True 3D fMRI using Spiral Projection Imaging

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Introduction: A new 3D method for rapid data collection, called Spiral Projection Imaging, has been developed[1]. It employs a set of k-space trajectory of a standard spiral data set (with optional density variations) rotated about an “in-plane” axis to ultimately measure a sphere in k-space (Fig. 1a). Due to the nature of spiral encoding and the radial projections of these spirals, motion artifacts are minimal, data collection is rapid, and the k-space oversampling allows one to update the center of k-space more rapidly than the duration of the total time to update all of k-space using appropriate data weighting methods[2]. These features make Spiral Projection Imaging an excellent candidate for 3D fMRI.

Methods: Spiral Projection Imaging was implemented on a 1.5T GE EXCITE echo-speed plus scanner. Data were collected from a volunteer with isotropic FOV=24cm and resolution=3mm, fully sampled spirals. The required 120 spiral planes (seen on edge in Fig. 1b) were collected in 3 interleaved groups of 40. For this initial study, the TR/TE/ADC = 62.5/30/8 msec, 2 interleafs per spiral plane, 5 sec/group, 15 sec for the entire data set (future studies should be able to reduce these durations). The entire data set was collected 13 times (3' 15"), and the volunteer interleaved right-handed finger tapping (at 45", 1' 45", and 2' 45") for 30" with a resting period. Data were reconstructed at 5 sec intervals using a sliding window approach and a weighting method[2] which completely refreshed the center of k-space with alternating groups, as illustrated in Fig. 1 c-e. For this preliminary study, the first 3 images were ignored to allow for approach to steady-state, and then the average of the "rest" data were subtracted from the average of the "tapping" data. The results are displayed in Fig. 1f,g. The time-course of the single pixel with the strongest difference is displayed in Fig. 1h.

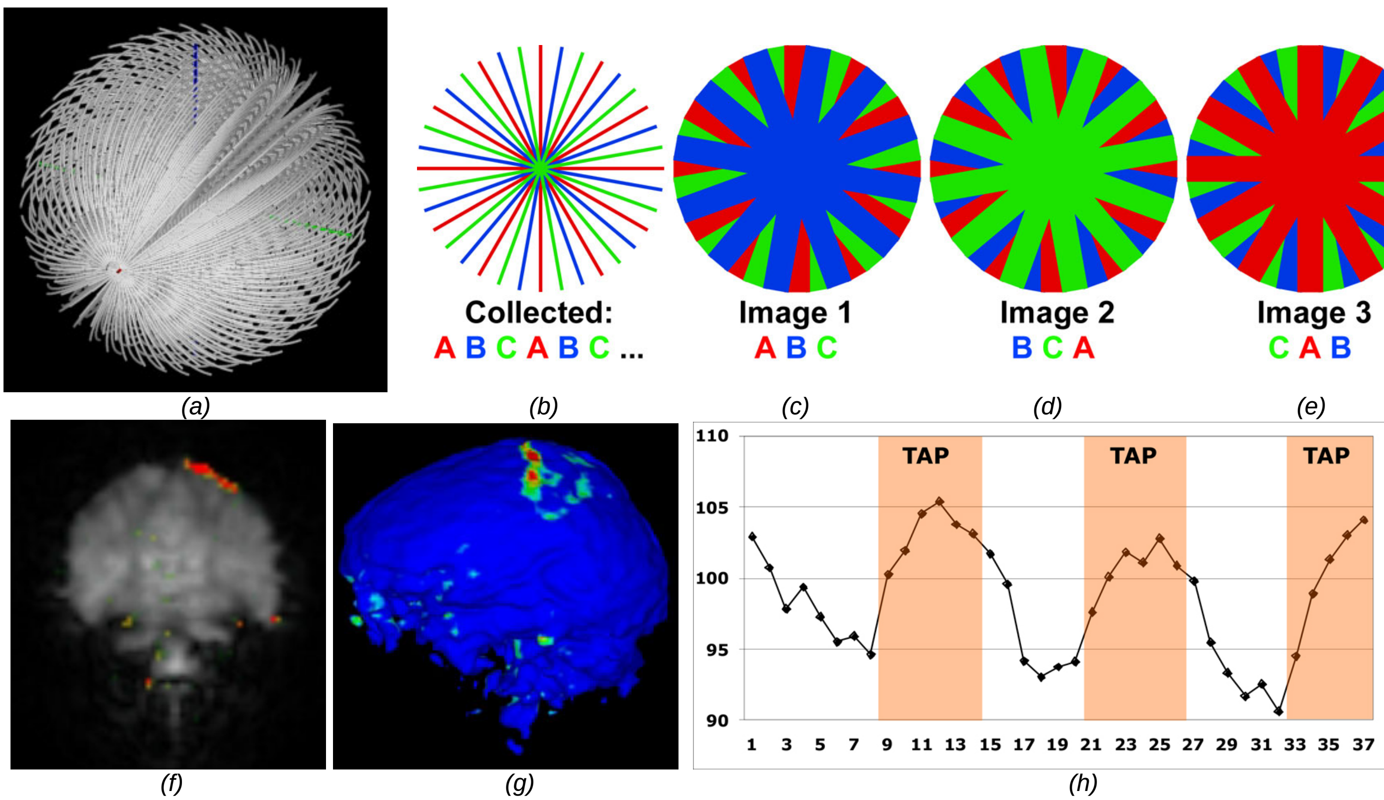

Fig. 1. Spiral Projection Imaging 3D k-space trajectory (a) showing 2D spiral rotated about k_x axis, and (b) the same trajectory looking down that axis, illustrating how 3 groups of spiral planes were collected. A weighting algorithm updated the center of k-space every 5 seconds with a different group of spiral planes (c-e), resulting in an activation seen in (f,g); the strongest time-course is shown in (h).

Discussion: The ADC window was kept short to reduce blurring, which greatly reduced the efficiency of this method - a 3D deblurring method is being explored which may allow the ADC window to be expanded, if desired (other methods of improving temporal resolution, such as undersampling, will also be explored). It is speculated, but not known, that the large BOLD signal response (10%) may be due to the short ADC duration, since all data contributing to the activation was collected near the optimal TE, unlike EPI methods, which collect some k-space data well before and after the desired TE.

References: 1. Spiral Projection Imaging abstract submitted at this meeting. 2. Mag Res Med 41(1), 179.