Comparison of fMRI with Accelerated Variable Density Spiral and EPI

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Introduction

In functional MRI, spiral trajectory has been proposed to reduce the signal dropout in the frontal orbital and lateral parietal region affected by the susceptibility-induced field gradient (SFG) [1-2]. With a spiral-in trajectory, the entire *k*-space except the origin is sampled before the prescribed echo time TE. This reduces T_2* weighting and enhances the BOLD contrast in regions affected by the SFG. However, the spatial resolution that can be achieved with a spiral-in trajectory is limited by the need to sample the entire *k*-space before TE. In addition, the spatial resolution of the activation map in the SFG region may be compromised due to the spatial blurring introduced by the combination of a large B_0 offset and a long readout window.

Parallel imaging techniques can be used to undersample a spiral trajectory, therefore improving the spatial resolution of spiral fMRI. However, most existing spiral parallel imaging methods [3-5] require either a long computation time due to their iterative nature, or have difficulty working with variable density (VD) spiral datasets where spacing between adjacent spiral lines vary continuously across the k-space. In this work, a recently proposed rapid *k*-space-based parallel imaging method for VD spiral, Generalized GRAPPA for wider spiral bands (GROWL) is applied to fMRI for reduced off-resonance artifacts and potentially higher temporal/spatial resolution and larger volume coverage.

Methods

The basic principle of GROWL for VD spiral is illustrated in Fig. 1. When compared with a uniform-density (UD) spiral, a VD spiral significantly undersamples the outer *k*-space (Fig. 1a). Using self-calibrated GROWL operators, each acquired spiral line is expanded into a wider band with a flexible width across the *k*-space, therefore eliminating any undersampled k-space region. The calibration of GROWL operators along various directions are performed using the fully-sampled central k-space region. With an undersampling factor of 4 at outer k-space, the readout window of a single-shot VD spiral is 20 and 25 ms, compared to 50 and 80 ms for UD spiral, at image resolutions of 96 × 96 and 128 × 128, respectively.

Functional MRI experiments were carried out to compare both VD spiral-in and spiral-out with EPI, using a standard paradigm for visual cortex activation (flickering checkerboards) with a block design alternating 15 sec off and 15 sec on. Healthy volunteers were scanned on a 3.0T clinical scanner (Achieva, Philips, Best, Netherlands), using an eight-channel head coil (Invivo, Gainesville, FL). Scan parameters are identical for EPI and spiral: FOV 230×230 mm^2, 8 slices with thickness of 5mm and gap of 2mm, TR/TE = 500/30 ms, flip angle = 40^0, image resolution: 96 × 96. Due to the non-iterative nature of GROWL, the reconstruction time is around 100ms per slice for both spiral datasets.

Results and Discussions

Figure 2 shows the activation maps overlaid directly on the EPI (Fig. 2a), spiral-out (Fig. 2b) and spiral-in (Fig. 2c) images. No off-resonance correction was carried out in this initial study, which explains some image blurring in the spiral datasets. Similar activations of the visual cortex were found in all datasets. On the other hand, signal dropouts were quite significant in the frontal orbital region of EPI and spiral-out images, while spiral-in images showed much less signal dropouts.

In conclusion, this study establishes the feasibility of using a highly undersampled variable density spiral trajectory for functional MRI. With a spiral-in trajectory, the susceptibility-induced signal dropout in the frontal orbital region is significantly reduced. Future work will investigate the possibility to increase spatial/temporal resolution and achieve larger volume coverage in fMRI using undersampled VD spiral trajectories.

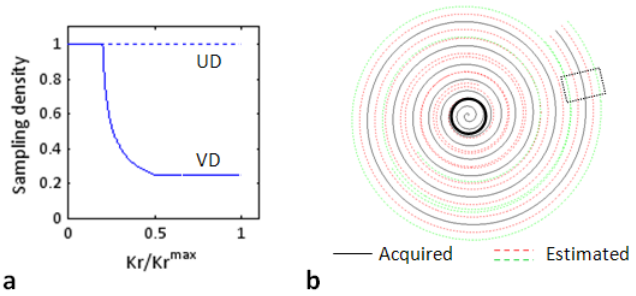

Figure 1 Basic principle of GROWL operator for VD spiral. **(a)** Sampling density of VD vs. uniform-density (UD) spiral. **(b)** GROWL operators are used to expand each acquired VD spiral line into a wider band with a flexible width across the k-space. Fully-sampled central circle is used for GROWL operator calibration.

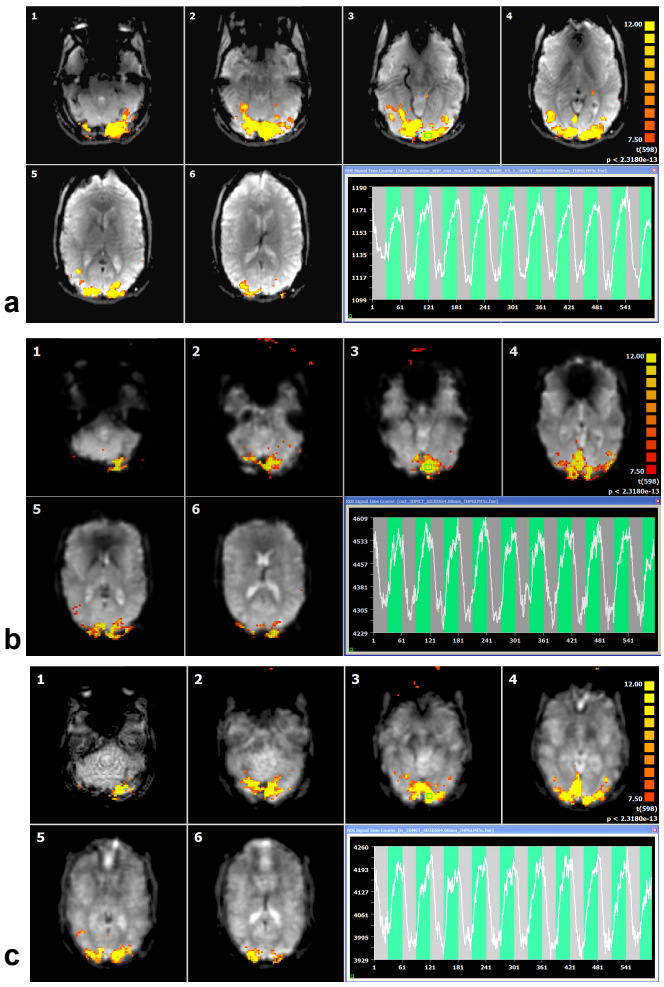

Figure 2 fMRI activation maps (thresholded at t > 7.5) directly overlaid over EPI **(a),** spiral-out **(b)** and spiral-in images **(c).** Three sets of image were acquired using identical scan parameters such as TR/TE and the pixel resolution.

References

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