Zoomed Resolution in Simultaneous Multi-slice EPI for fMRI

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Introduction High spatial resolution imaging with EPI has always been hampered by T2* decay of the echo train limiting the achievable spatial resolution. Resolution can be increased by "zoomed" approaches: outer volume suppression (OVS) utilizing saturation rf pulses, inner volume imaging with intersecting excitation and refocusing rf pulses in SE-EPI and parallel imaging (PI) which can be combined with the former two sequences. Recently the simultaneous multi-slice (SMS) technique has been used to reduce the scan time of multi-slice EPI [1-2]. To achieve high spatial resolution we introduce Zoomed Multi-Band Imaging (ZOMBI) which combines SMS EPI with OVS instead of GRAPPA to avoid g-factor increase found in prior works [3]. In fMRI the elimination of PI imaging will not only eliminate one source of g-factor penalty in SNR but also eliminate potential sources of phase drift, motion sensitivity and temporal noise. Here we evaluate ZOMBI with different MB acceleration factors, slice thickness and compare to SMS EPI with PI in plane undersampling.

Methods Experiments were performed in 4 normal volunteers on a 3T Siemens Trio scanner or 7T Siemens scanner with 32 channel phased array coil. The ZOMBI sequence was implemented with OVS using dual-band rf pulses that are composed of two skewed saturation pulses [4] right before the slice excitation pulse. The imaging parameters were as below: TR=1500 ms, TE=30ms, FOV =192x78mm2, image matrix=128x52, 36 slices, in-plane resolution=1.5x1.5 mm2 and slice thickness=1.5 mm or 2 mm. At 7T 16 slices with 100% gap were acquired with TR=3000ms to reduce SAR. The SMS was limited to MB=2 with FOV/2 or MB=3 slices with FOV/3 controlled aliasing [5]. The slice-GRAPPA reconstruction was performed with kernel size of 5. Four sequences were compared: ZOMBI (MB=2, resolution 1.5x1.5x2mm3, denoted as "M2"), ZOMBI (MB=2, resolution 1.5x1.5x1.5mm3, denoted as "M2(iso)"), ZOMBI (MB=3, resolution 1.5x1.5x2.0mm3, denoted as "M3") and SMS EPI (MB=2, in plane undersampling factor=2, FOV=192x192mm2, denoted as "M2P2"). Use of higher MB was limited by the reduced coil sensitivity covering the relatively closely spaced thin slices. 3T experiments used flashing checker, 3 sets of 30s on and 30s off repeated 3 times. The 7T paradigm was 8 Hz checker, 18 seconds on 18 seconds off. The t-test (degrees freedom=16) was used to generate the activation map. Different accelerations were compared based on the mean t-value and the number of voxels with t-value above 1.5 ($p<0.05$, uncorrected).

Results and Discussion The use of signal suppression in two parallel regions of brain prevented their aliasing into the central region of interest when using high spatial resolution on the phase encoded direction which exceeds the otherwise larger FOV. This "zoomed" SMS imaging achieved 1.5 mm isotropic resolution without the use of in-plane PI. The BOLD activation signals are shown in **Figs 1-2** with M2 having higher t-scores than MB3 and M2P2. The comparison of the mean t-value and number of voxels above the threshold of 1.5 are shown in **Fig 3**, with M2 having higher mean t-value and more voxels than M2P2. Compared to OVS EPI without SMS [6], the requisite number of OVS pulses is reduced and therefore the rf power deposition (SAR) is mitigated by sharing their effect with multiple simultaneously acquired slices and can be further reduced by using a singlebanded OVS pulse.

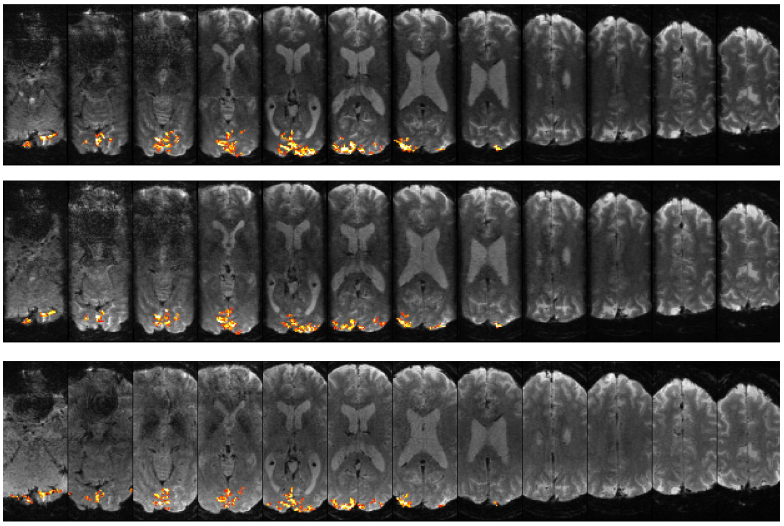

Fig 1 *MB2* **(top)** with higher t-score than *MB3* **(middle)** and *M2P2* (**bottom**). The *M2P2* images were cropped to compare here.

Conclusion Zoomed imaging combined with SMS EPI achieves high spatial resolution in both in-plane and slice axes while maintaining faster TR improving temporal SNR in fMRI studies. This obtainable high resolution is immediately useful for vision science research at 3T. With higher SNR and CNR provided at 7T and higher field magnets, this approach can be extended to sub-millimeter studies for detailed cortical specific fMRI research.

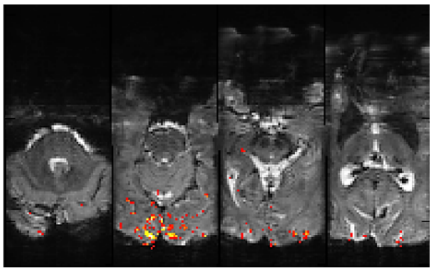

Fig 2 *MB-2(iso)* acquired on 7T.

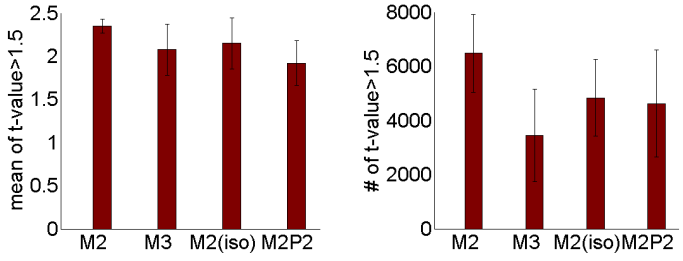

Fig 3 (left) mean t –value > 1.5 threshold **(right)** # of voxels above threshold.

References: [1] Feinberg DA et al Plos One 2010;5, e15710. [2] Moeller S et al MRM 2010;63:1144-53 [3] Breuer F et al MRM 20009 62:739-46. [4] Pfeuffer et al NeuroImage 2002;17:272-86. [5] Setsompop K et al MRM 2012;66, 1210-24 2012 [6] Heidemann R et al, MRM 2012; 6, 1506-16. Acknowledge: NIH R44 NS073417, 5R44NS63537 (first 2 authors made equal contribution).