Brain Responses to Symmetry in Early Infancy

Aurore Maloh[1,2], Lara Pierce[1], & Peter J. Kohler[1,2]

[1]Department of Psychology, York University, ON; [2]Centre for Vision Research, York University, ON

Background

Visual symmetry is a fundamental property of environments and supports object recognition and perceptual organization.

Early behavioural studies show that infants can discriminate visual patterns[1] and are sensitive to reflection symmetry[2].

Adult brain imaging studies show that **wallpaper groups** - 17 regular textures that comprise the complete set of possible symmetries in the 2D plane - elicit strong symmetry-specific responses[3], with stronger responses to reflection than rotation[4].

It remains unclear whether brain responses to symmetry are present in early infancy, and whether infants show differential sensitivity to reflection (PMM) versus rotation (P4) symmetry.

Research Questions:

1. How do infant brains respond to visual symmetry, specifically reflection (PMM) versus rotation (P4)?
2. Does sensitivity to reflection symmetry emerge early in development or arise later with visual experience?

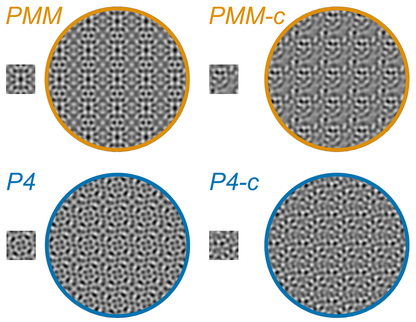
Stimuli

Stimuli were generated using an algorithm that produces near-infinite exemplars from each wallpaper group by varying a random noise seed region. Each wallpaper group consists of a repeating lattice that tiles the image. Stimuli were controlled for low-level properties, including the ratio of lattice area (1/8) and spatial frequency content (1 cpd).

2 conditions were used:

- PMM: reflection symmetry
- P4: rotation symmetry

A phase-scrambled control was created for each exemplar, preserving low-level properties while removing global symmetry structure.



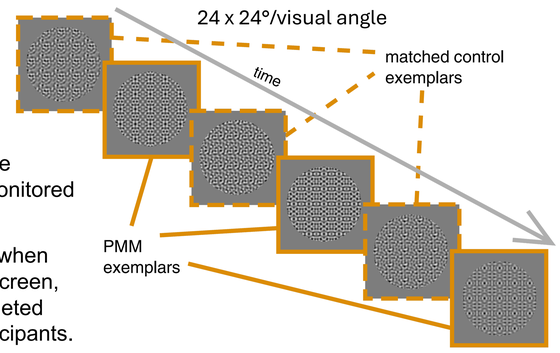
Experiment Design

Stimuli alternated periodically between a wallpaper group exemplar and a matched phase-scrambled control image, to elicit Steady-State Visual Evoked Potential (SSVEP)[5] responses from the visual cortex. Each image was shown for 500 ms for a stimulus update rate of 1 Hz. Each trial consisted of 10 cycles, and the first and last cycles were excluded from analysis. PMM and P4 conditions were presented in separate trials in randomized order.

21 infants (2-9 months) were recruited via social media, mom groups and word of mouth.

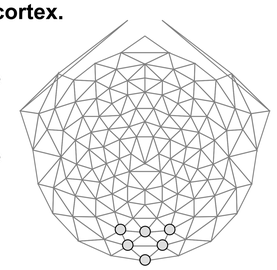
They completed a passive viewing task and were monitored throughout.

Trials were initiated only when calm and looking at the screen, with the number of completed trials varying across participants.



Analysis

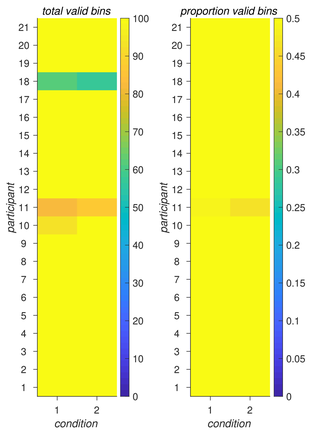
Data was collected using a 124-electrode Hydrocell Geodesic Sensor Net (Magstim EGI). **Our analysis focuses on six electrodes over the occipital cortex.**



SSVEPs data was filtered in the spectral domain and then projected back into the time domain to generate single-cycle average timecourses. The first six odd and even harmonics were filtered separately.

- *Even harmonics:* capture brain responses common to both symmetry and control images, driven mainly by low-level image-update responses.
- *Odd harmonics:* capture differential responses between symmetry and control images, isolating symmetry-specific brain responses.

Infant Results



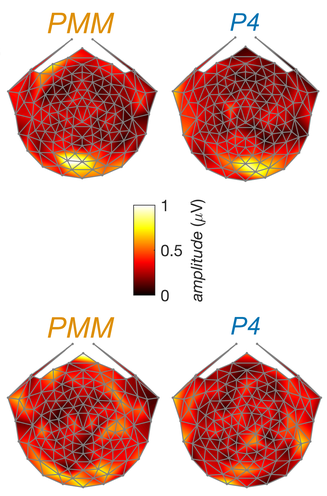
Some variability in the amount and proportion of usable data across participants

