Evaluation of Multiband-DABS ASL for resting-state fMRI

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TARGET AUDIENCE: Physicists and neuroscientists interested in multiband techniques, ASL and applications to fMRI.

PURPOSE: Resting-state networks (RSNs) in the brain are typically derived from BOLD fMRI data [1,2]. Studies have shown that it is possible to use Arterial Spin Labelling (ASL) to identify the intrinsic RSNs [3,4]. However, the spatial coverage of ASL is limited, due to T_1 relaxation leading to a loss in the ASL signal on the time scale of image acquisition, meaning that one can only investigate specific networks rather than the whole brain [5]. Multiband (MB) acquisitions provide a technique in which multiple slices are excited simultaneously. This can be used to shorten the volume acquisition time, or to extend the slice coverage to yield significant gains for ASL [6]. DABS (Double Acquisition Background Suppression) is a technique which combines the acquisition of background suppressed (BS) short TE (echo time) ASL images, in which physiological noise is reduced, with BOLD data, which is collected at the end of the TR period with TE ~ T_2^* (Figure 1). Here, we incorporate MB acquisition into DABS to form a MB-DABS sequence which was then tested at 3T.

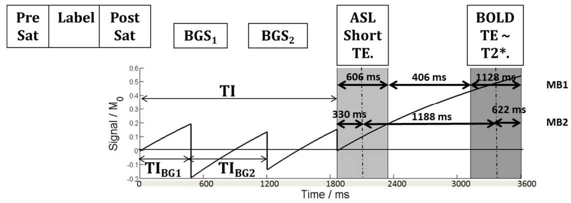

Figure 1: DABS scheme: 1st acquisition forms the ASL volume, whilst the 2nd volume is BOLD weighted. The duration of each volume and the temporal separation is shown for MB1 and 2.

Aim: To assess the use of a multiband DABS sequence for ASL and BOLD functional connectivity measures, with whole head coverage.

METHODS: *Data Acquisition:* Five healthy subjects were scanned on a Philips Achieva 3T scanner using a 32-channel receiver coil. Resting-state data were acquired using a MB-DABS sequence with FOV 168 x 200 mm^2, 3 x 3 x 5 mm spatial resolution and 18 slices (ascending order). A FAIR ASL scheme was used with background suppression pulses applied at TI_{BS1} = 339 ms, TI_{BS2} = 560 ms and a post-label delay TI = 1500 ms, TE_{ASL} = 13 ms, TE_{BOLD} = 30 ms, TR for label-control pair acquisition was 7.2 s. For conventional single band (MB1), the acquisition time of the ASL and BOLD volumes was 606 ms and 1128 ms respectively, with a temporal spacing of 406 ms; for dual slice acquisitions (MB2), the durations of the ASL and BOLD volume acquisitions was considerably shorter at 330 ms and 622 ms, respectively, with a temporal spacing of 1188 ms (Figure 1). 82 dynamics were collected in ~ 10 minutes for both single and MB2 acquisitions.

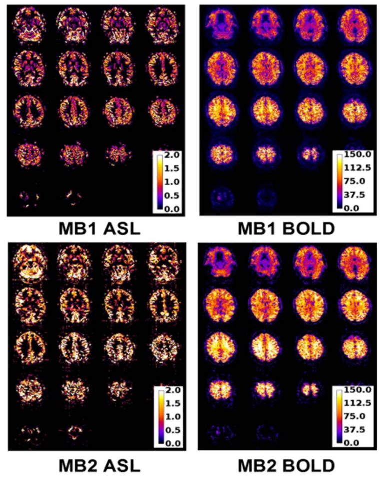

Figure 2: tSNR maps for MB1 and MB2 acquisitions of ASL and BOLD.

Data Analysis: DABS data were first separated into ASL and BOLD time-series. RETROICOR was used to correct the physiological noise in the BOLD data before motion correction using AFNI (afni.nimh.nih.gov/afni/); since ASL data was acquired with background suppression, it did not require physiological noise correction, and it was realigned using the BOLD alignment parameters. ASL and BOLD data were sinc-interpolated to an effective TR of 3.6 s, label and control images were then subtracted to provide a perfusion weighted (PW) image time series and BOLD data interleaved. ASL and BOLD images were transformed into the MNI standard space and analysed using MELODIC in FSL (www.fmrib.ox.ac.uk/fsl/) with 20 output components.

RESULTS: Figure 2 shows example tSNR maps (mean / standard deviation of time series) for MB1 and MB2 ASL/BOLD acquisitions. The tSNR of MB2 ASL data were higher than MB1 and more consistent across slices due to the lack of label decay. MB2 BOLD DABS data also had greater tSNR, as a result of the longer temporal spacing. Figure 3 shows RSN's for MB1 and MB2 ASL/BOLD data. MB1 ASL data consistently detected only the visual network (VN) for all subjects, whereas MB2-ASL was able to identify the visual network (VN), default mode network (DMN), sensorimotor network (SMN) and dorsal attention network (DAN); corresponding networks were observed in the BOLD data.

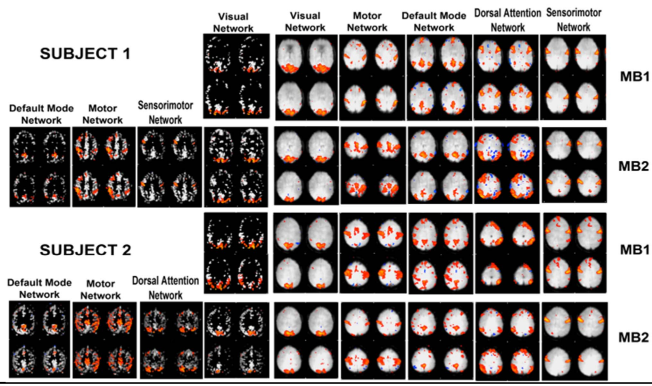

Figure 3: Example RSNs from ASL and BOLD for both MB1 and MB2; only the visual network (VN) is identified in MB1-ASL, whilst MB2-ASL provides sensitivity to multiple RSNs of DMN.

DISCUSSION: Use of MB-DABS improves sensitivity to detect RSNs with whole brain coverage. In MB1 ASL data, the ASL label decays over the volume acquisition, resulting in greatest sensitivity to the VN. MB2 ASL data yields homogeneous tSNR across the whole brain, providing sensitivity to detect RSNs across the whole brain . Also, in MB2 DABS, the greater temporal separation of the two volume acquisitions allows greater T_1-recovery and hence, higher BOLD tSNR and increased sensitivity compared to MB1.

CONCLUSION: The use of MB-DABS improves the tSNR of both ASL and BOLD data across the whole brain for RSN analysis. This method will allow the assessment of metabolism-flow coupling across multiple fundamental brain resting state networks.

References. [1]Biswal *et al.* Magn Reson Med 1995;34:537-541.[2] McKeown MJ, *et al.* Hum Brain Mapp 1998: 6(3):160–188. [3]Chuang *et al* Neuroimage. May 1, 2008; 40(4): 1595–1605 [4]Zhu *et al* PLOS one 2012 Volume 7 Issue 9 e44556 [5]Mullinger *et al.* Neuroimage 99 (2014) 111-121
[6] Feinberg DA, Beckett A, Chen L.Magn Reson Med. 2013 Dec;70(6):1500