MEDICAL UNIVERSITY OF VIENNA

Towards objective scotomata assessment using fMRI-based retinotopic mapping: a connectomic approach

David Linhardt[1], Maximilian Pawloff[2], Michael Woletz[1], Martin Tik[1], Maria Vasileiadi[1], Markus Ritter[2], Ursula Schmidt-Erfurth[2], Christian Windischberger[1]

[1] High Field MR Center, Center for Medical Physics and Biomedical Engineering, Medical University of Vienna, Vienna, Austria
[2] Department for Ophthalmology and Optometry, Medical University of Vienna, Vienna, Austria

Introduction

Assessment of neural function on the visual cortex by retinotopic fMRI allows for mapping the functional status of an individual's visual field. Population receptive field (pRF) mapping is of particular interest in patients suffering from diseases that cause dysfunctions in the retina referred to as scotomata (Ritter et al., 2018). The critical point in pRF-based scotomata assessment lies in setting the threshold between activated and non-activated voxel. Current gold-standards use static thresholds based on the explained variance and may lead to under- or overestimation of scotomata extend. Here we present a new method based on reference data from the Human Connectome Project (HCP) that enables automatic scotomata assessment independent of threshold levels.

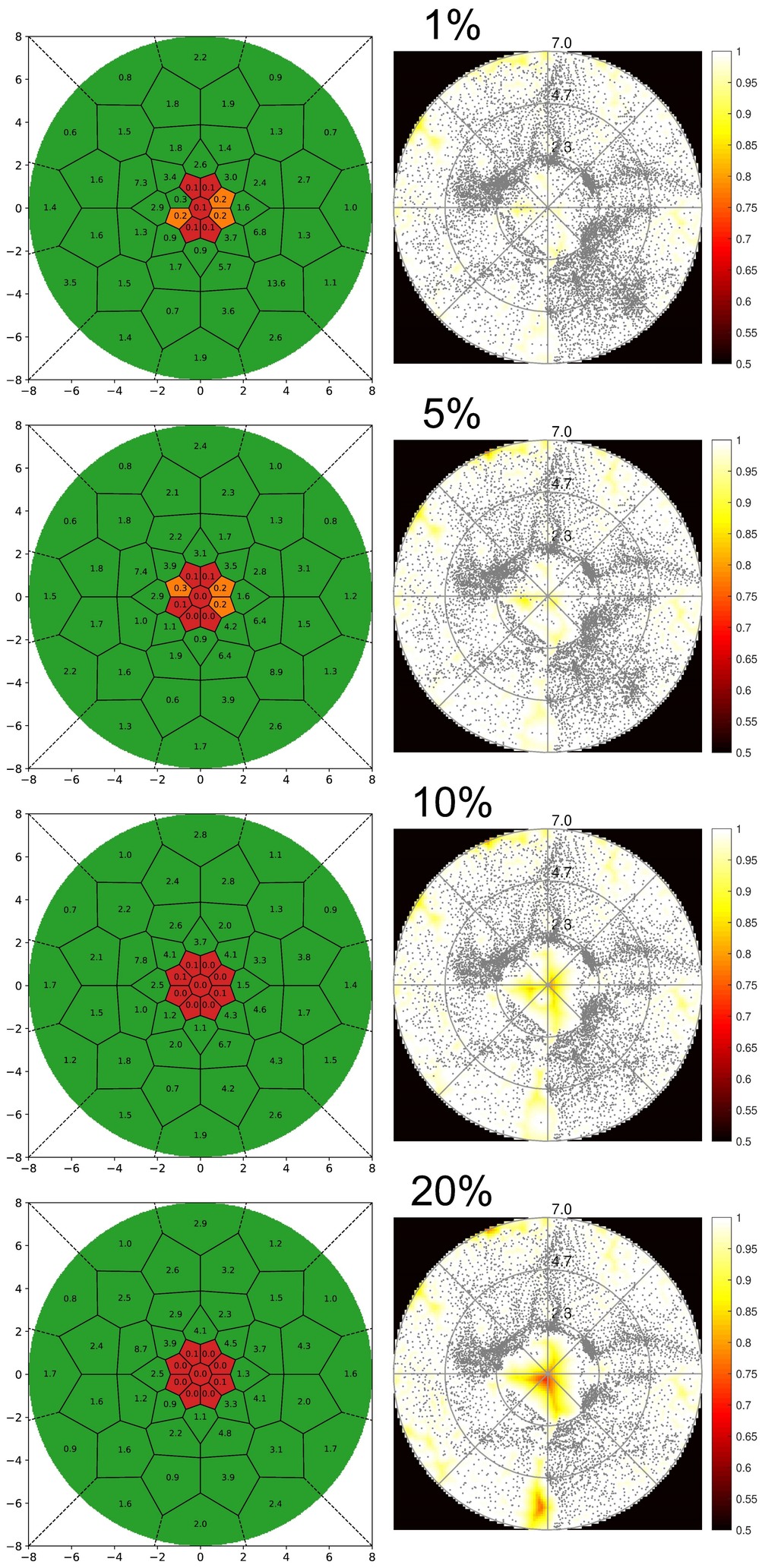

Figure 1: This figure shows pRF mapping results of an exemplary healthy subject's single run. These measurements were performed using a sweeping bar aperture with a simulated scotoma of 2° radius. Different rows indicate different variance explained thresholds. On the right-hand side, the classical coverage map as obtained from mrVista is shown. This map is flipped along the y-axis to rather be in the space of an ophthalmologic fundus image, than in visual field space. The detected scotoma varies a lot between different threshold coverage maps. The left column shows the novel plotting method based on a circular grid. Here, irrespective of the chosen variance explained threshold, the artificial scotoma is detected consistently.

