YORK U
VISTA
VISION: SCIENCE TO APPLICATIONS
Centre for Vision Research

Spatial Tuning of Visual Responses to Symmetries in Textures

Yara Iskandar[1], Christopher Lee[2], Sebastian Bosse[3], Peter J Kohler[1]

[1]Dept. of Psychology and Center for Vision Research, York University, Toronto, ON, [2]Image Design Inc., [3]Fraunhofer HHI, Berlin, Germany

kohler visual neuroscience lab
york university, toronto

BACKGROUND

The importance of symmetry for many domains of visual perception[1] has led to an interest in understanding the brain mechanisms involved.

We explored the spatial mechanisms underlying symmetry responses, by measuring Steady-State Visual Evoked Potentials (SSVEPs) using high-density electroencephalography (EEG).

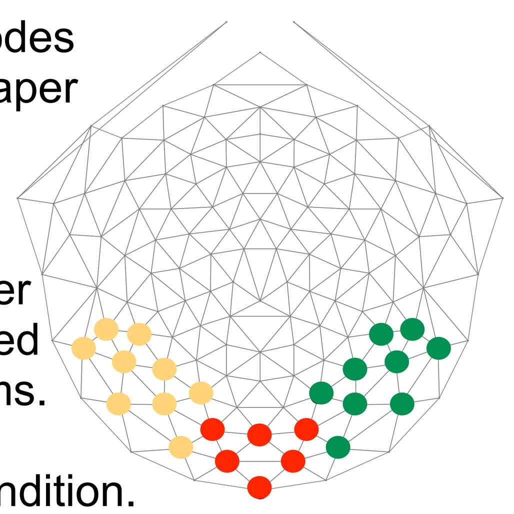
Our stimuli were exemplars from a class of regular textures - wallpaper patterns - that have previously been shown to generate robust symmetry-specific responses in visual cortex.[2]

- Experiment 1 tested the influence of spatial frequency content, similar to previous work with single-axis reflection symmetry.[3]
- Experiment 2 tested the influence of the repeating lattice structure that tiles the plane in all wallpaper groups.
- Experiment 3 was a replication of Experiment 1, with more carefully selected stimuli.

METHODS

We focused on wallpaper groups *PMM*, which contains bilateral reflection symmetry, and *P4*, which contains 4-fold rotation symmetry.

EEG data was collected from 128 electrodes as participants observed exemplar wallpaper stimuli.



