Brain Responses to Symmetry during Early Infancy

Peter J. Kohler[1,2], Shaya Samet[1,2], Yara Iskandar[1,2], & Lara Pierce[1]

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

Supported by The Natural Sciences and Engineering Research Council of Canada,
The Canada First Research Excellence Fund, and The Faculty of Health at York University

Vision Sciences Society 2023 **Poster 36.303**

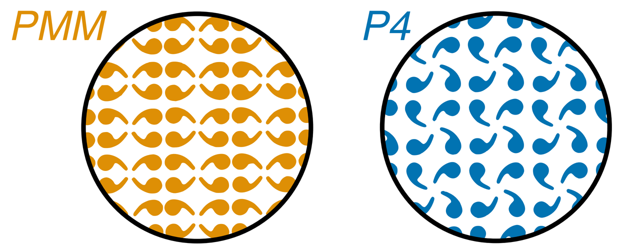
Background

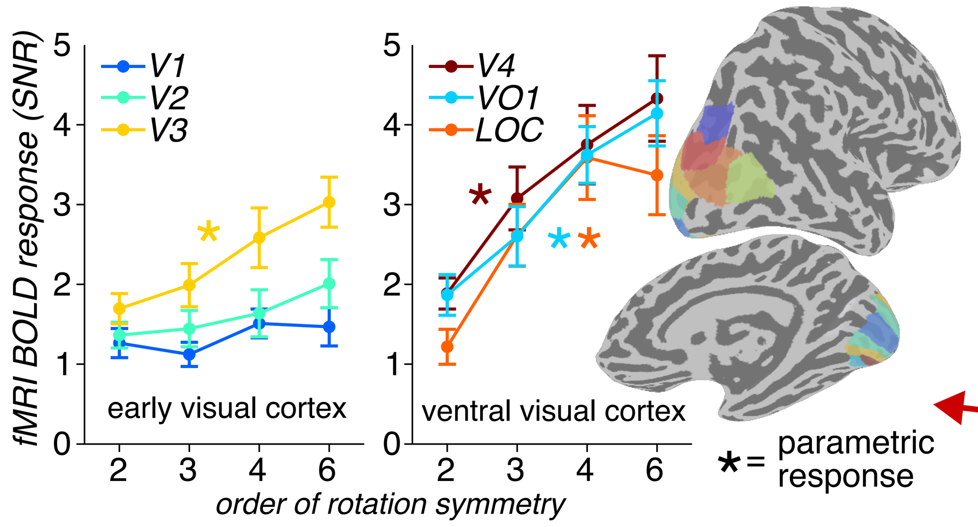
Humans and other animals are highly sensitive to symmetries in their environment, and vision research has demonstrated the symmetry is an important cue to perception of objects and scenes.

Is sensitivity to symmetry innate or does it arise over early development due to exposure to symmetries in the visual environment?

There is behavioral evidence for reflection symmetry sensitivity in infants, primarily using preferential-looking paradigms[1]. Here we build on this work by using high-density EEG to measure symmetry responses from 3-month-old infants.

We use stimuli from a class of regular textures known as wallpaper groups – a set of 17 unique combinations of symmetry types. We focus on two groups that prominently feature reflection and rotation symmetries, respectively.





The visual cortex of both humans[3] and macaques[4] responds strongly to reflection and rotation symmetries in wallpaper group textures.

