Spatial Mechanisms Mediating Visual Responses to Symmetries in Textures

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Background

Symmetry has been shown to play a role in numerous domains of visual perception.[1]

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 symmetric-specific responses in visual cortex.[2]

We examined symmetry responses in two experiments: The first tested the influence of spatial frequency content, similar to previous work with single-axis reflection symmetry.[3] The second tested the influence of the repeating lattice structure that tiles the plane in all wallpaper groups.

Methods

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

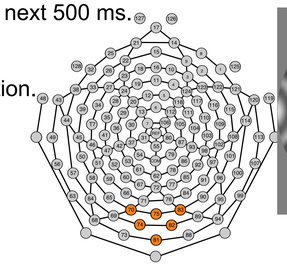
We focused on wallpaper groups *PMM*, which contains bilateral reflection symmetry, and *P4*, which contains four-fold rotation symmetry.

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.

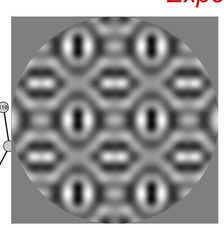
Here we present data from an electrode region-of-interest over occipital cortex.



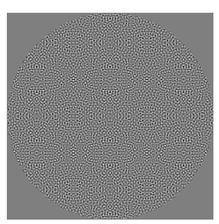
Experiment 1: *Spatial Frequency (n = 40)*
Images were generated based on log-domain band-limited random noise patches with centre frequencies varying between 1 and 8 cycles-per-degree (cpd), lattice ratio (see below) was held constant at 1/8.