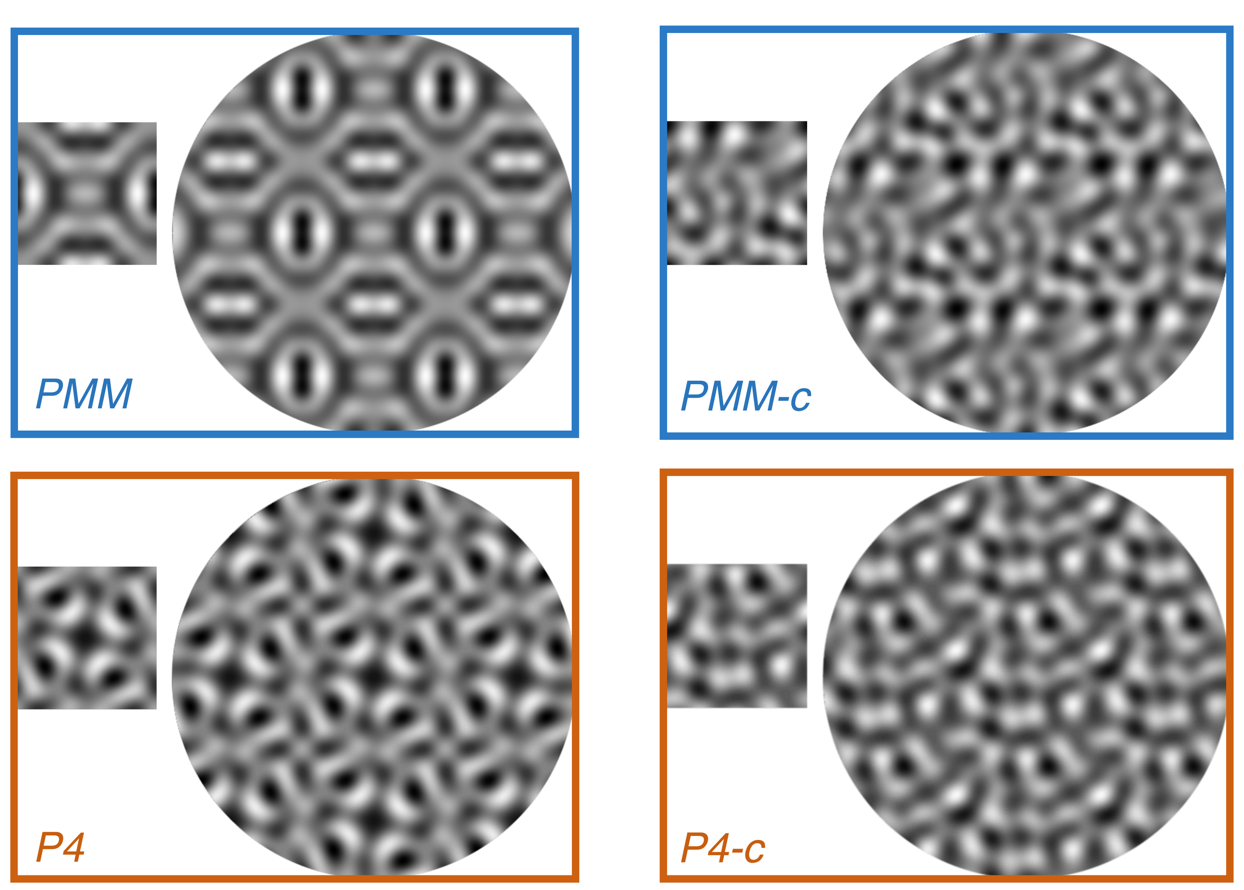
We used a 1 sec stimuli cycle in which control images matched to each wallpaper exemplar were shown for 500 ms, followed by the wallpaper exemplar for next 500 ms.

8 distinct conditions, with 20 trials per condition.

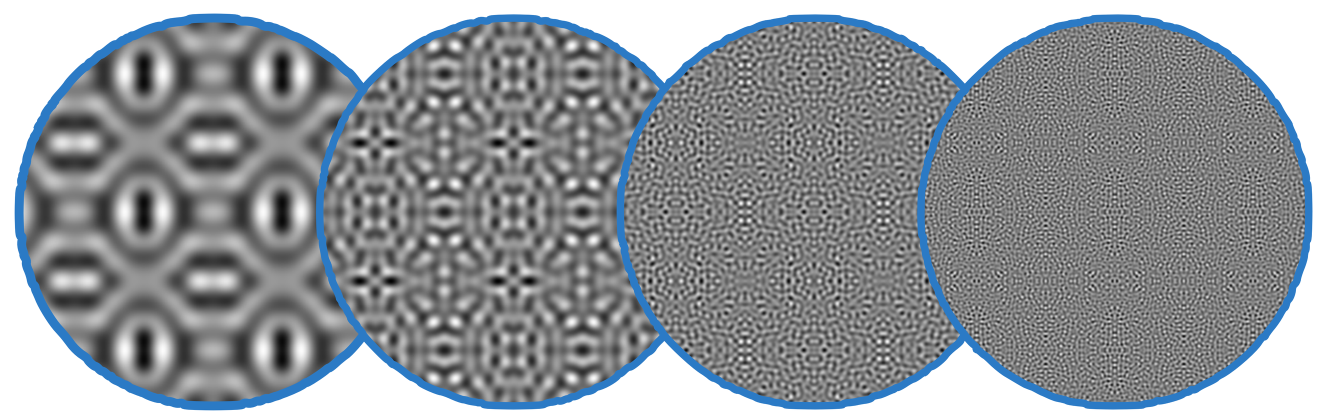
Here we present data from an electrode region-of-interest over left temporal cortex, occipital cortex, and right temporal cortex.