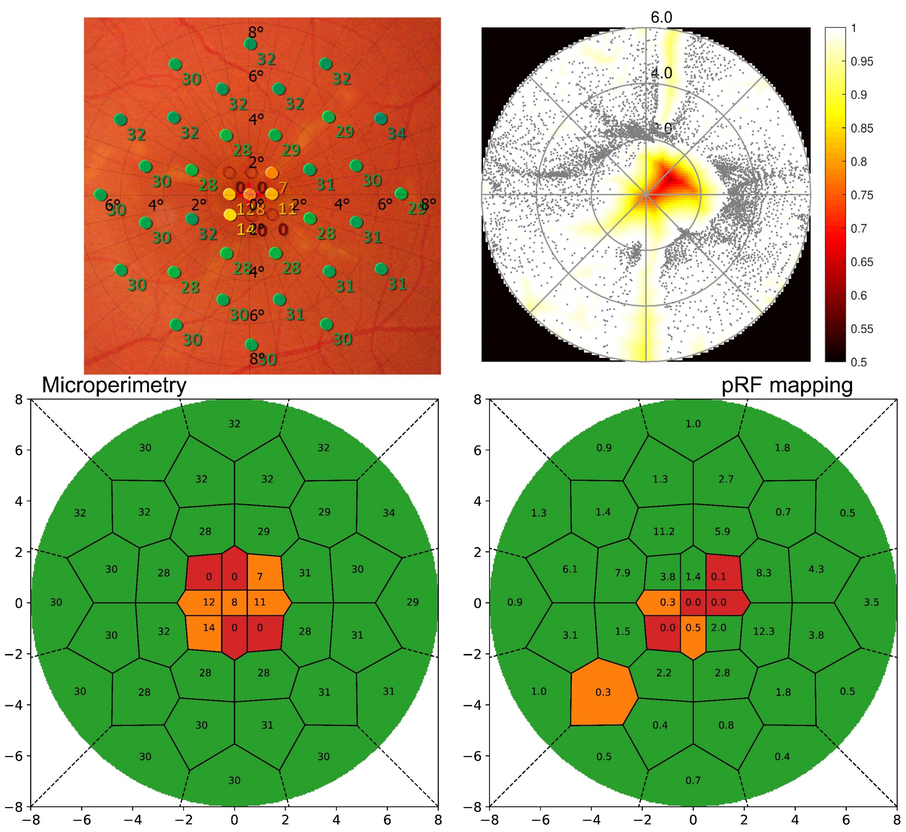

Figure 2: This Stargardt's disease patient suffers from retinal degeneration in foveal regions. The resulting loss of vision can clearly be seen in the standard ophthalmologic Microperimetry (MP) measurement as shown on the top left. pRF mapping results are shown as coverage map on the top row. For optimal comparability, the MP grid was used to calculate our general map. On the bottom row, the rated MP values are shown (complete loss of vision, red: 0; impaired vision, orange: 1-19; good vision, green: 20-32). In comparison, the novel displayment of the pRF results as shown on the bottom right yielding highly similar results from just one retinotopic mapping run.

Methods

Functional classification is based on the comparison of individual pRF mapping results to group reference data. For this, the HCP retinotopy dataset (Benson et al., 2018) is perfectly suited since it contains 181 healthy subjects measured on a 7T scanner. For comparability, we re-analysed the HCP data using mrVista and restricted the analysis to the primary visual cortex. We defined a grid across the visual field and for every corresponding grid-points area, we quantified the number of pRF centres relative to the total number of active centres to obtain a subject-specific map of pRF centre density. For each grid area we calculated a distribution of centre density across the 181 HCP subjects. Based on these distributions, we defined three levels in the classification process: fully functional (above the 5% percentile; green), dysfunctional (below 0.1% of HCP average density; red), partly functional (in between; orange).

We tested our implementation on data of 20 healthy subjects with simulated scotomata acquired on our 7T Siemens scanner using a 32-channel head coil. Additional to a T1-weighted anatomical scan (0.7mm isotropic), functional data of the visual cortex was acquired using the CMRR-EPI sequence (TR=2000ms, 1mm isotropic, 32 slices). For each subject, data consisted of a single run of a bar aperture revealing a reversing checkerboard, sweeping through the visual field in eight different directions. A central area of 2° radius was not stimulated to simulate a foveal scotoma. In addition, one patient suffering from Stargardt's disease was also analysed using the HCP control repository.