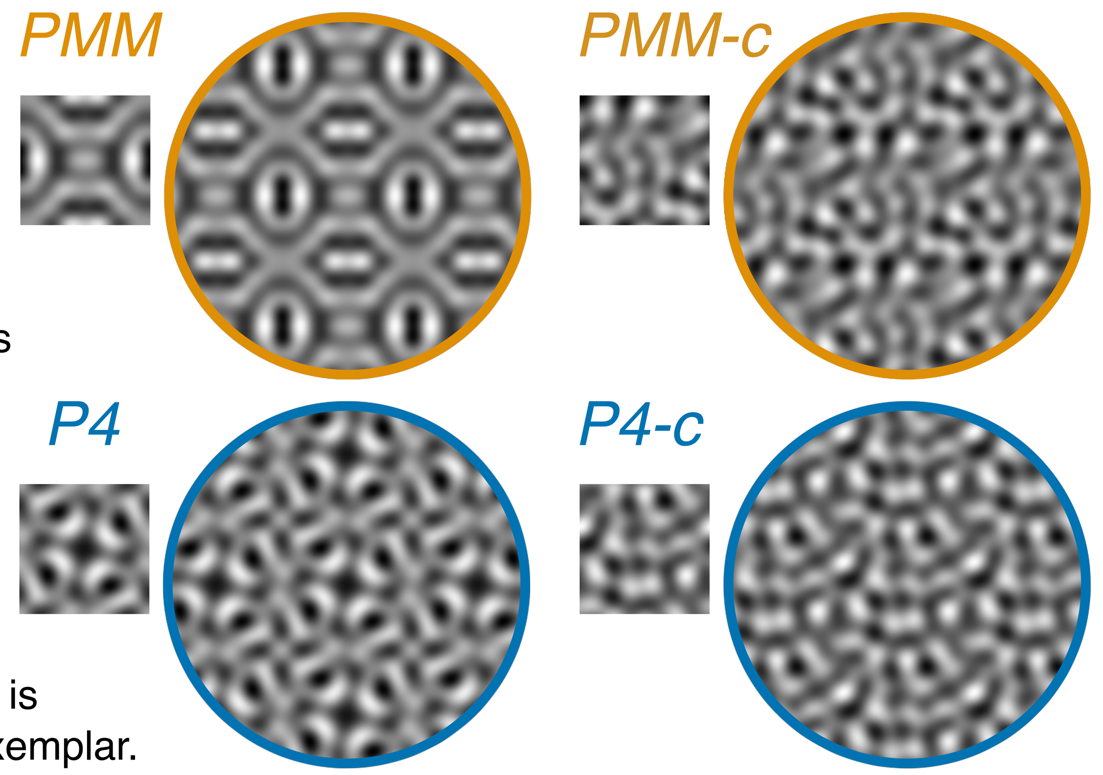
data from Kohler et al. (*J. Neurosci.*, 2016)

Here we use a Steady-State Visual Evoked Potentials (SSVEPs)[4] paradigm that allows us to isolate brain responses that are driven by symmetries in our textures[3].

Stimuli

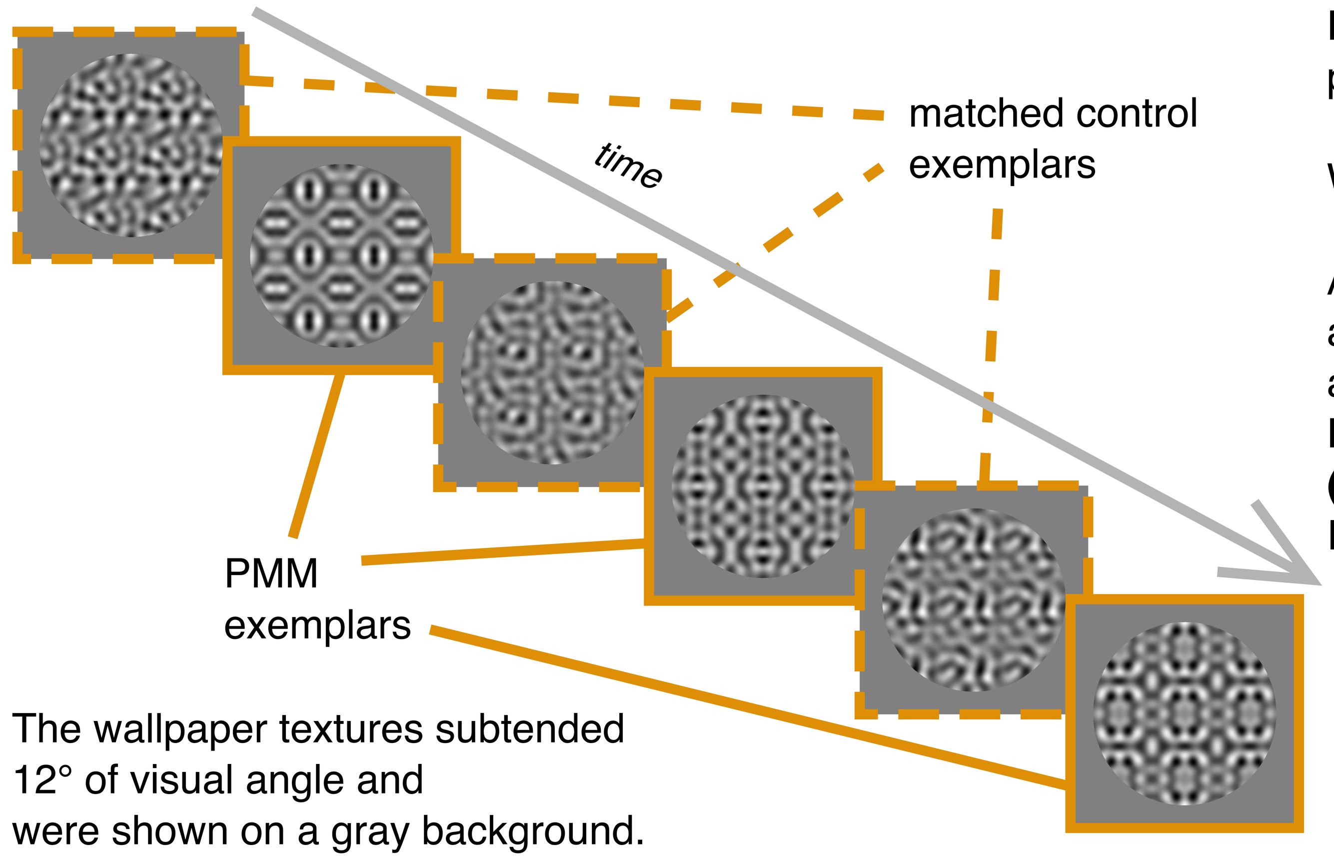
Our stimuli were generated using an algorithm which allows us to generate a near-infinite number of exemplars from each wallpaper group by varying a random-noise seed region. Each wallpaper group consists of a lattice that is repeated to tile the plane. Our algorithm allows us to control the ratio of the lattice area to the overall wallpaper (1/8) and the spatial frequency content (1 cpd).