Wallpaper Groups

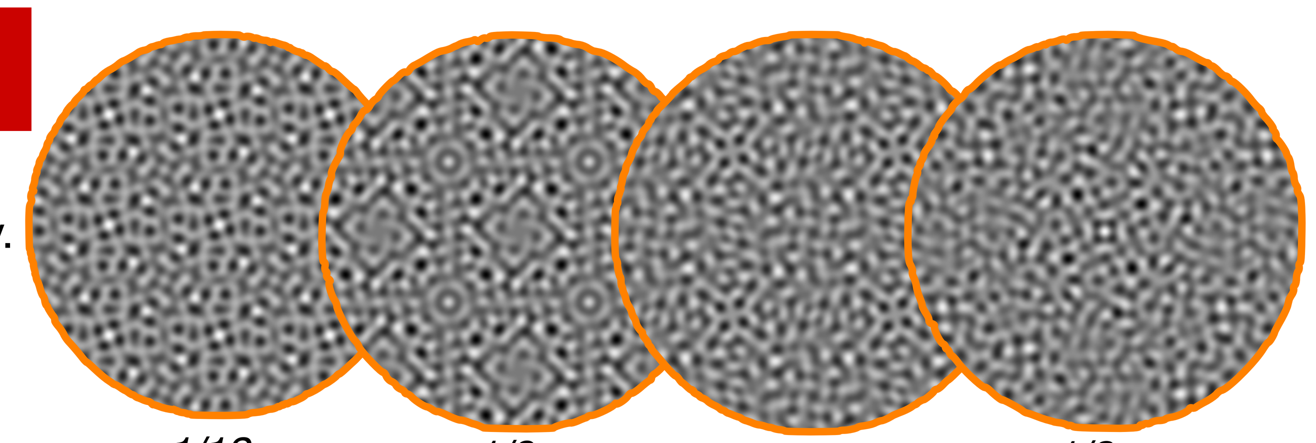
Wallpaper groups: 17 unique combinations of symmetry types that represent the complete set of symmetries in 2D images.



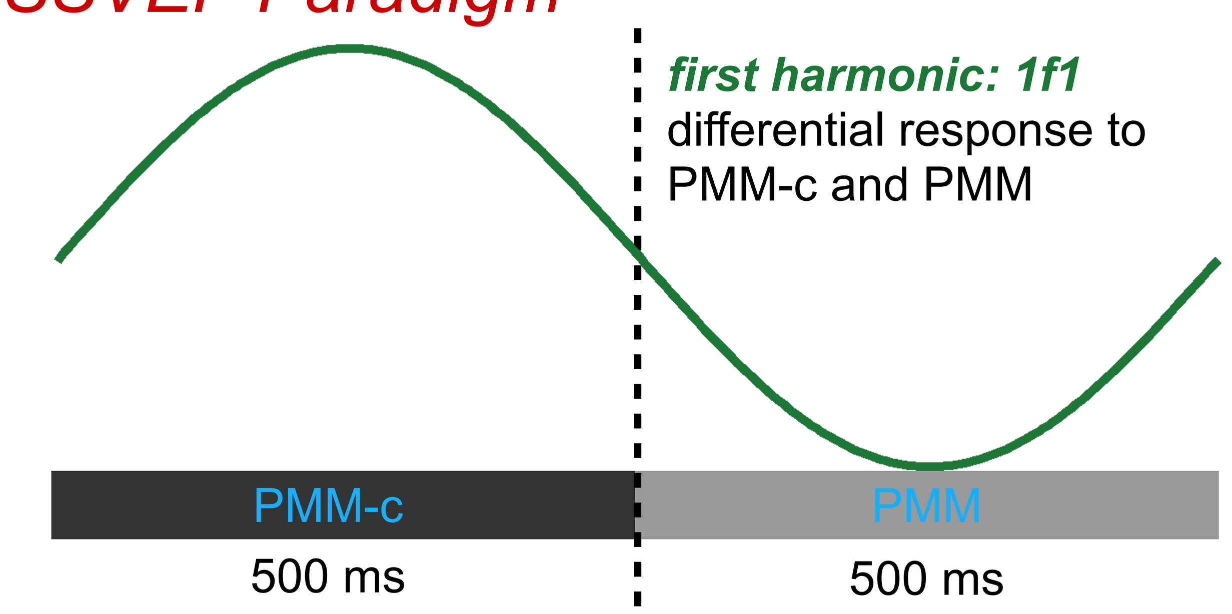
Experiment 1 & 3: *Spatial Frequency (n = 40 / 23)*
Images were generated based on log-domain band-limited random noise patches with centre frequencies varying between 1 and 8 cycles-per-degree (cpd), lattice ratio was constant (1/8).



