Whole brain fMRI in 370ms: exploring the benefits of high temporal resolution 3D-EPI-CAIPI
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Target audience: Neuroscientists or physicists with an interest in high temporal resolution fMRI.

Purpose: Controlled aliasing [1] with segmented 3D-EPI can be used to increase either temporal resolution [2] or in-plane spatial resolution [3]. The supported extent of under-sampling in parallel imaging depends largely on local g-factors. 2D-CAIPIRINHA helps restrict g-factors to a tolerable level by distributing k-space samples more evenly in 3D k-space [4], making effective use of coil sensitivity variations in the two phase-encoding directions.

In this study, controlled aliasing with 3D-EPI is used for high temporal resolution fMRI, demonstrating the ability of higher sampling rates acquisitions to filter out physiological signal fluctuations resulting in improved statistical power on the detection of resting state networks.

Method: All data was acquired on a 7T (Siemens, Germany) scanner with a 32Ch head Rx coil (Nova Medical Inc., USA). MR data was acquired using 3D-EPI-CAIPI at 3 different sampling rates while monitoring the respiratory and cardiac cycles. Common parameters: TR/TE=48/26ms, FA=13°, matrix size=106x106x60, 2x2x2mm³, rBW=31.44 Hz/Pixel and, when parallel imaging was performed, ACSaor=106x48x36 and GRAPPAkernel=3x3. Remaining in parameters: TR_{volume}=3.18s; PPA=1x1, NSA=94, R=1; TR_{volume}=1.06s: PPA=1x3(Δ=1), NSA=283, R=3; TR_{volume}=0.371s: PPA=1x6(Δ=2), NSA=68, volume=808, R=8.

Two runs at each protocol were performed in a randomized order. An MP2RAGE anatomical was also acquired [4]. After motion-correction using MCFLIRT [5], power spectra for physiological signals and MR data was analyzed. All datasets were temporally low-pass filtered (f=0.14Hz) to filter out respiration and cardiac pulsation while keeping slow BOLD activity. Subsequently the datasets were temporally down-sampled to produce TR_{volume}=3.18s (94 volumes). All functional datasets were re-registered to the anatomical images and ICA was performed using MELODIC [6]. Resting state networks (RSNs) were identified visually. g-factor maps were calculated using 100 pseudo replicas [6].

Results: The power spectra of the physiological signals and whole brain averaged fMRI time courses are shown in Figure 1. The insets show examples of the whole-brain images acquired and i/g maps. The image quality at all sampling rates was acceptable, with R_v=8 (TR=0.371s) resulting in only ~11% additional g-factor losses compared to R_v=3 (TR=1.06s). With the 3.18s TR, both the respiratory and cardiac peaks (observed at −0.28Hz and −1.26Hz respectively), were aliased into the BOLD frequency range (0.04Hz−0.13Hz, Fig.2, green band). With a TR=1.06s, only the cardiac peak was aliased whereas TR=0.371s was sufficient to sample both the physiological peaks well (MR signal power spectra -blackshows both respiratory and cardiac peaks and the BOLD baseline is significantly lower). Figure 3 shows the temporal SNR achievable in fMRI [7] clearly out-weighing the relatively mild g-factor penalty. Higher temporal resolution enables better characterization of physiological signal fluctuations which can then be removed by: either low-pass filtering or via physiological noise reduction schemes [8−9].

The 8-fold acceleration demonstrated in this abstract, TR_{volume}=0.37 opens the door to the study of subtler temporal information with BOLD fMRI.

Discussion and conclusion: Use of 2D-CAIPIRINHA with 3D-EPI can exploit the coil sensitivity variations better, reducing g-factor noise in the reconstructed datasets and thus enabling higher net acceleration factors. An increased acceleration has a direct impact on the temporal resolution and temporal SNR achievable in fMRI [7] clearly out-weighting the relatively mild g-factor penalty. Higher temporal resolution enables better characterization of physiological signal fluctuations which can then be removed by: either low-pass filtering or via physiological noise reduction schemes [8−9]. The 8-fold acceleration demonstrated in this abstract, TR_{volume}=0.37 opens the door to the study of subtler temporal information with BOLD fMRI.


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