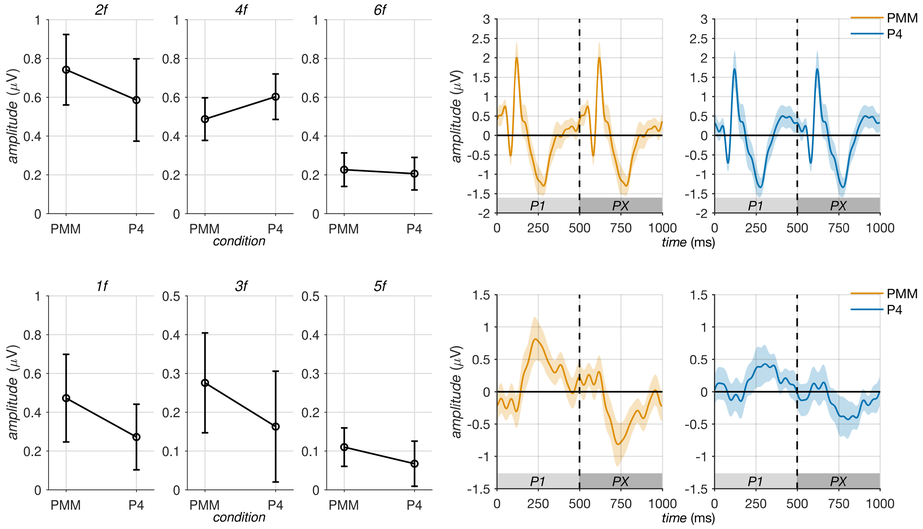
Even Harmonics

- localized occipital responses for both conditions
- comparable amplitudes across harmonics
- clear image-update responses, similar waveforms across PMM and P4

Odd Harmonics

- occipital responses for PMM and P4
- stronger PMM response across harmonics
- measurable symmetry responses for PMM and P4





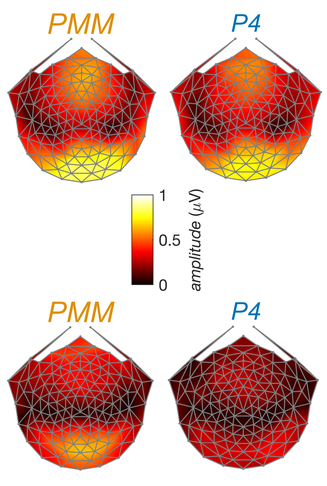
Adult Comparison Results

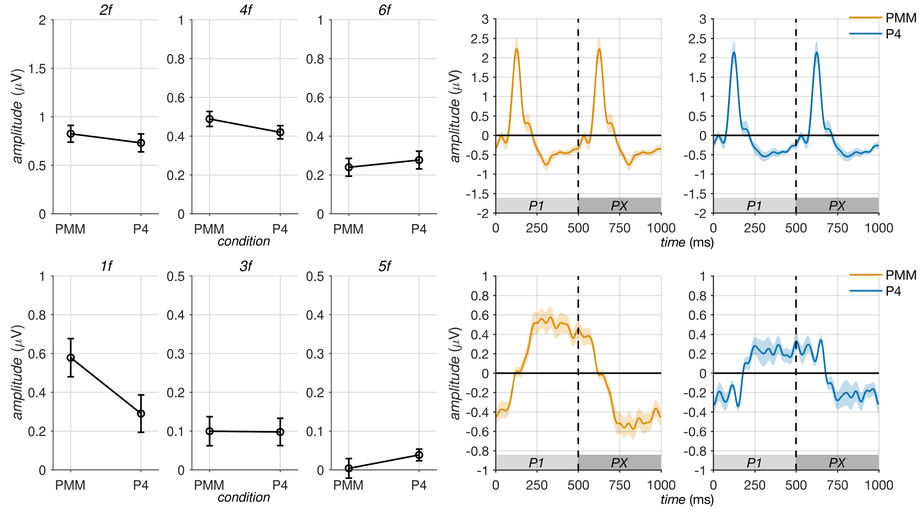
Even Harmonics

- localized occipital responses for both conditions
- comparable amplitudes across harmonics
- clear image-update responses, similar waveforms across PMM and P4

Odd Harmonics

- occipital responses more localized for PMM
- stronger responses for PMM than P4, particularly at the 1st harmonic
- clear symmetry responses across conditions, slightly stronger for PMM





Discussion

Results revealed robust image onset responses for PMM and P4, indicating that infants were generally equally willing to look at the screen for both conditions.

Measurable responses to reflection and rotation symmetry were also found in infants, with stronger responses observed for reflection than rotation.

To our knowledge, these are the first measurements of brain responses to symmetry in early infancy.

Future work may include an age-by-response strength analysis to compare symmetry responses across different infant age groups.

References

1. Fantz, R. L. (1958). Pattern Vision in Young Infants. *The Psychological Record*, 8, 43.
2. Humphrey, G.K., & Humphrey, D.E. (1989). The role of structure in infant visual pattern perception. *Can. J. Psychol. Rev. Can. Psychol.* 43, (165–182).
3. Kohler, P.J., Clarke, A, Yakovleva, A, Liu, Y & Norcia, A.M. (2016). Representation of Maximally Regular Textures in Human Visual Cortex. *J. Neurosci.* 36, (714–729).
4. Kohler, P.J., Samet, S, Iskandar, Y & Pierce, L (2023). Brain responses to symmetry during early infancy. *J. Vis.* 23, 5576.
5. Norcia, A. M., Appelbaum, L. G., Ales, J. M., Cottereau, B. R. & Rossion, B. (2015). The steady-state visual evoked potential in vision research: A review. *J. Vis.* 15, 4.