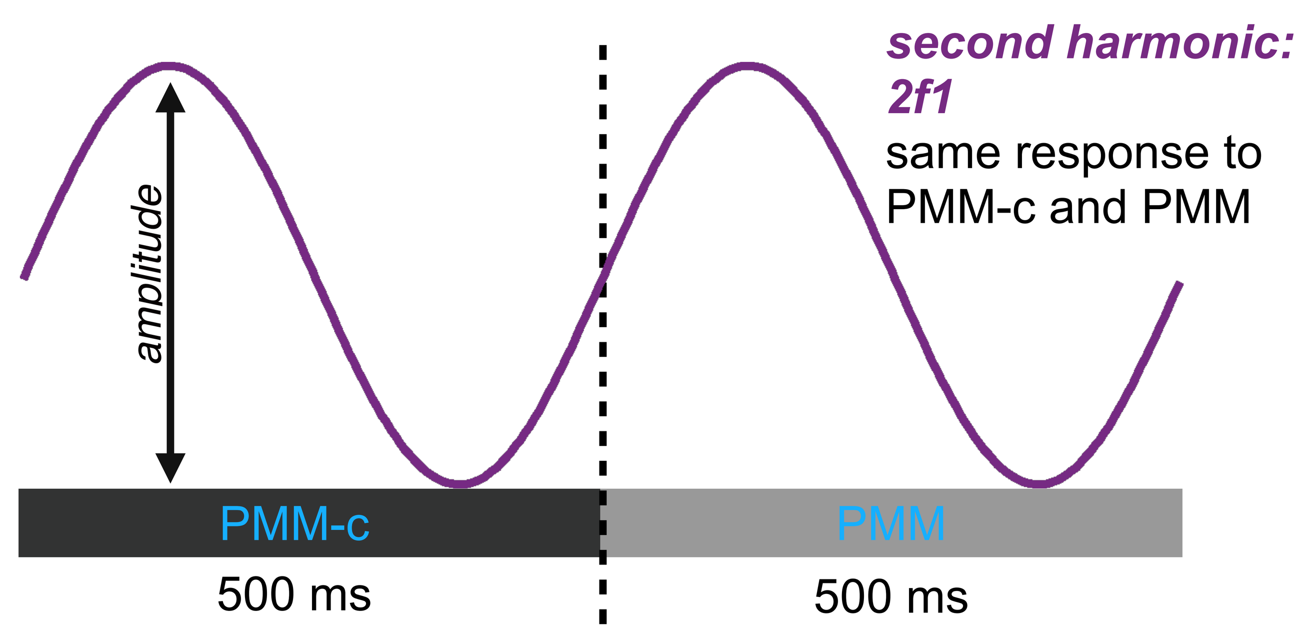
Experiment 2: *Ratio (n = 28)*
For the lattice ratio experiment, spatial frequency was kept constant at 2 cpd and the ratio of the lattice to the overall wallpaper area varied between 1/12 and 1/2.