We used a phase-scrambling procedure to generate controls for each PMM and P4 exemplar that were matched in terms of low-level visual properties. Here we show exemplars from each wallpaper group with their matched exemplars. The lattice is shown next to each exemplar.



Experiment Design

Stimuli were shown periodically to elicit periodic SSVEP responses from visual cortex. A stimulus cycle consisted of a wallpaper group exemplar followed by a matched control exemplar. Each image was shown for 500 ms for a stimulus update rate of 1 Hz. We presented 10 cycles per trial, and the first and last cycle were excluded from further analysis.



The wallpaper textures subtended 12° of visual angle and were shown on a gray background.

PMM and P4 conditions were shown in separate trials, presented in random order.

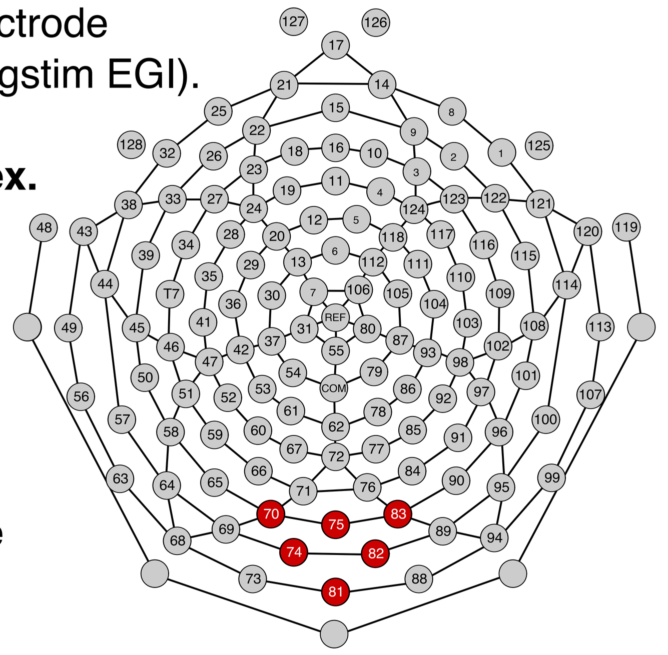
We ran 40 adult participants and 4 infants - so far.

Adult participants completed 20 trials per condition as part of a larger experiment in which the ratio and spatial frequency content was varied for both PMM and P4 across conditions **(presented by Yara Iskandar, talk 31.12).**
Infant participants completed 25-35 trials per condition.

There was no task. Adult participants were told to maintain fixation at the center of the screen. Infants were monitored during the EEG recording and trials were not initiated until they were calm and looking at the screen.

