Symmetry responses in marmoset visual cortex measured with SSVEPs

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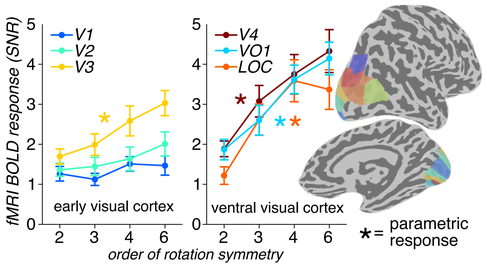
Background

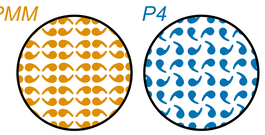
Humans and other animals are highly sensitive to symmetries in their environment.
Vision research has demonstrated that symmetry is an important cue to perception of objects and scenes.

Brain imaging experiments have shown that the visual cortex of both humans[1,2] and macaques[3] respond strongly to reflection and rotation symmetries.



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

Here we use steady-state EEG to test if symmetry produces similar brain responses in another non-human primate species, common marmosets (Callithrix jacchus).

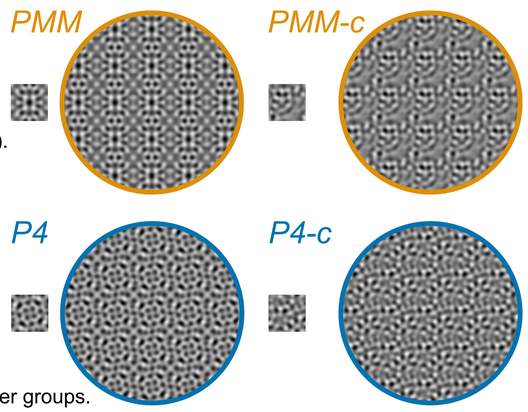


We use stimuli from a class of regular textures known as wallpaper groups – a set of 17 unique combinations of symmetry types.
We focus on two groups that prominently feature reflection and rotation symmetries.

Stimuli

Multiple distinct exemplars from each wallpaper group were generated based on varying random-noise seed regions that enable rich variability across exemplars.

Each wallpaper group consists of a lattice that is repeated to tile the plane. We controlled the ratio of the lattice area to the overall wallpaper (1/25) and the spatial frequency content (1 cpd).

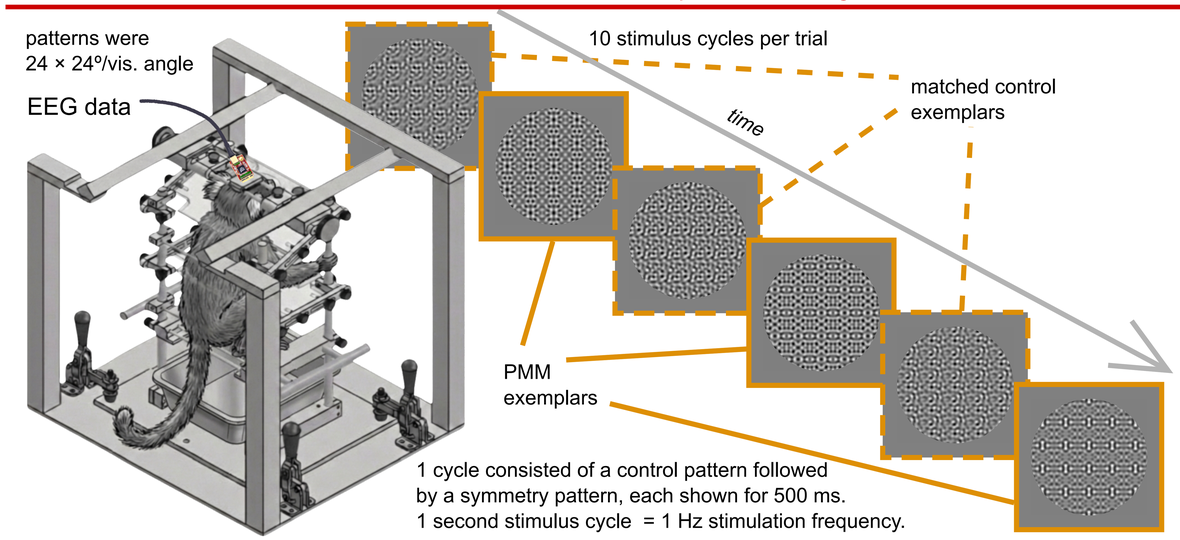


We generated control patterns for each PMM and P4 exemplar that were matched in terms of low-level visual features. Here we show example patterns along with the lattice.

24 distinct control-exemplar pairs for each of the two wallpaper groups.

Steady-State Visual Evoked Potentials (SSVEPs): Visual stimuli that update periodically will elicit periodic steady-state responses in visual cortex.

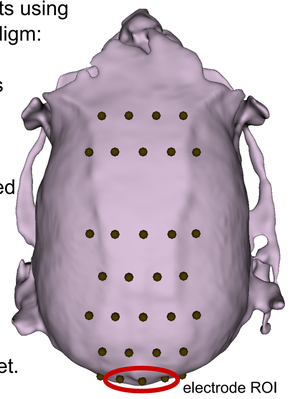
Experiment Design



1 cycle consisted of a control pattern followed by a symmetry pattern, each shown for 500 ms.
1 second stimulus cycle = 1 Hz stimulation frequency.