SSVEP Paradigm



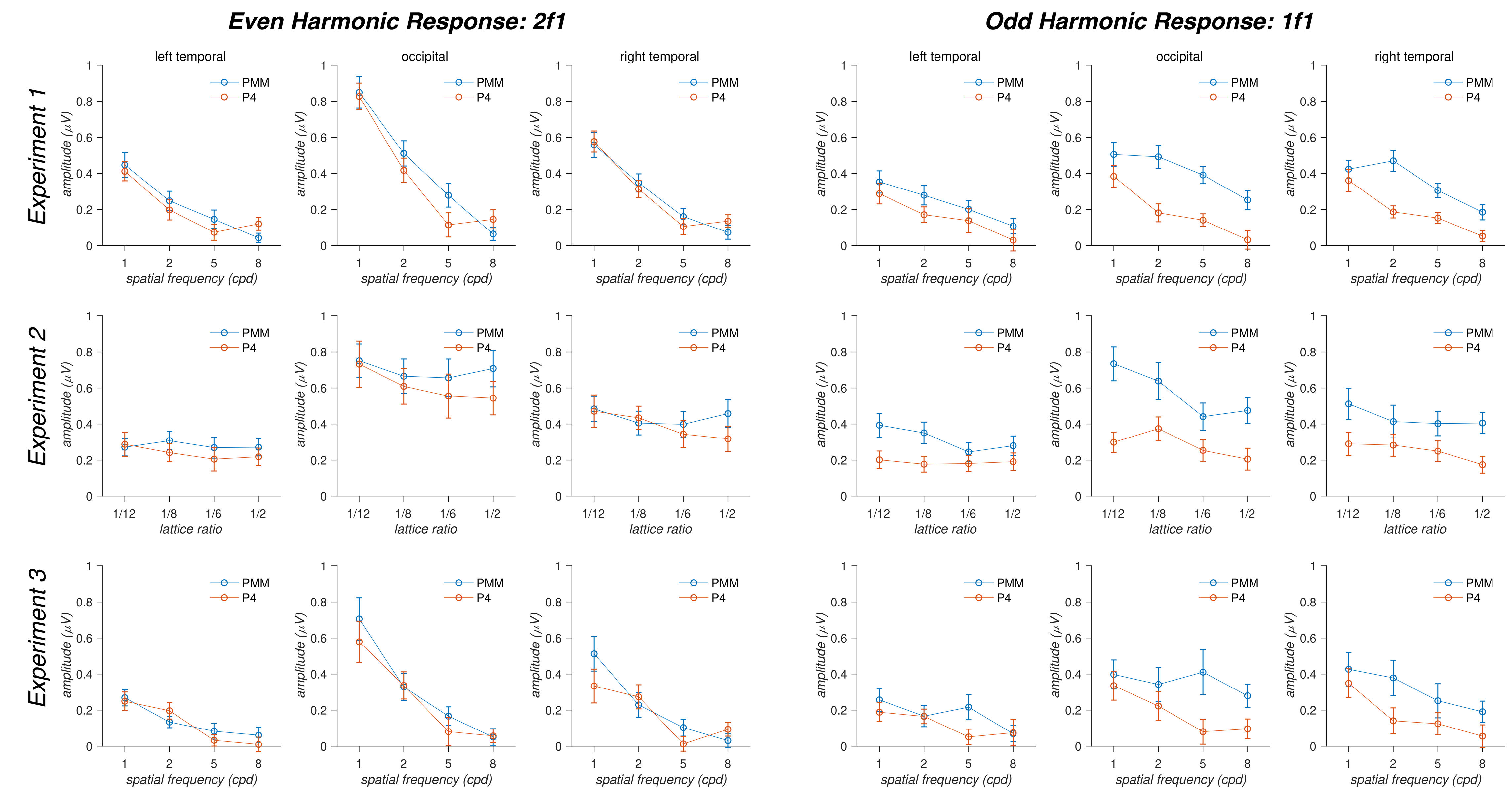
Odd Harmonics: Reflect symmetry-specific responses[2] *1f1, 3f1, 5f1, 7f1*



