Investigating Resting-state Functional Connectivity Using Passband bSSFP

Joe S Cheng[1,2], Iris Y Zhou[1,2], Patrick P Gao[1,2], Russell W Chan[1,2], Queenie Chan[3], Henry Ka Fung Mak[4], Pek Lan Khong[4], and Ed X. Wu[5]
[1]*Laboratory of Biomedical Imaging and Signal Processing, The University of Hong Kong, Hong Kong, Hong Kong,* [2]*Department of Electrical and Electronic Engineering, Hong Kong, Hong Kong,* [3]*Philips Healthcare, Hong Kong, Hong Kong,* [4]*Diagnostic Radiology, The University of Hong Kong, Hong Kong, Hong Kong,* [5]*The University of Hong Kong, Hong Kong, SAR, China, Hong Kong*

INTRODUCTION: Resting-state functional MRI (rsfMRI) using blood-oxygen-level-dependent (BOLD) contrast has become increasingly useful for functional connectivity in normal and diseased brains[1]. To date, most rsfMRI studies have exploited blood oxygenation level-dependent (BOLD) contrast using T2*-weighted gradient-echo (GE) echo planar imaging (EPI) [2], which suffers from signal dropout and image distortion due to magnetic susceptibility and inherent long TE. Recently, T2/T1-weighted passband balanced steady-state free precession (bSSFP) was promoted for distortion-free, high spatial resolution task based functional imaging providing contrast in parenchymal regions near small vessel [3, 4]. In this study, we aim to explore the feasibility of bSSFP for rsfMRI study as an alternative to GE-EPI.

METHODS: Participants: Six right-handed subjects (F/M=3/3, median age =24 yrs) took part in the study. **Data acquisition:** MRI was performed on a 3T scanner (Achieva Philips) with an 8-channel SENSE head coil. **(1)** To examine its capabilities, for one subject one GE-EPI and three bSSFP sessions were acquired at identical spatial resolution (3.75 x 3.75x5 mm^3 and temporal resolution as 3 s, number of dynamic scans =100). To this end, the parameters for bSSFP were: NSA=12, TR/TE=4.0/2.0 ms, FA=30^o and for GE-EPI: TR/TE = 3000.0 /70.0 ms, FA=90^o, NSlice=33. Each bSSFP session imaged one slice intersecting either parietal frontal, visual cortex or motor cortex. **(2)** To test its reproducibility, another 4 subjects went through 2 sessions of bSSFP covering motor cortex and 2 covering visual cortex. **(3)** To take its advantage of distortion-free, one bSSFP and one GE-EPI were acquired covering prefrontal cortex (PFC) in a coronal view. **Data analysis:** Data analysis was carried out using FSL 4.1.7 (www.fmrib.ox.ac.uk/fsl). Preprocessing included motion correction, skull removal, spatial smoothing with 5mm, deletion of the first 5 volumes and high-pass filtering with a 0.01Hz cutoff. Single session ICA implemented in MELODIC v3.10 was employed [5]. The number of network components was set as 35 given that the largest number automatically estimated for bSSFP was 36.

RESULTS: Fig 1 illustrates five typical RSNs maps derived from bSSFP and GE-EPI datasets [2, 6]. The bSSFP RSNs' spatial extents are better localized to grey matter, while the spectral distribution of both methods concentrated on low frequency (< 0.1Hz). Fig 2 shows reproducible b-SSFP RSNs in different subjects, representing medial visual, occipital and lateral visual and motor cortex network. For each RSN, the averaged power spectrum of the ICs' time courses constrained to low frequencies (<0.1Hz). Additionally, bSSFP exhibits less signal void and distortion in prefrontal cortex than GE-EPI (Fig. 3a) and thus ventral medial PFC is identified (Fig. 3e). Left, right and medial PFC networks are as well detected (Fig. 3b-d).

DISCUSSIONS AND CONCLUSIONS: This study has demonstrated the ability of passband bSSFP to study resting-state functional connectivity. RSNs spatially and temporally similar to those derived from traditional GE-EPI can be reproducibly detected. Although the mechanism the passband bSSFP contrast is not fully understood, our results indicated that resting-state passband bSSFP detects BOLD fluctuation as does in GE-EPI or SE-EPI [3]. The power spectrums of the bSSFP RSNs are predominant below 0.1Hz, in line with most literature. Furthermore, being distortion- free, bSSFP has the advantages of revealing RSNs in areas near air sinus such as ventral medial PFC, a key structure in decision making and moderating social behavior[7, 8]. With inherited short TR, b-SSFP can be combined with 3D imaging trajectories. Future study extending to high-resolution 3D b-SSFP remains to be done allowing for normalization across subjects and more resistant to blood flow and motion artifact.

