Retinotopy using multifocal fMRI with a correlation-based approach

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Introduction

This study aims to develop an efficient method for retinotopy mapping and apply the retinotopy to reconstruct visual image from human brain activity[1]. Multifocal method, utilizing concurrent sequences of stimuli in multiple visual field locations, has been shown an efficient method for retinotopy mapping. In the previous investigation [2], an m-sequence approach was used to generate stimulate sequences for discrete regions of the visual field. However, the m-sequence method widely used in mapping electroretinogram response does not account for hemodynamic response function (HRF) of BOLD mechanism. In this study, we proposed optimal sequence search method based on correlation analysis.

Material and Methods

Three volunteers with normal or corrected-to-normal vision underwent multifocal retinotopy mapping 3T whole-body MR system (Siemens, Tim Trio, Germany) after obtaining informed consent. The imaging sequence used in this study was a single-shot gradient-echo EPI sequence and the parameters were (TR = 1000 ms, TE = 50 ms, matrix = 64 x 64, FOV = 240 x 240 mm, slice thickness 3.0 mm, no slice gap, flip angle = 90 ˚ , number of measurement = 540). Ten slices were acquired to cover the entire calcarine sulcus. The 540-second session was performed two times for each subject. The stimulus images and timing was controlled with Psychtoolbox. The spatial layout of the stimulus was a circular field extending to 12 ˚ radius, divided into 5 rings, each with 12 sectors, making 60 distinct regions. Figure 1 shows Fig. 1). The total extent of the five rings was from 1 ˚ to 12 ˚ eccentricity, with the midpoints of the rings being at 1.6, 3.0, 4.8, 7.1, and 10.2 ˚ eccentricity. Each region has its own stimulus sequence (PR-1 to PR-60, which will be presented in the next paragraph). For the data analysis, we used the general linear model (GLM) to derive efficient estimates of the region specific activation maps [1].

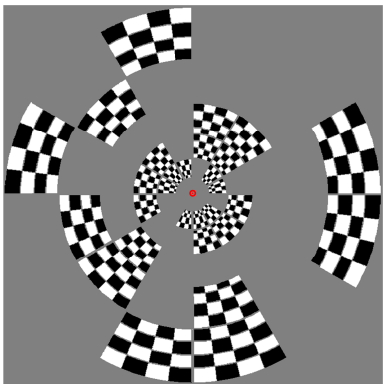

Figure 1. The first frame in the sequence, reversing contrast at 5 Hz.

The optimal sequences of the 60 discrete regions were determined by a correlation approach. The optimization procedure implemented in MATLAB (Mathworks, MA) first defined two kinds of 20-second stimulus blocks, A and B, whereas A represented 10-second ON followed by 10-second OFF and B represented 10-second OFF followed by 10-second ON. The scan time was 540 and therefore required 27 blocks. The procedure first generated 27 blocks for visual field no.1 with randomized types (i.e., A and B) and formed a paradigm (PR-1). The procedure then repeated the paradigm generation for N-th visual field (PR-N). The candidate PR-N was selected when the correlation coefficients between PR-N and previously obtained paradigms were lower than 0.35. The obtained paradigms formed the design matrix of GLM.

Results

This study obtained two sessions of multifocal fMRI experiments and averaged the data of the two sessions to increase signal-to-noise ratio. Figure 2 shows the results obtained from a 22-year-old male volunteer. Figure 2a demonstrates eccentricity mapping from fovea (green) to periphery (yellow). Figure 2b shows retinopy mapping in angular dimension that separate from the lower to the upper lip of the calcarine sulcus.

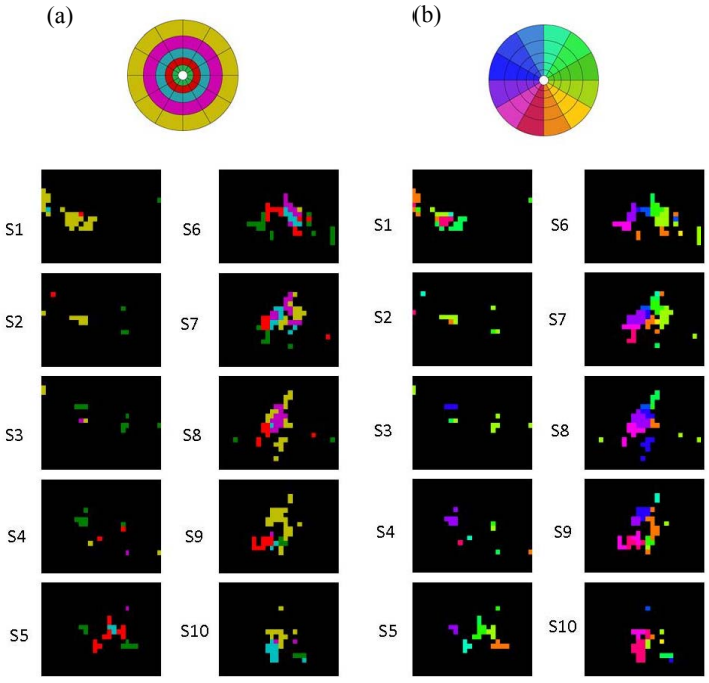

Fig. 2. Maps obtained of multifocal mapping. The voxels are labeled with the number of the region producing maximum t value of multifocal GLM analysis. The colors of voxels were assigned according to the corresponding visual fields (a: ring , b: sector).

Discussion and Conclusions

This preliminary study generated stimulus sequences of multifocal fMRI experiments by a correlation approach. The previous investigations used m-sequence approach producing nearly orthogonal binary sequences. However, the error of othogonality in the "design matrix" of GLM analysis is greatly reduced when accounting for the effect of HRF. In this study, we propose the correlation approach that is potentially able to produce less correlated response in the multifocal fmri study. The preliminary results show that this method can attribute V1 regions into 60 visual fields. Although HRF effect is not yet included in our method, our result suggests the correlation approach is feasible. More detail comparison of the m-sequence method and the correlation method requires further investigations. In conclusion, multifocal fMRI combined with stimulus sequences produced by correlation approach is a potentially efficient method of retinotopy mapping in the visual cortical areas.

Reference

[1] Miyawaki et al , Neuron 2008, 60:915-929

[2] S. Vanni, et al, NeuroImage 27 (2005) 95– 105