We recorded two datasets using the same SSVEPs paradigm:

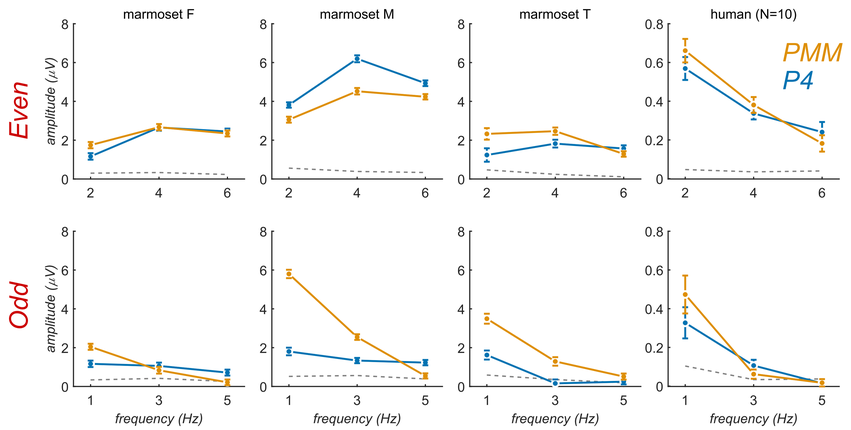
- EEG from 3 marmosets using a custom 32-channel flexible skull-mounted grid (NeuroNexus) implanted under a lightweight recording chamber.
- Human comparison EEG using a 128-electrode Magstim EGI sensor net.



First and last cycles of each trial were excluded from analysis. The remaining data were folded and averaged, and DFT was used to obtain 0.5 Hz resolution spectra.

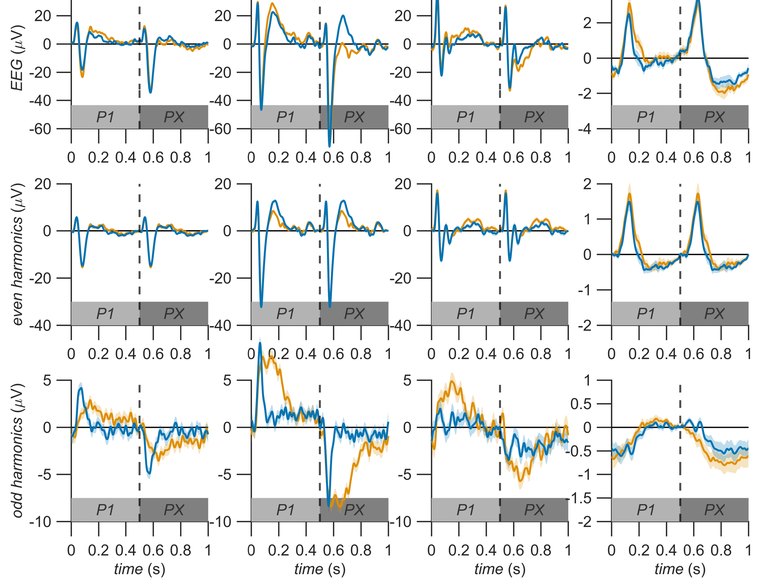
Results: ROI Harmonics

Regions-Of-Interest over occipital cortex in marmosets (3 electrodes) and humans (6 electrodes).
Both even and odd harmonics produce measurable responses.
In both marmosets and humans, PMM produce stronger odd harmonic responses than P4.



Results: ROI Waveforms

SSVEP data was filtered in the spectral domain and then projected back into the time domain to generate even- and odd-harmonic single-cycle average timecourses.



Results: Topographies

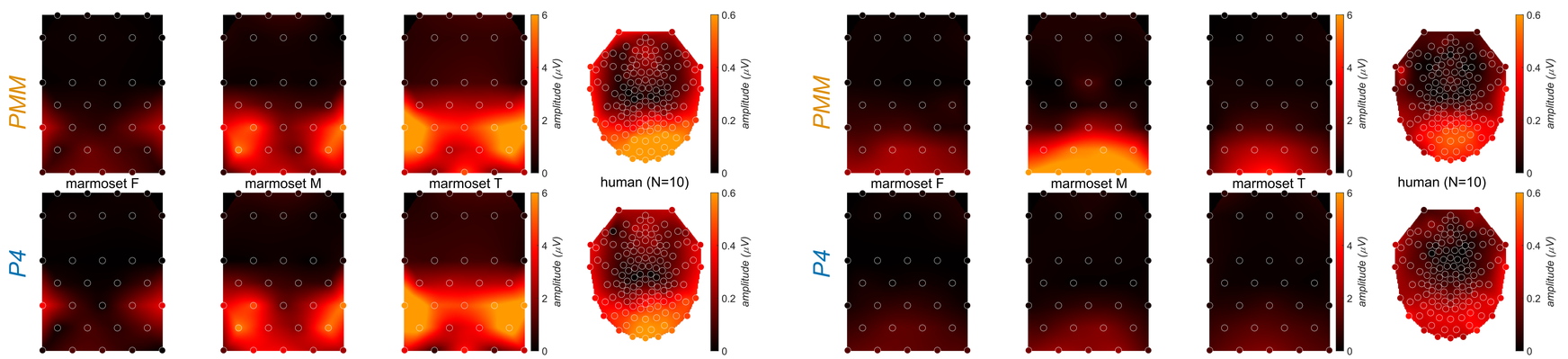
SSVEPs are measurable as narrow-band peaks in the spectra at integer multiples of the stimulation frequency called harmonics.

Even Harmonics (Second harmonic shown below)

Same responses for the two images in each pair = low-level image-update responses.

Odd Harmonics (First harmonic shown below)

Different responses for the two images in each pair = symmetry responses[2].



Conclusions

Marmoset monkeys produce responses to reflection and rotation symmetry that can be measured with our SSVEPs paradigm.

SSVEPs have earlier onsets for marmosets than for humans. This is true for both low-level image-update responses and symmetry responses.

Marmoset responses to symmetry are less sustained than observed for humans in the literature[4] and in the current dataset, especially for rotation symmetry.

References

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