Data Analysis

Data were collected using a 128-electrode Hydrocell Geodesic Sensor Net (Magstim EGI). **Our analysis focuses on six electrodes over occipital cortex.**



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

The even harmonics capture brain responses that are the same for the symmetry exemplars and the matched control exemplars.
Even harmonics will capture relatively low-level image-update responses.

The odd harmonics capture brain responses that differ between the symmetry exemplars and the control exemplars. The response to symmetries in the wallpaper groups will be isolated in the odd harmonics[2].

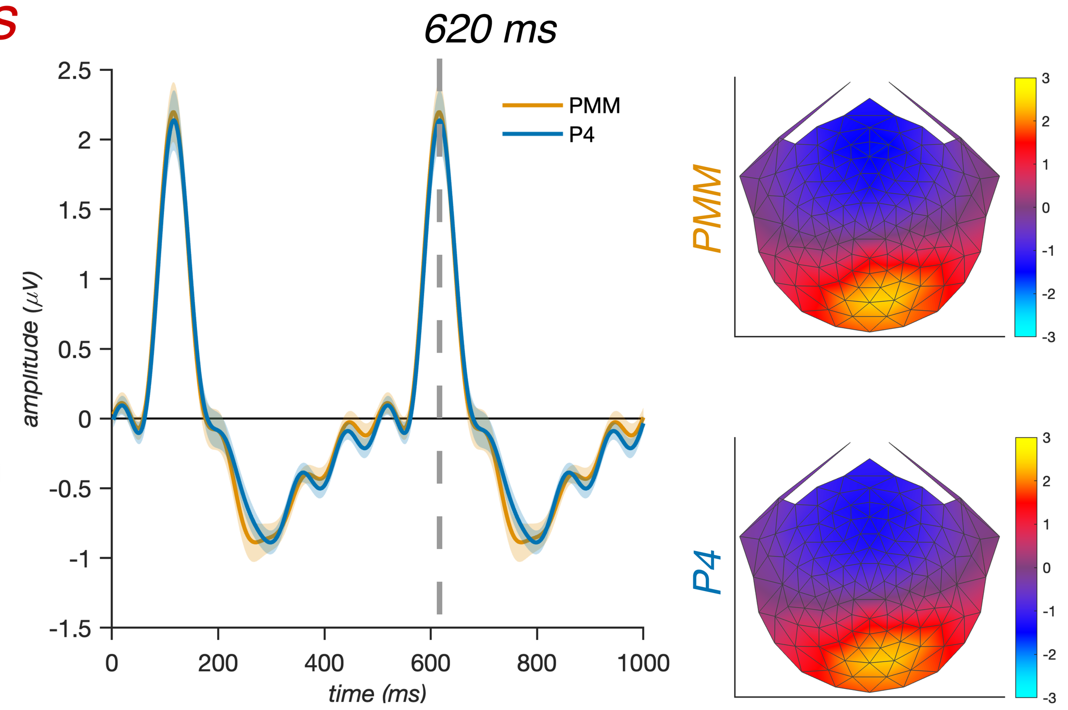
Adult Data

Even Harmonics

image onset response peaking ~120 ms after the image update

no difference between P4 and PMM

topography centered on early visual cortex

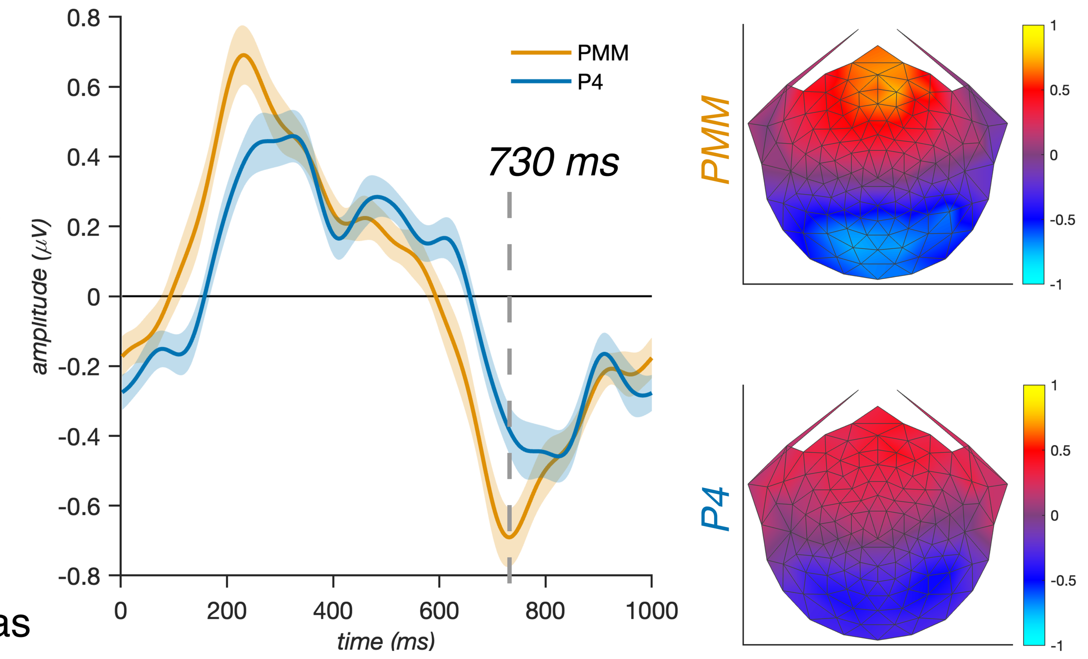


Odd Harmonics

symmetry response peaking ~230 ms after the image update

difference in amplitude and possibly phase between PMM and P4

topography perhaps slightly broader, consistent with the involvement of higher-level visual areas