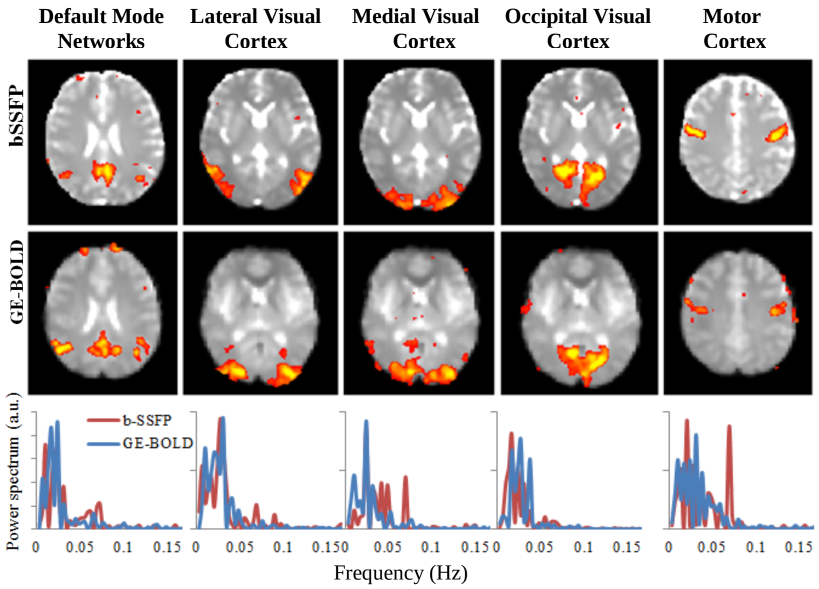

Fig. 1: ICs representing RSNs derived from b-SSFP and GE-BOLD datasets, with

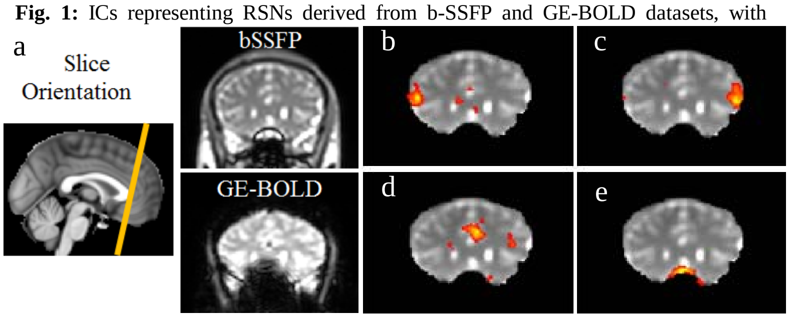

Fig. 3: Raw bSSFP and GE-BOLD images of a coronal slice intersect the prefrontal cortex (PFC) (a); bSSFP ICs representing left PFC (b), right PFC (c), medial PFC (d), and ventral medial PFC (vmPFC) (e). Due to less signal void and distortion in prefrontal cortex than GE-EPI thus vmPFC is identified.

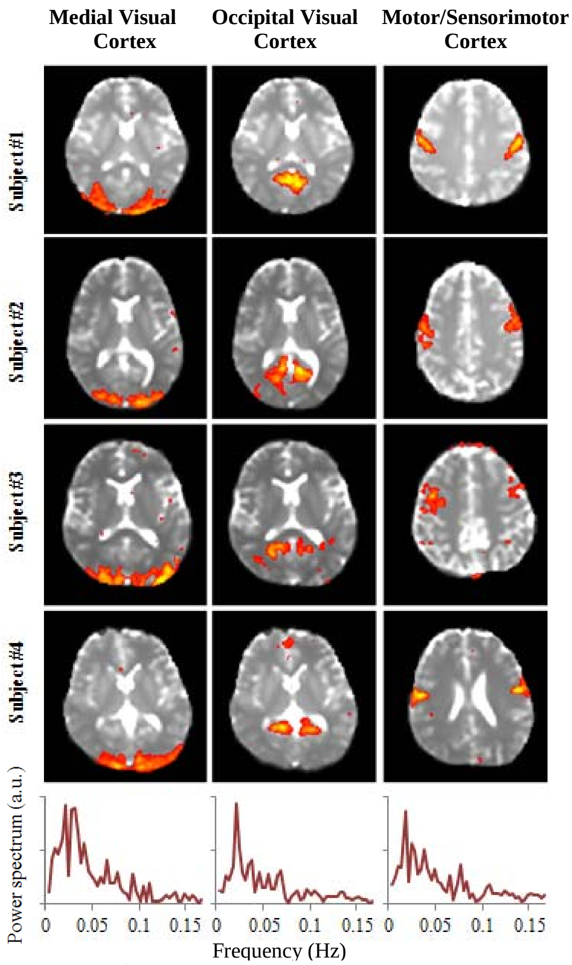

Fig. 2: ICs of b-SSFP representing medial VC, occipital VC and motor/ sensorimotor cortex for 4 subjects. Averaged power spectrums of the RSNs are shown.

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