with echo shifting in the top row, and for reference the TE 12 ms in the bottom row. The data quality is comparable to routinely obtained multiband imaging without echo shifting.

This technique is likely to be of advantage for relatively low spatial resolution acquisitions acquired at lower static magnetic field strengths. As the desired resolution increases so then will the ETL, and the in-plane acceleration factor necessary in order to achieve a reasonable TE will then have to be increased correspondingly. This will then lead to a reduction in the maximum useable multiband factor. For coarse resolution studies at for example 5mm isotropic resolution a volume TR in the range of 100ms will be attainable. The use of echo shifting means that all the slice data has to be acquired in rapid succession, but this can also be an advantage when performing language experiments, or combining the data with EEG acquisition. This variant of echo shifting has the advantage that the optimal flip angle can be used. The method will also improve from the application of blipped CAIPI, but again the CAIPI shift factor and the MB factor should not be multiples of each other (7). It was previously shown that the extra gradients required for shifting did not deteriorate image quality (4).

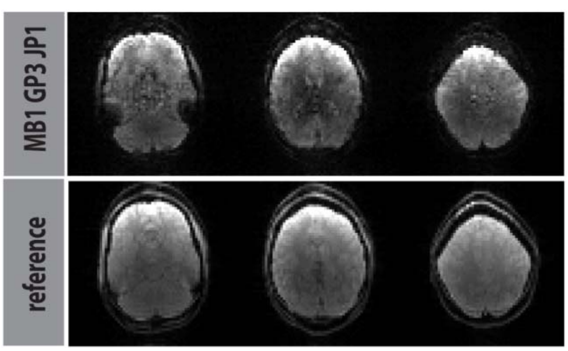

Figure 2. MESH EPI data are shown in the top row and reference data obtained using the same pulse sequence but no shifting in the bottom row.

Conclusion

MESH EPI will increase the efficiency of fMRI particularly at 1.5 and 3T. Application at 3T will roughly double the acquisition efficiency at standard spatial resolutions, and triple it at 1.5T.

References

1. Moeller S, Yacoub E, Olman CA, Auerbach E, Strupp J, Harel N, Ugurbil K. Multiband Multislice GE-EPI at 7 Tesla, With 16-Fold Acceleration Using Partial Parallel Imaging With Application to High Spatial and Temporal Whole-Brain fMRI. Magn Reson Med 2010;63(5):1144-1153.
2. Liu GY, Sobering G, Duyn J, Moonen CTW. A Functional MRI Technique Combining Principles Of Echo-Shifting With A Train Of Observations (PRESTO). Magn Reson Med 1993;30(6):764-768.
3. van Gelderen P, Duyn JH, Ramsey NF, Liu G, Moonen CTW. The PRESTO technique for fMRI. Neuroimage 2012;62(2):676-681.
4. Gibson A, Peters AM, Bowtell R. Echo-shifted multislice EPI for high-speed fMRI. Magnetic Resonance Imaging 2006;24(4):433-442.
5. Chang WT, Nummenmaa A, Witzel T, Ahveninen J, Huang S, Tsai KWK, Chu YH, Polimeni JR, Belliveau JW, Lin FH. Whole-head rapid fMRI acquisition using echo-shifted magnetic resonance inverse imaging. Neuroimage 2013;78:325-338.
6. Blaimer M, Breuer FA, Seiberlich N, Mueller MF, Heidemann RM, Jellus V, Wiggins G, Wald LL, Griswold MA, Jakob PM. Accelerated volumetric MRI with a SENSE/GRAPPA combination. J Magn Reson Imag 2006;24(2):444-450.
7. Setsompop K, Gagoski BA, Polimeni JR, Witzel T, Wedeen VJ, Wald LL. Blipped-controlled aliasing in parallel imaging for simultaneous multislice echo planar imaging with reduced g-factor penalty. Magn Reson Med 2012;67(5):1210-1224.