An assessment of motion artefacts in multi band EPI for high spatial and temporal resolution resting state FMRI

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Purpose: Multiband (MB) echo planar imaging (EPI) is a recent MRI technique capable of acquiring multi-slice, whole brain FMRI data with sub-second temporal resolution. The technique employs MB pulses to simultaneously excite *n* non-contiguous slices which are then separated by utilizing spatial information in multi-channel receive arrays with parallel imaging reconstruction[1-4]. MB-EPI thereby acquires *n* images in each EPI echo train as opposed to the single image acquired by conventional "single-band" EPI, and therefore offers increased temporal and/or spatial resolution. Further, by increasing the temporal degrees-of-freedom, MB-EPI increases the temporal SNR, improving multivariate analyses such as independent component analysis (ICA). However, it is reasonable to expect MB-EPI to exhibit increased motion sensitivity due to the combination of short TR (spin history) and parallel imaging. In this study, the performance of MB-EPI with different acceleration factors was compared to that of standard EPI with respect to sensitivity to subject motion.

Protocol	Isotropic res. (mm)	MB factor	TR (s)	TE (ms)
MB-EPI	3	1	3	30
MB-EPI	2	1	6.1	36
MB-EPI	2	4	1.6	39
MB-EPI	2	8	0.8	40

Table 1: Scanning protocols used to acquire 15 min resting FMRI data with normal / bad subject motion

Methods: 6 healthy volunteers (both MRI naïve and MRI trained) were scanned on a 3T Siemens Verio scanner equipped with a 32-channel receive-only head coil array. Each volunteer was scanned on 4 occasions in order to compare 2mm MB with acceleration factors of 4 and 8 (MB4-2mm and MB8-2mm) with un-accelerated data at 2mm (MB1-2mm) and the "more conventional" 3mm resolution (MB1-3mm, with GRAPPA R=2) (Table 1). The complete protocol included resting and task conditions, but here we focus on resting-state data. All sequences used partial Fourier=7/8 and flip angle 90°. 15 minutes of resting FMRI data (eyes open) were acquired using each of the four protocols, under two conditions: **(i)** volunteers were instructed to remain still (normal motion), and **(ii)** volunteers were asked to make deliberate, realistic movements throughout the 15 minute scan (bad motion). MELODIC, the ICA tool in FSL[5], was used to identify and remove artefact components (ICA "clean-up"). Following alignment to MN152 standard space, all subjects' datasets were temporally concatenated for group-wise ICA (30 and 100-dimensional). Group-ICA spatial maps were dual-regressed into individual datasets to derive subject/session-specific spatial maps and associated timecourses[6]. The latter were used to derive session-specific network matrices[7]. Thus we could compare sensitivity and reproducibility of session-level RSN spatial maps and network matrices.

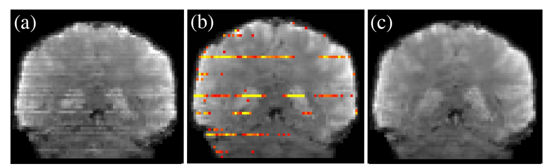

Fig. 1: ICA-based motion correction of multiband data **(a)** Sample MB4-2mm coronal slice pre "clean-up" **(b)** motion component identified by ICA **(c)** Post "clean-up" corrected data.

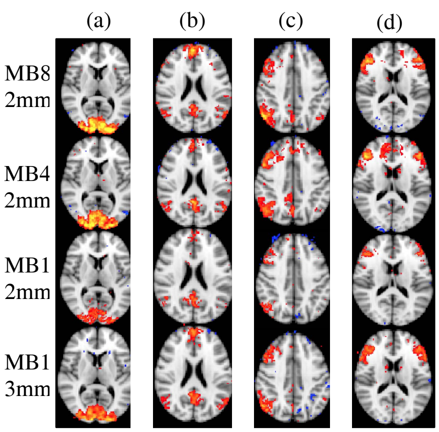

Fig. 2: Sample ICA components from post "clean-up", bad motion data.

Results: Figure 1 shows a sample coronal slice of MB4-2mm data resulting from a bad head motion resting FMRI run. The banding artefact present in Figure 1(a) indicates strong interaction of MB with motion. Figure 1(b) shows an ICA spatial map corresponding to motion-related artefacts. Figure 1(c) shows the same image post "clean-up". Normal head motion runs did not demonstrate this motion artefact strongly. In Figure 2, four sample RSNs (identified by 30-dimensional group ICA) from ICA-cleaned, bad motion data from each of the four protocols are shown. The results demonstrate a high level of agreement between the standard MB1-3mm protocol and both MB4-2mm and MB8-2mm. MB1-2mm performed worst in all cases. Figure 3 illustrates the similarity of the 100-dimensional group-averaged network matrices (full correlation below the diagonal, partial correlation above) between all four protocols. Normal motion, post "clean-up" data provided the highest similarity between both MB4-2mm and MB8-2mm and MB1-3mm (figure 3, black circles). High levels of head motion reduced correlations, but these were improved with ICA "clean-up". MB4-2mm vs MB8-2mm demonstrate slightly higher similarity than standard MB1-3mm with either MB4-2mm or MB8-2mm. Note that these results were acquired with 90^0 flip angle, which is expected to reduce signal in MB8-2mm by about 15% compared to imaging at the Ernst angle.

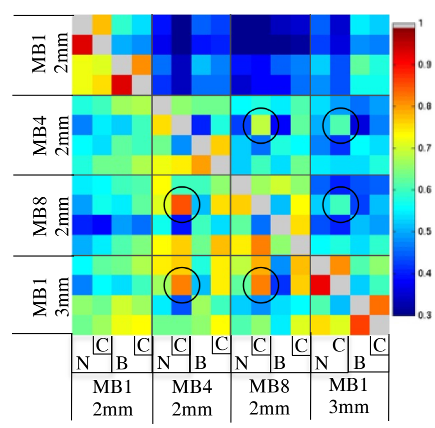

Fig. 3: Similarity of average network matrices (across all subjects) following 100-dimensional ICA (B=bad motion, N=normal motion, C=post "clean-up")

Discussion and Conclusions: Although MB-EPI exhibits some motion sensitivity, retrospective "clean-up" of the data using ICA is remarkably successful at removing artefacts. By increasing temporal degrees of freedom, accelerated MB-EPI supports higher spatial resolution, in our case with no loss in statistical significance compared to the standard protocol. In summary, accelerated MB-EPI is an important new MRI technique capable of providing high resolution, temporally rich resting FMRI datasets for more interpretable mapping of the brain's functional networks. *Funded by the NIH Human Connectome Project (1U54MH091657- 01), NIH Grants P30 NS057091, P41 RR08079/EB015894 (Ugurbil) and EPSRC (Miller).*

References: **[1]** Moeller, et al. *MRM* 2010; 63: 1144-1153. **[2]** Feinberg, et al. *PLoS One* 2010; 5(12): e15710. **[3]** Setsompop, et al. *MRM* 2012; 67(5): 1210-1224. **[4]** Larkman, et al. *JMRI* 2001; 13(2): 313-317. **[5]** Beckmann & Smith. *IEE TMI* 2004; 23(2): 137-152. **[6]** Filippini, et al. *PNAS* 2009; 106(17):7209:7214. **[7]** Smith, et al. *Neuroimage* 2011; 54(2): 875-891.