Visual Image Reconstruction of Brain Activities and Retinotopic Mapping: An Optimization method

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Target Audience: fMRI researchers interesting in visual image reconstruction.

Purpose

This study aims to exploit multi-focal functional MRI(fMRI) which utilizes concurrent sequences of stimuli in multiple visual field locations for retinotopic mapping [1,2], and to reconstruct visual image according the retinotopy and brain activities obtained by fMRI. Reconstructing the visual image using the results of visual fMRI and retinotopy requires selecting statistical thresholds to justify the existence of stimuli-related brain activities. Therefore, this study presents an approach to find the optimal t threshold according to a receiver operating characteristic (ROC) analysis.

Material and Methods

Ten 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 EPI sequence with the parameters (TR: 1000ms, TE:50ms, number of slice:13, matrix size:128 x 88, FOV:240 x 240 mm, slice thickness:4.0mm, slice orientation: coronal, number of measurements:540). The stimulus images and timing was controlled with Psychtoolbox-3 (http://www.psychtoolbox.org). 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. 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 (see Figs. 1a and 1b). The checker-board frequency was 5 Hz. Each region has its own stimulus sequence produced by a correlation analysis [3]. This experiment is termed EXP-M (M for multifocal). We subsequently performed a visual fMRI experiment for visual reconstruction using the same EPI parameters and the stimulation was a 60-sec paradigm with interleaved 10-sec on and 10-sec off blocks. The stimulating images were shown in Fig.1(c,d). The experiment for visual image reconstruction is termed EXP-V.

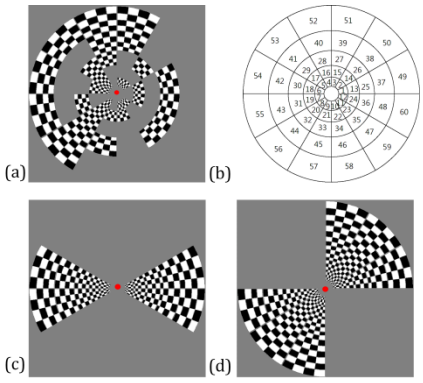

Figure 1 Images for visual stimulation

To reconstruct the visual images, we first used a general linear model (GLM) to derive the region specific activation maps using the EXP-M and EXP-V data sets. The maps are referred to as $\mathrm{MF}t_n$(Multifocal t map, n=1-60) and STt (t-map obtained by visual STimulation experiment), respectively. Each t map was normalized to the maximum value in the map. The pixels in $\mathrm{MF}t_n$ with their t values lower than a threshold, termed threshold A (th-A), were set to 0 and the generated map was $\mathrm{MF}t_n'$. We then used the following equation to reconstruct the visual image, ReconImg(n), n=1-60:

$$\mathrm{ReconImg(n)} = \sum_{x=1}^{128}\sum_{y=1}^{88}\sum_{z=1}^{13} \mathrm{MFt_n}'(x,y,z) \times \mathrm{STt}(x,y,z)$$

ReconImg(n) was then normalized to its maximum value. Finally, we regarded the regions in normalized ReconImg(n) with values higher than a threshold B (th-B) as regions with the visual stimulation and generated the final reconstructed visual image $\mathrm{ReconImg}'(\mathrm{n})$. The next step is to optimize th-A and th-B. We varied th-A and th-B (from 0 to 1 with a step size of 0.1) to obtain $\mathrm{ReconImg}'(\mathrm{n})$. We then estimated the reconstruction accuracy (ACC) with the ROC analysis using the visual stimulation used in EXP-V as a reference standard for each participants and averaged the analysis results obtained from all participants to identify the optimal thresholds (th-A and th-B). The procedures are displayed in Figure 2.

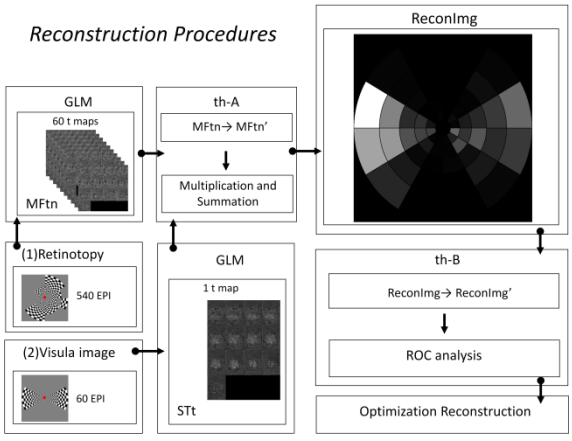

Figure 2 Reconstruction procedure

Results

The group result of the ROC analysis is displayed in Fig.3. The obtained optimal thresholds were (th-A: 0.3, th-B: 0.1) and the optimized accuracy was 81%. Figure 4 displays an example of reconstructed visual images with varied thresholds.

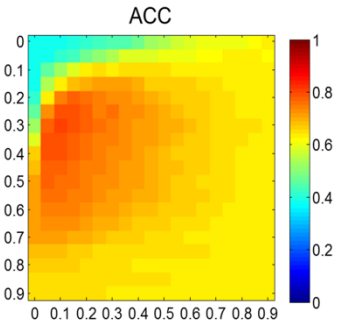

Figure 3 ACC obtained using (left-right: th-A, th-B)

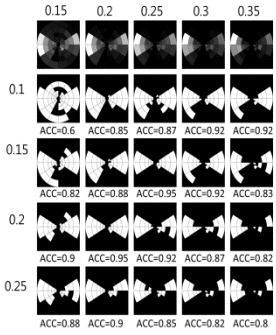

Figure 4 Reconstructed images using varied thresholds (left-right: th-A).

Discussion and Conclusions

This study attempts to reconstruct a visual image using the retinotopy and the visual fMRI. We developed a procedure to identify the optimal thresholds for this experiment. This study also demonstrated ROC analysis method in assessing the accuracy of the visual image reconstruction. In conclusion, this study successfully reconstructed the visual image by the fMRI technique. Compared to previous investigations, we regard the contributions of this study are the optimization method for visual image reconstruction.

Reference

[1] Miyawaki et al , Neuron 2008, 60:915-929
[2] S. Vanni, et al, NeuroImage 27 (2005) 95– 105
[3] Chang YW et al. ISMRM 2012 (#2082)