Potential application of MVPA and decoding stimuli for clinical diagnosis of visual field deficits

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Introduction:

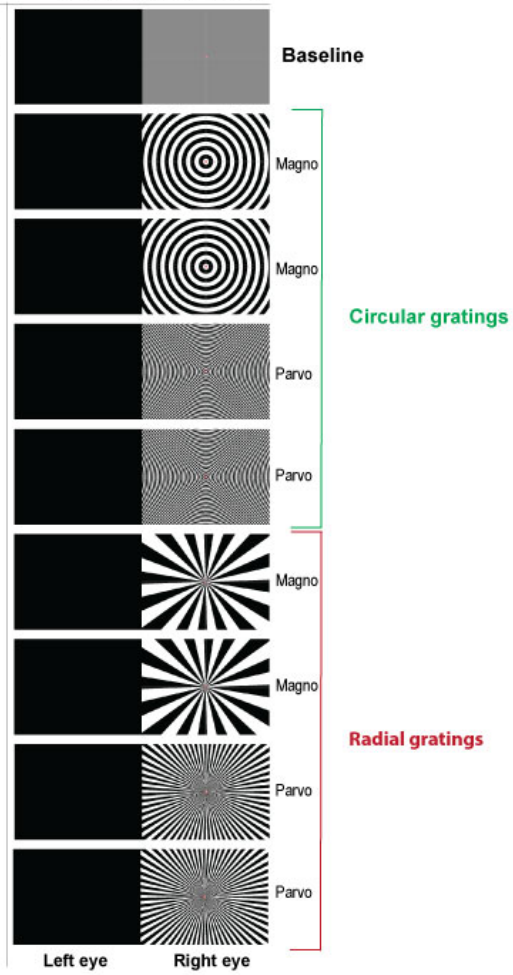
In this study, we aim to develop and evaluate the possibility of estimating the parts of the visual field that are visible to patients of optic neuropathies via decoding of a specific group of visual stimuli. It was shown that a scotoma in the visual field can decrease the BOLD response in the primary visual area. Furthermore, univariate responses in early visual areas have showed a correspondence of visual field deficits and the fMRI-based reconstructed cortical visual field maps[1,2]. Hence, we expect that these visual deficits cause low decoding rates compared to those from control subjects. Visual stimuli decoding can be done by multivariate pattern analysis (MVPA), which is known to be more informative about cortical activation patterns than the univariate methods[3]. Here, we investigate the possibility of applying region specific/searchlight-based MVPA on fMRI obtained in relatively short fMRI acquisition duration (~22 min per eye) for clinical applications.

Methods:

We obtained functional magnetic resonance imaging (fMRI) data from 2 healthy young subjects using a Siemens 3 Tesla Prisma scanner. Each subject completed 16 runs of task fMRI; in 8 runs, the right eye was stimulated; in the others, the left eye was stimulated (the non-stimulated eye was presented with a black image for whole run duration). Eight different blocks were presented in each run, which included radial and circular gratings with different spatial and temporal frequencies, and dynamic characteristics (Figure 1). The order of runs and stimulus blocks was randomized for each subject. The VisuaStim (Resonance Technology, Inc.) goggles were used for stimulus presentation, with a resolution of 800 × 600 and field of view of 22.5° x 30° (v x h). The fMRI data were pre-processed using the FSFAST toolbox. We used the CoSMoMVPA package to decode the stimulus using the searchlight analysis and support vector machine (SVM) classifier considering the voxels between white and pial surfaces[4]. Leave-one-out strategy was used to obtain the decoding accuracy maps, which then were mapped to the fsaverage standard cortical surface. This procedure resulted in two whole-brain surface maps of decoding accuracy per subject, corresponding to the accuracies obtained when the left or right eye was stimulated. To interpret the decoding results, the Benson retinotopic atlas was used to define the regions of interests (ROIs) in visual areas, V1, V2, and V3, as well as to predict the voxel-wise eccentricity and polar angle[5]. Selecting SVM was based on the results obtained from the ROI-based decoding rates using all voxels within V1, V2, and V3; we tested the native Bayes, nearest neighbor and SVM classifiers and observed that SVM yields better accuracy across the ROIs and hemispheres.

Figure 1
Stimuli characteristics

Spatial resolution	Temporal resolution	Dynamic	Duration (sec)	Illustration of stimulus
—	—	—	10.10 - in between stimuli 16.16 - first and last baselines	Baseline
0.5 cycle/°(visual angle)	10 Hz	flickering	8.08	Magno
0.5 cycle/°(visual angle)	10 ° (visual angle)/sec	expanding/contracting	8.08	Magno
2 cycle/°(visual angle)	2Hz	flickering	8.08	Parvo
2 cycle/°(visual angle)	2 °(visual angle)/sec	expanding/contracting	8.08	Parvo
16 cycle/360°	10 Hz	flickering	8.08	Magno
16 cycle/360°	10 cycle/second	clockwise/anti-clockwise rotation	8.08	Magno
63 cycle/360°	2 Hz	flickering	8.08	Parvo
63 cycle/360°	2 cycle/second	clockwise/anti-clockwise rotation	8.08	Parvo

