Multiplexed spiral sequence for high temporal resolution resting state fMRI

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Introduction

There is growing interest in shorter whole-brain fMRI acquisition times to allow clear separation of signals from resting state networks (RSN) and unwanted physiological fluctuations (due to e.g. motion, respiratory and cardiac cycles). Unfortunately, effective acceleration of single-shot 2D fMRI sequences such as EPI or spiral is very limited with parallel imaging. Simultaneous multi-slice ("multiplexed") 2D EPI helps overcome this limitation and greatly improves temporal resolution (1,2). We investigate multiplexed spiral-in acquisition as a more efficient approach which exploits that TE is at the end of the sequence. A factor three multiplexing allows whole brain coverage with 36 slices in 420ms. RS fMRI at 3T showed clear sampling of RSN and physiological fluctuations in the time courses.

Methods

A multiplexed 2D spiral-in sequence was implemented on a 3T Siemens Trio with 32-channel head coil (Fig 1). Three sagittal 5mm slices, 60mm apart, were simultaneously excited using a PINS pulse design (3) to acquire 36 slices in 12 excitations. Data were reconstructed using gridding and factor-3 GRAPPA to separate the aliased slices (1). RS scans of 3'30" duration were run on three subjects. Parameters: matrix 64x64, FoV 220mm, 36 slices of 5mm, no gap, TE=30ms, flip angle 60deg, spiral-in readout. One fat-saturation was applied per volume. The conventional TR was 1.615s and the multiplexed TR was 0.42s. Data were analyzed in FSL MELODIC (4,5) set to 25 independent components.

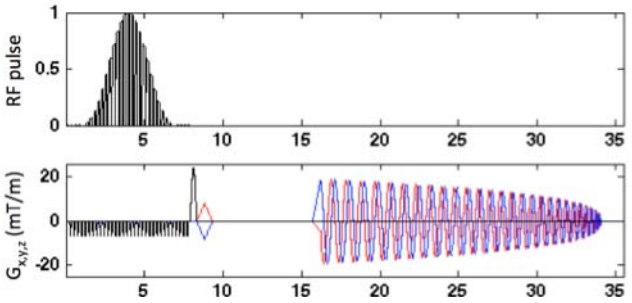

Fig 1: Multiplexed spiral sequence with PINS RF pulse. Sampling efficiency is maximized by the spiral-in readout: Within 35ms, three sagittal slices are simultaneously excited and acquired at TE=30ms.

Results

The image quality is illustrated in Fig 2. Fig 3 shows single subject examples of the parietal RSN as well as highly resolved respiratory and cardiac fluctuations. The short TR of 420 ms permits full resolution of highly localized cardiac activity at 73 bpm or less.

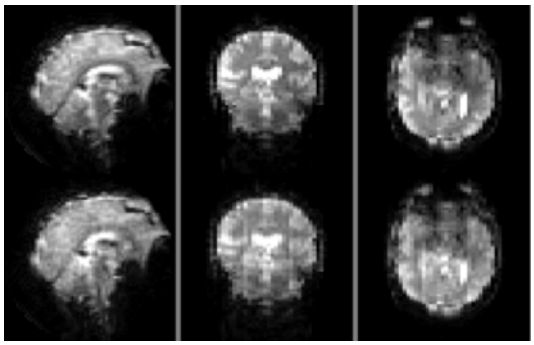

Fig 2: Full scan with TR 1615ms (top), and multiplexed scan with TR 420ms (one fat saturation per volume)

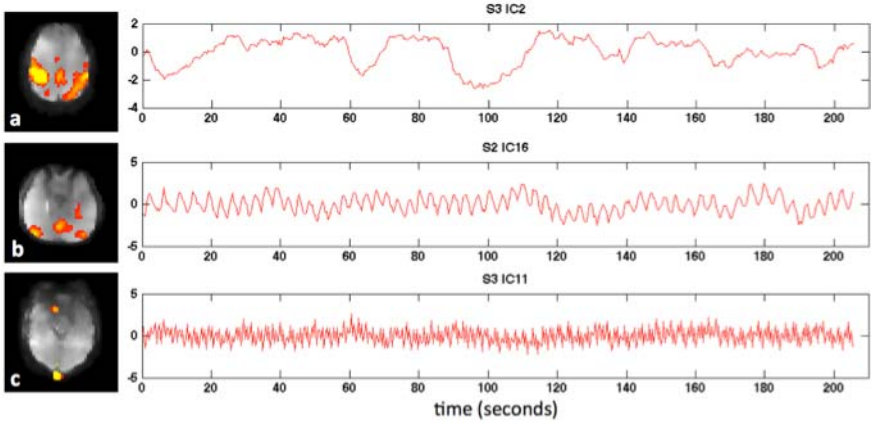

Fig 3: Example IC maps and corresponding time courses, illustrating the tremendous temporal resolution of 420ms. (a) slow RS activity in the parietal network, (b) DMN components, strongly modulated by respiratory signal changes (3.8s period), (c) highly localized cardiac pulsation in the sagittal sinus at 56 bpm. The short TR of 420ms allows each heartbeat to be resolved.

Discussion

We have demonstrated a spiral-in sequence with multiplexing that allows for whole brain fMRI with 420 ms temporal resolution. Respiratory and cardiac activity in the timecourses was resolved without aliasing. This ability should aid our understanding of physiological fluctuations and their possible contribution to resting state networks (6). It will also permit more specific data filtering and the design of nuisance regressors for connectivity or task fMRI analyses. A TR of 350 ms or less will be possible with axial slices and multi-band excitation.

References

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