Results

Figure 1 shows the results of one healthy subject for different explained variance thresholds. The right column displays the standard coverage map, while results of the new scotomata assessment method are shown in the left column. It can be seen that while coverage maps change considerably across threshold levels, maps calculated with the new method show perfect classification results for thresholds above 5%. Even at 1% threshold, the new method clearly shows the central scotoma at 2° radius.

As the method was developed to quantify scotomata in patients with retinal disease, Figure 2 displays results from a Stargardt's disease patient. Microperimetry (MP) results from clinical examination are shown (left) overlaid to a fundus image and rated. On the right side, the standard pRF coverage map is shown along with the novel classification result. For optimal comparability between retinotopy and ophthalmology results, the grid used in MP was also applied to the pRF results. Other than the standard coverage plot, the new method shows clear scotomata results comparable to the MP outcome.

Conclusion

When interpreting pRF mapping results on patients with retinal dysfunctions, the choice of the appropriate variance-explained threshold has a tremendous influence on scotomata detection making objective ophthalmologic staging on pRF results almost impossible. The herein suggested procedure yields the possibility for an unbiased investigation of the dynamics of scotomata independent of the chosen threshold and on flexible grids which can be adapted to MP results.

Author Contact

References

Benson, N.C., Jamison, K.W., Arcaro, M.J., Vu, A.T., Glasser, M.F., Coalson, T.S., Van Essen, D.C., Yacoub, E., Ugurbil, K., Winawer, J., Kay, K., 2018. The Human Connectome Project 7 Tesla retinotopy dataset: Description and population receptive field analysis. Journal of vision 18, 23-23.

Ritter, M., Hummer, A., Ledolter, A.A., Holder, G.E., Windischberger, C., Schmidt-Erfurth, U.M., 2018. Correspondence between retinotopic cortical mapping and conventional functional and morphological assessment of retinal disease. British Journal of Ophthalmology.

david.linhardt@meduniwien.ac.at
www.fmri.at