Stimulus-specific biases in population receptive field mapping

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Introduction

Mapping the population receptive fields (pRFs) in the human visual system (Dumoulin, 2008) has enabled detailed insights into the processing of visual stimuli in healthy individuals as well as in patients suffering from ophthalmologic diseases. This mapping technique is used to evaluate the retinotopic organisation of the human visual cortex, typically using BOLD-fMRI performed during a visual stimulation task. For accurate results, stimulation tasks typically comprise dynamic patterns shown through temporally varying apertures that allow for encoding the position of the visual field. Selecting the optimum stimulus is not trivial. Different stimulus variants have been proposed and their effects on the pRF results have been compared using descriptive statistics (Alvarez et al., 2015). Here we present a novel method of comparing the results of different stimuli on a group level based on voxelwise correspondences on the single-subject level.

Methods

All 181 subjects, published in the HCP 7T Retinotopy Dataset (Benson et al., 2018) were re-analysed using analyzePRF (Kay et al., 2013), similar to the originally published data, but separated according to stimulus type, i.e. the rotating wedge stimulus was combined with the expanding and contracting ring stimulus and the two moving bar stimuli were combined into one stimulus, yielding estimates for Gaussian-shaped pRFs in each grayordinate. Single-subject results were then sampled on a circular grid, using the estimates of the pRF location as inputs, using Gaussian averaging, i.e. grayordinate parameter estimates were averaged at each sampling point using a Gaussian with a full width at half maximum equal to the mean distance between neighbouring sampling points. Group results were then obtained by averaging the single-subject results at each sampling point. This procedure was done twice, once with each of the two stimuli as input. Vector fields were then plotted, pointing from each sampling point to each of the average locations of the pRFs obtained using the other stimulus and colour coded using the average pRF size parameter in both stimuli.

Vector shifts were tested for significance using the Hotelling's t-squared test across subjects and Bonferroni corrected for multpiple comparisons across the number of sampling points.

In order to reduce the influence of the sampling position and a regression to the mean the difference contrast between the two vector maps was also computed.