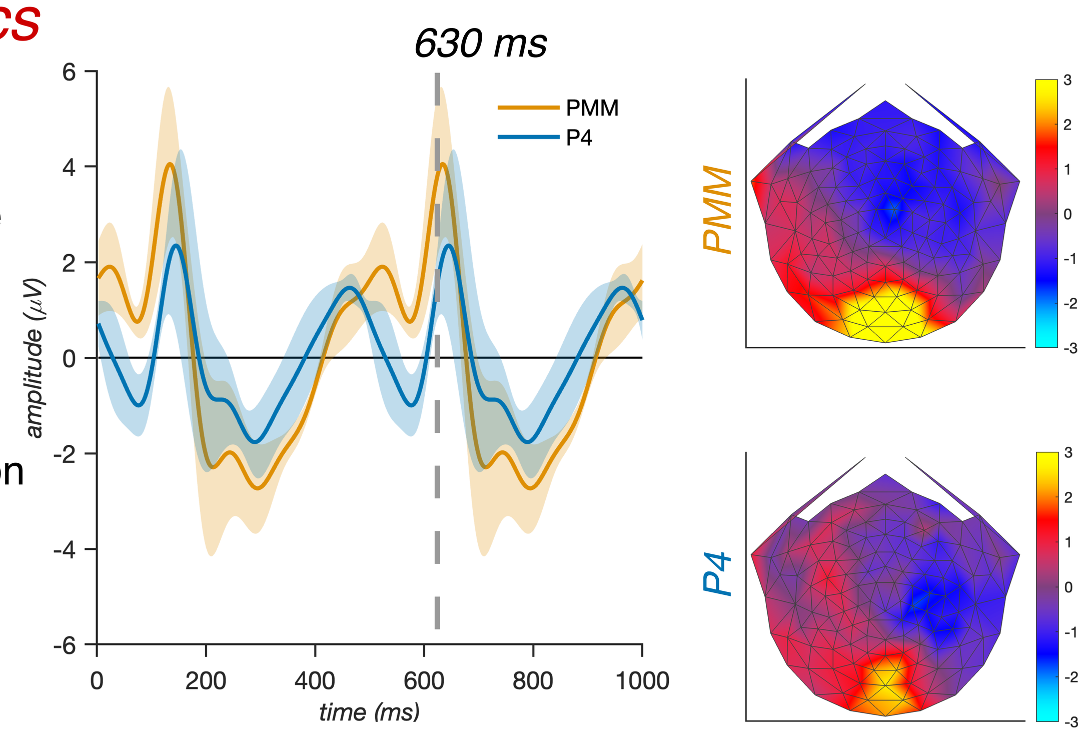
Infant Data

Even Harmonics

image onset response peaking ~130 ms after the image update

no difference between P4 and PMM

topography centered on early visual cortex

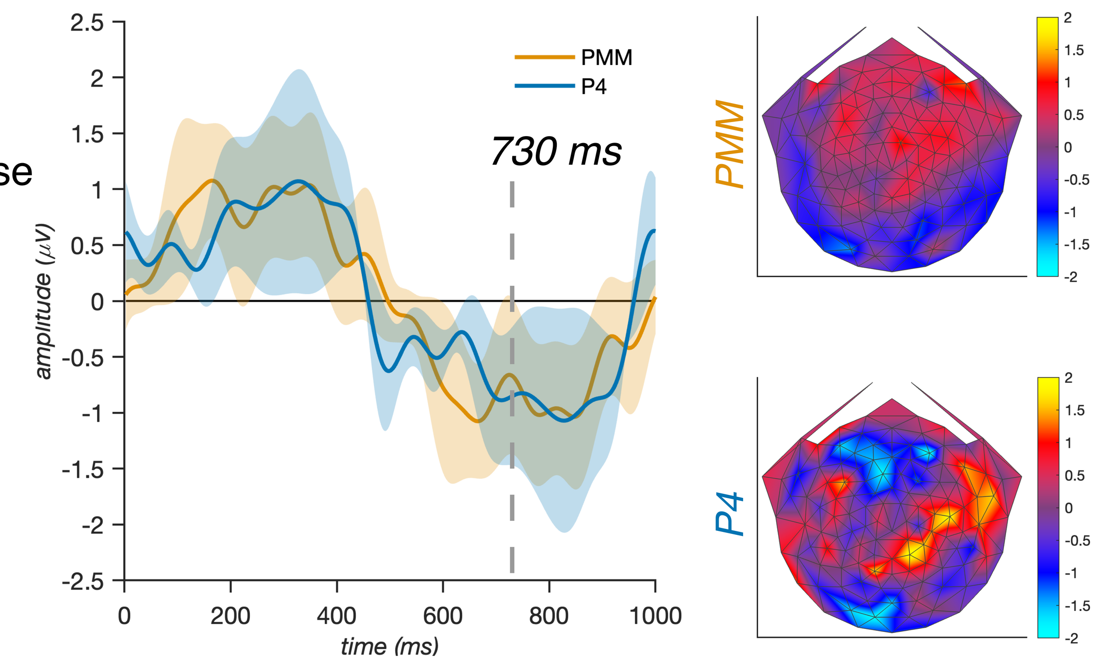


Odd Harmonics

hint of a symmetry response peaking ~230 ms after the image update response

no clear difference in amplitude or phase

we need more data to say anything definitive about the topography

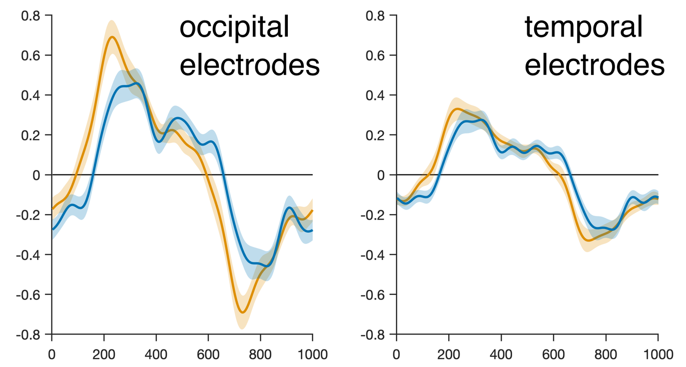


Conclusions

Adults

higher amplitude symmetry responses for reflection (PMM) than rotation (P4). This is consistent with prior work using both wallpaper groups and more standard symmetry patterns.

phase difference between reflection and rotation may indicate differences in the temporal dynamics of the underlying mechanism.



interestingly, amplitude difference largely goes away when looking at data from electrodes over temporal cortex.

Infants

results are *very* preliminary, we need more participants.

hint of a symmetry response - may be substantial individual variability.

no clear difference between PMM and P4 - perhaps advantage for reflection arises over development.

References

1. Humphrey, GK & Humphrey, DE (1989). The role of structure in infant visual pattern perception. *Can. J. Psychol. Rev. Can. Psychol.* **43**, (165–182).
2. Kohler, PJ, Clarke, A, Yakovleva, A, Liu, Y & Norcia, AM (2016). Representation of Maximally Regular Textures in Human Visual Cortex. *J. Neurosci.* **36**, (714–729).
3. Audurier, P. et al. Symmetry Processing in the Macaque Visual Cortex (2021). *Cereb. Cortex* **32** (2277–2290).
4. 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.