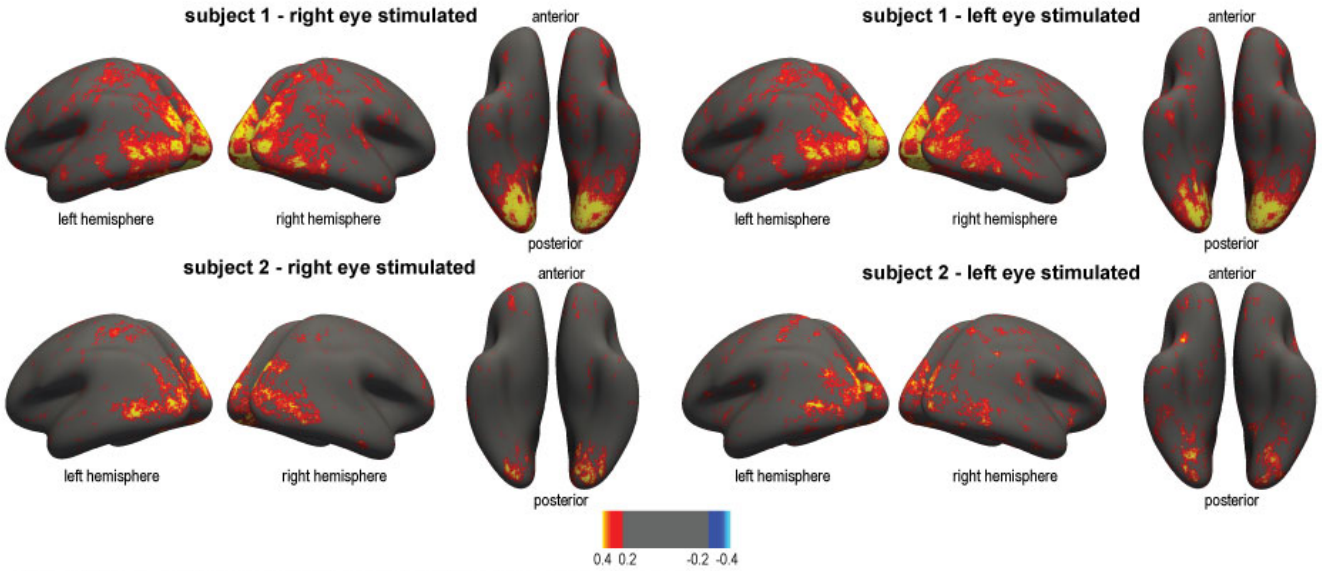


Results:

The results in healthy subjects indicate higher than chance decoding rates in the range of 0.5-11 eccentricity, and it starts to decay as we get to the regions that are out of scope of active stimulation. The decoding rates are highest in V3, followed by V2, and then V1, which indicates the possibility of the role of higher-level areas in giving insight into visual deficits and increasing the accuracy of the results (Figure 2).

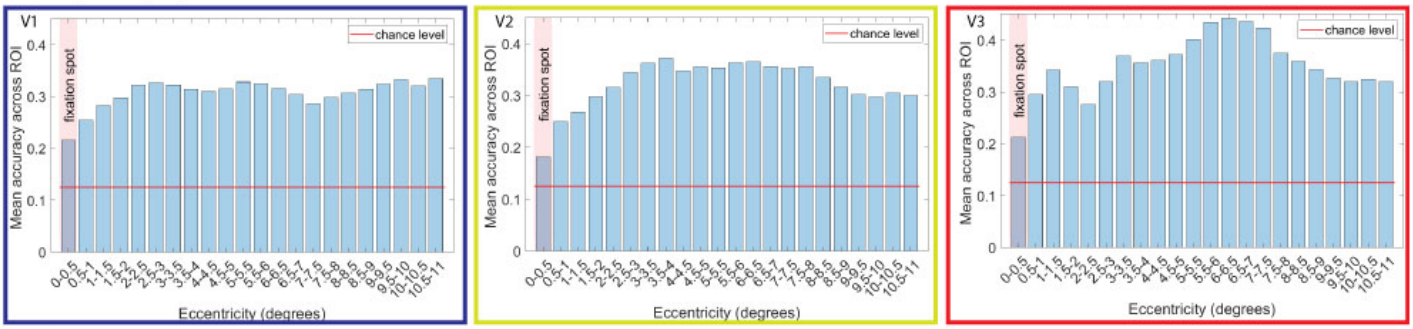
Figure 2

a - Decoding maps on the fsaverage surfaces



b - Decoding values in the right V1, V2, and V3 plotted vs eccentricity values

subject 1 - right eye stimulated



V1 (0 to 15 degrees of eccentricity) right hemisphere

V2 (0 to 15 degrees of eccentricity) right hemisphere

V3 (0 to 15 degrees of eccentricity) right hemisphere

Conclusions:

Decoding stimuli using responses in early visual areas brings up the possibility of building the empirical decoding accuracy distributions as a function of retinotopic eccentricity using data from healthy subjects. In our future work, we will calculate decoding rates from patients with visual deficits, and compare the results with the region-specific decoding distribution obtained from a cohort of control subjects; this comparison will indicate the probability of a visual field deficit. Limitations to this strategy include the reliance on a probabilistic retinotopy atlas, and the need

for subject's reliable fixation of gaze. However, such visual deficit evaluation could add information regarding the coordinates and nature of the visual deficits.

Modeling and Analysis Methods:

Activation (eg. BOLD task-fMRI) [1]
Methods Development
Multivariate Approaches [2]

Keywords:

Data analysis
Design and Analysis
FUNCTIONAL MRI
MRI
Multivariate
Vision

[1|2]Indicates the priority used for review

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No

Please indicate below if your study was a "resting state" or "task-activation" study.

Task-activation

Healthy subjects only or patients (note that patient studies may also involve healthy subjects):

Patients

Was any human subjects research approved by the relevant Institutional Review Board or ethics panel? NOTE: Any human subjects studies without IRB approval will be automatically rejected.

Yes

Was any animal research approved by the relevant IACUC or other animal research panel? NOTE: Any animal studies without IACUC approval will be automatically rejected.

Not applicable

Please indicate which methods were used in your research:

Functional MRI

For human MRI, what field strength scanner do you use?

3.0T

Which processing packages did you use for your study?

Free Surfer

Provide references using author date format

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