Even Harmonics: Reflect low-level visual processing *2f1, 4f1, 6f1, 8f1*

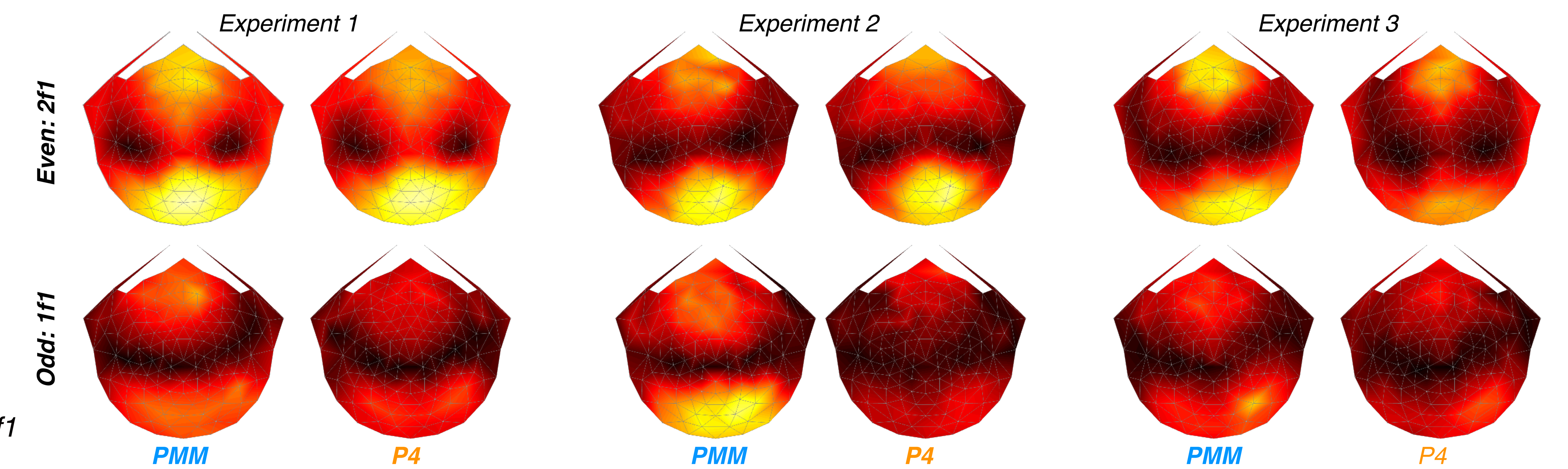
RESULTS

Single-cycle average timeseries were Fourier transformed into the spectral domain. Here we are plotting the first (1f1) and the second (2f1) harmonic. Based on previous findings, we expect the symmetry response to be isolated in the odd harmonics, whereas the even harmonics should capture an image-update response reflecting more generalized processing.



Topographies

Whole-scalp topographies were created by plotting the amplitude of the frequency components.



CONCLUSIONS

Responses to reflection and rotation symmetries in wallpaper groups are highly dependent on spatial frequency, and were strongest at low spatial frequencies.[3]

Low-level responses *not* related to symmetry, as captured by the even harmonics, also varied strongly with spatial frequency.

Topographies reveal a possible right lateralization for symmetries which are most prominent at low spatial frequencies and smaller lattice scales.

References

1. Bertamini, M., Silvanto, J., Norcia, A. M., Makin, A. D. J., & Wagemans, J. (2018). The neural basis of visual symmetry and its role in mid- and high-level visual processing. *Annals of the New York Academy of Sciences*, *1426*(1), 111–126.
2. Kohler, P. J., Clarke, A., Yakovleva, A., Liu, Y., & Norcia, A. M. (2016). Representation of Maximally Regular Textures in Human Visual Cortex. *The Journal of Neuroscience*, *36*(3), 714–729.
3. Dakin, S. C., & Hess, R. F. (1997). The spatial mechanisms mediating symmetry perception. *Vision Research*, *37*(20), 2915–2930.