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

Experiment 1

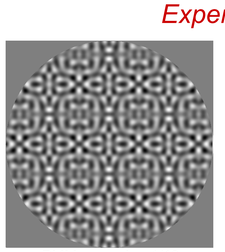


PMM exemplar: 1cpd

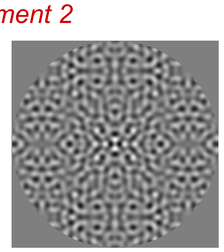


PMM exemplar: 8cpd

Experiment 2



PMM exemplar: 1/12

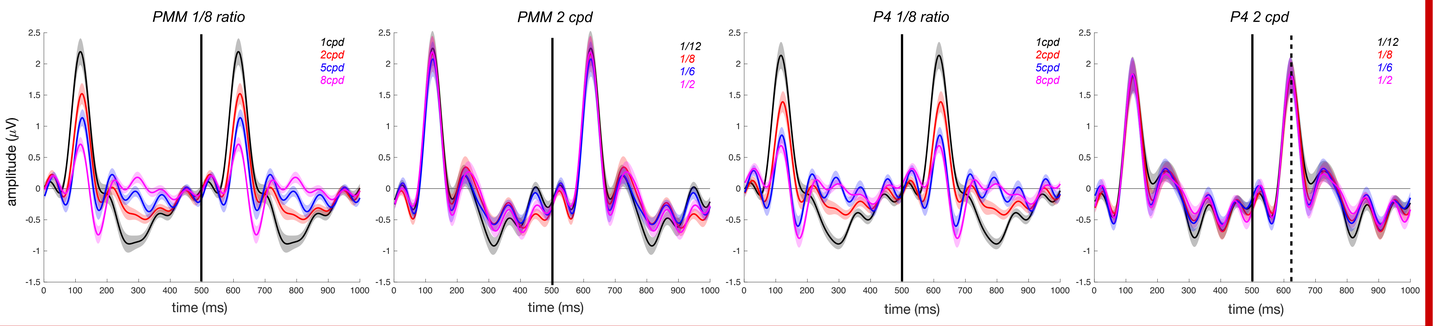


PMM exemplar: 1/2

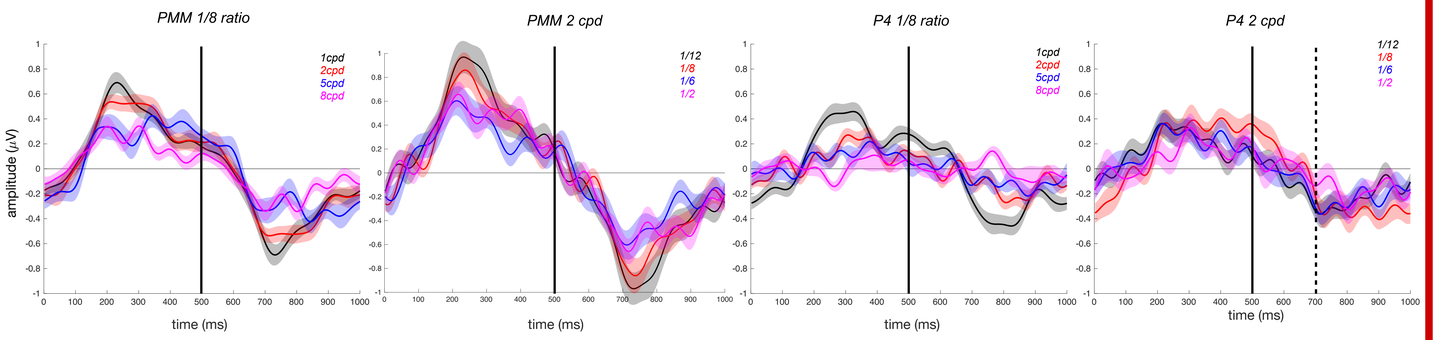
Results

SSVEP data were filtered in the spectral domain and then projected back into the time domain to generate single-cycle averages. Filtering was done separately for the first six odd and even harmonics.
Based on previous data, we expect the response to symmetries in the wallpapers to be isolated in the odd harmonics.

Even Harmonics

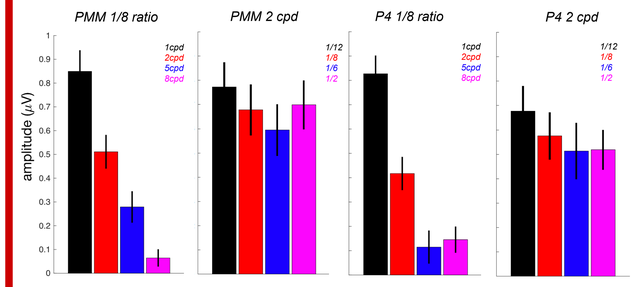


Odd Harmonics



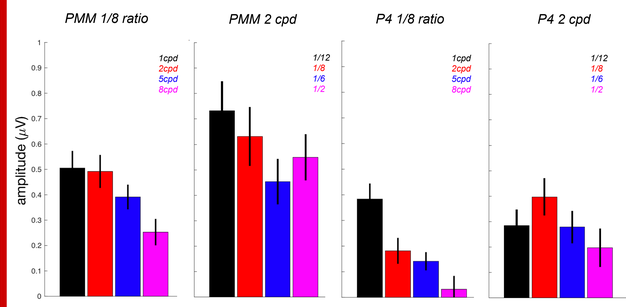
Results

Even harmonic response: 2f1



Even harmonic response varies strongly with spatial frequency content, but much less so with ratio.

Odd harmonic response: 1f1

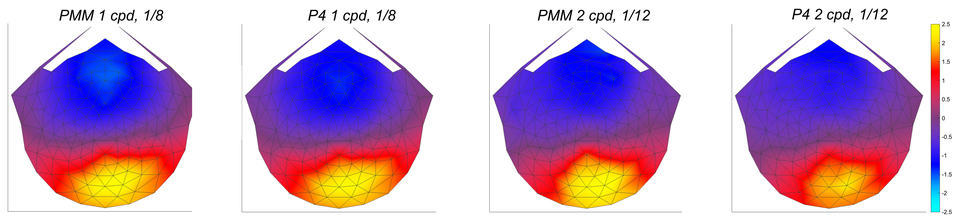


Odd harmonic response varies between PMM and P4, and both spatial frequency and ratio appears to have differential effects on PMM and P4 responses.

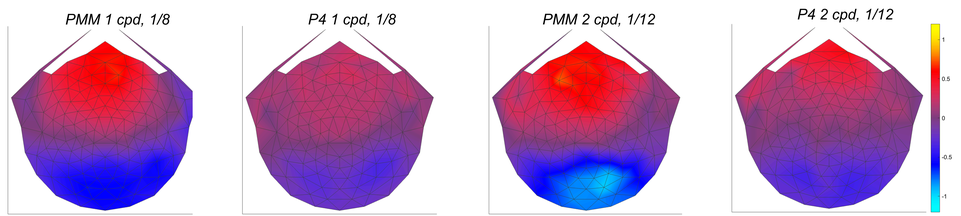
Results: Topographies

Whole-scalp topographies based on filtered waveform data at 700 ms for the odd harmonics and at 600 ms for the even harmonics.

Even Harmonics



Odd Harmonics



Conclusion

Responses to reflection and rotations 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.

The effect of ratio was less pronounced in both odd and even harmonics.

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.
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3. Dakin, S. C., & Hess, R. F. (1997). The spatial mechanisms mediating symmetry perception. *Vision Research*, *37*(20), 2915–2930.