Evaluation of multi-echo multi-band EPI with ME-ICA denoising at 7T

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Introduction: For functional MRI the inherent physiological 'noise' can be divided into BOLD and non-BOLD related components which can be separated on the basis of the echo time (TE) dependence and independence [1]. The multi-echo (ME) technique offers a great opportunity for post-hoc cleanup of task and resting state fMRI data [2] while also improving the functional contrast-to-noise ratio (CNR) throughout the brain [3]. At the same time, it is highly desirable to increase the temporal resolution by using multi-band (MB) EPI to improve the detection of BOLD signal changes [4]. The logical next step is therefore to merge the benefits of the ME-EPI and MB-EPI techniques. Here we perform a systematic comparison of combined ME-MB-EPI with at different in-plane and slice acceleration factors at 7T for resting state fMRI.

MB	PE	TE [ms]	TR [ms]	Volumes
1	2	9, 26, 42	2740	130
1	3	7, 19, 31, 43	2640	136
2	2	9, 26, 42	1370	261
2	3	7, 19, 31, 43	1320	273
3	2	9, 26, 42	912	392
3	3	7, 19, 31, 43	879	410

Tab 1. Acquisition parameter sets for measurements with three echos (grey rows) and four echos (white rows).

Methods: Data were acquired on a Siemens 7T with 32ch head coil. Three subjects were scanned with six different ME-MB-EPI protocols as shown in Table 1. Common parameters were 2.5 x 2.5 x 2 mm^3 voxels, 0.5 mm gap, 42 slices, matrix 80 x 80, 6/8 partial Fourier, BW 2404 Hz/px, fixed scan time of 6 min. Fat saturation and FoV/2 slice shifts were used. Data were processed in the AFNI based ME-ICA toolbox [2] which included correction for spikes, motion and linear signal trends. Afterwards the ICA based multi-echo denoising was performed as described in Kundu et al [2] by regressing out components from the time series that exhibit a non-BOLD like behavior. Brain-extracted datasets were subsequently resampled to 2 x 2 x 2 mm^3 and aligned to MNI152 standard space in FSL. This allowed us to use a template of 10 resting state networks (RSNs) [5] as input for the dual-regression analysis [6] to obtain Z-maps that can be compared across the six different sequences. Mixture modeling was performed to correct Z-stats for residual autocorrelation. For every subject, RSN and sequence we extracted the maximum Z-score of the obtained statistical maps.

Results: In Fig 1 Z-map overlays of four commonly observed networks for each of the six protocols can be seen. Fig 2 (top) shows the median ratios between the two different slice acceleration factors and the non-MB sequence for three and four echoes. For MB-factor 2 these were 1.45 with GRAPPA 3 (4 echoes) and 1.23 with GRAPPA 2 (3 echoes) respectively. For MB-factor 3, the ratios were 1.4 with GRAPPA 3, and 0.98 with GRAPPA 2. Fig 2 (bottom) shows the median ratios between higher (4 echoes) and lower (3 echoes) in-plane acceleration factors for MB-1 with 0.71, MB-2 with 1.11 and MB-3 with 1.07.

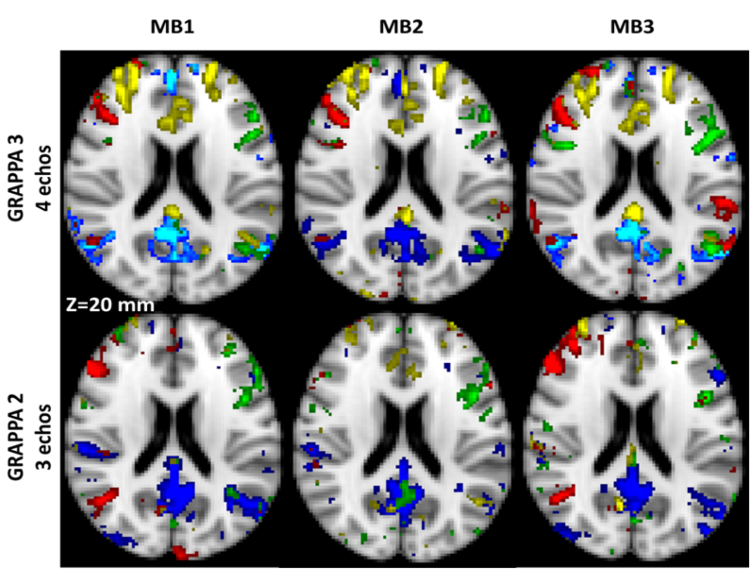

***Fig 1 (left)**. Four example RSNs in form of overlaid Z-statistic images with a thresholded at Z = 6 derived from subject 2 in MNI152 standard space. Blue: Default mode network; Yellow: Cingular opercular network; Red: Right frontal parietal control network; Green: Left frontal parietal control network.*

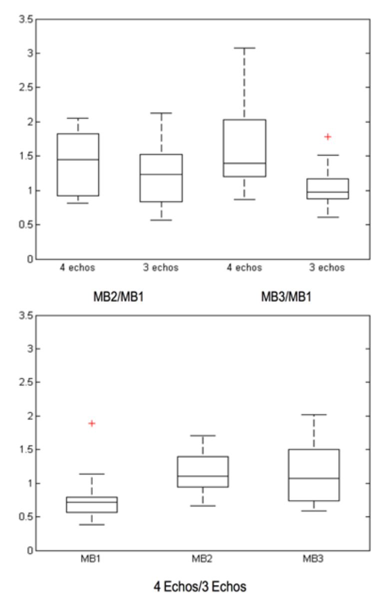

***Fig 2 (right)**. Boxplots over all RSNs and subjects for multi-echo and multi-band comparison.*

Discussion: The results indicate an overall better performance of the MB accelerated sequences when acquiring four echoes (GRAPPA 3) compared to three echoes (GRAPPA 2). This suggests that benefit of the tighter sampling of the BOLD response outweighs the g-factor noise penalty incurred by the higher in-plane under sampling factor. This is likely attributable to a more reliable separation of BOLD and non-BOLD components by the ME-ICA toolbox and also in qualitative agreement with the original reports on non-multiband multi-echo EPI in [3].

References: [1] Krüger G (2001). MRM 46(4), 631-637 [2] Kundu P (2012). NeuroImage 60, 1759-70 [3] Poser BA (2006). MRM 55, 1227-35 [4] Feinberg (2010). PloS one 5(12), e15710 [5] Smith SM (2009). PNAS 160, 13040-45 [6] Beckmann (2009). NeuroImage 47 (2009): S148.