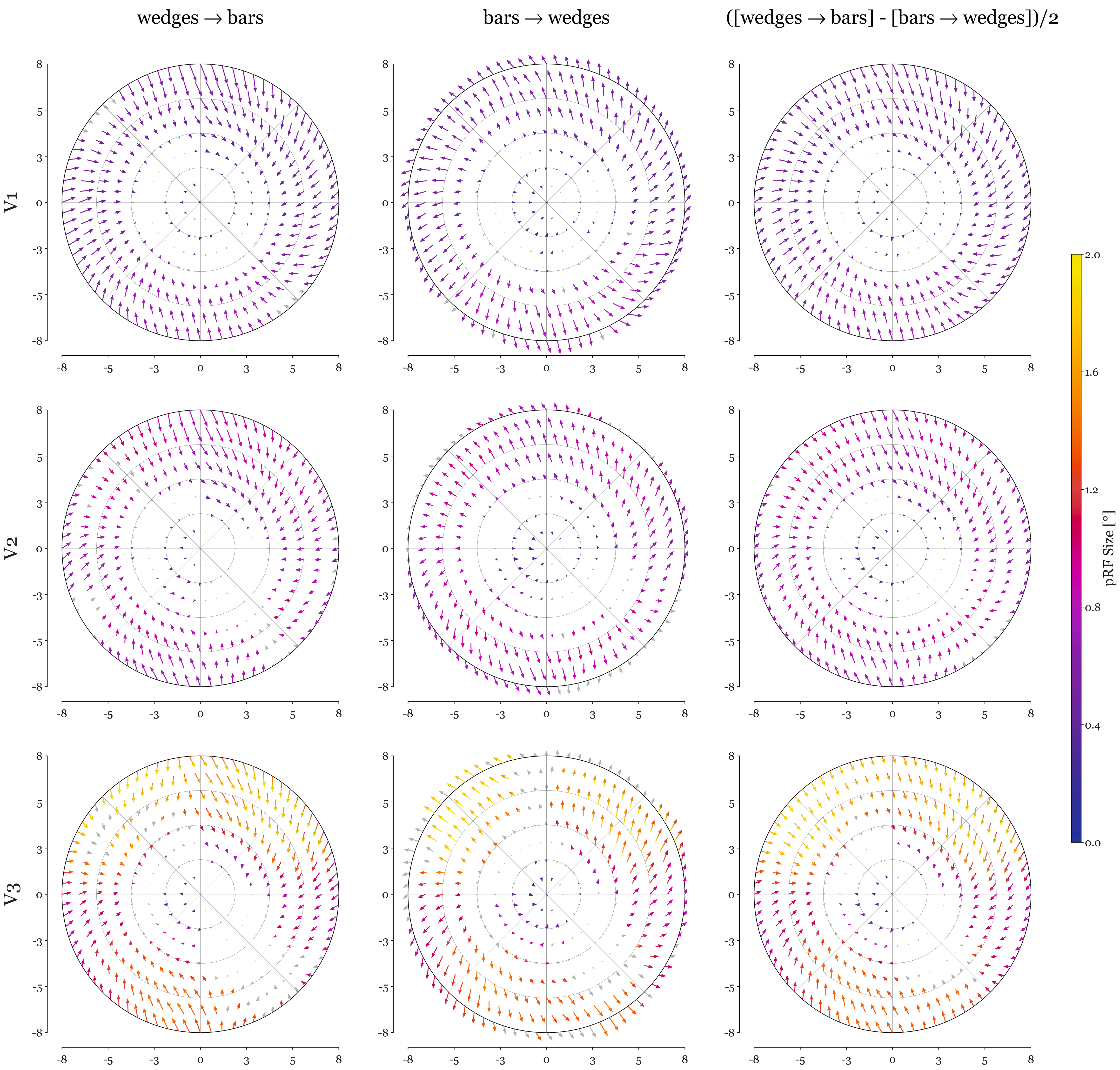

Figure 1 Shifts in the population receptive fields (pRFs) in terms of position and size from the wedge stimulus to the bar stimlus and vice versa for V1, V2 and V3, averaged across subjects as well as the contrast between both vector maps. The shaft of each arrow is at a position determined using one stimlus, while the tip points to the position estimated using the other stimulus. The colour at the shaft represents the size, that is the standard deviation of a 2D Gaussian, of the pRF in one stimulus, while the colour at the tip represents the size of the other stimulus. Arrows that failed a Bonferroni corrected significance test ($p < 0.05$) using a Hotelling's t-squared test are shown in grey. All positions are in degree of the visual field.

Results

The resulting group vector fields can be seen in Figure 1 for V1, V2 and V3. It can be seen, that for all visual regions studied, estimates obtained using the bar stimulus are slightly shifted towards the centre of the visual field for areas outside a 3° radius, while the below 3° radius, pRF centres are estimated in more peripheral areas compared to the combined wedge and ring stimulus. It can also be seen, that the pRFs using the bar stimulus were estimated to be rotated in a clockwise orientation compared to the combined wedge and ring stimulus and counter-clockwise in the reversed condition. Also, pRF sizes tend to increase from V1 to V3 and estimates based on the bar stimulus tend to be higher compared to the combined wedge and ring stimulus.

The results are consistent with respect to sampling site (bar or wedge and ring stimulus), as seen by the contrast plot, suggesting a neglible effect of a regression to the mean.

Conclusion

We have presented a new method for generating group results using pRF estimates and used it to compare two different stimulus configurations in a large, publicly available dataset. The consistent results across the different visual areas, showing differences between the two assessed stimuli, indicating that stimulus selection has a direct effect on the pRF mapping results obtained on a group level. Further research is needed to improve both the stimulus as well as the analysis in pRF mapping to ensure optimal coverage of the visual field with reliable results that are independent of the data acquisition approach.

References

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