Brain Responses to Symmetries in Naturalistic Novel Three-Dimensional Objects

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Background

Symmetries are prevalent in natural and man-made objects and scenes. The literature on symmetry perception have mostly relied on patterns that are symmetrical in the image-plane[1]. However, during natural vision, symmetrical objects in the world are often distorted by perspective such that they do not produce image-plane symmetry on the retina. Perspective-distorted symmetry creates weaker brain responses than image-plane symmetry[2], and EEG studies using using Event-Related Potentials (ERPs) have found that distorted symmetry elicits symmetry responses only when participants are engaged in symmetry-related tasks[3].

Motivation

The current study uses a Steady-State Visual Evoked Potentials (SSVEPs) paradigm to investigate symmetry responses to naturalistic, novel objects. Our experiment design allows us to compare responses to symmetries in the image-level and perspective-distorted symmetry.

Methods

Naturalistic, novel three-dimensional objects with vertical reflection symmetry axes were procedurally created in *Blender* (a 3D graphics software) and rendered to produce images under two conditions:

1. Viewing direction orthogonal to object symmetry Producing symmetries in the image-plane
2. Objects rotated relative to viewing direction so that symmetries present in object were distorted due to perspective

Asymmetrical objects were produced and rendered using the same approach. Pairs of asymmetrical and symmetrical images, and pairs of two asymmetrical images were created so that image-level differences were equated across every pair in all sets.

Image-level

Perspective-distorted

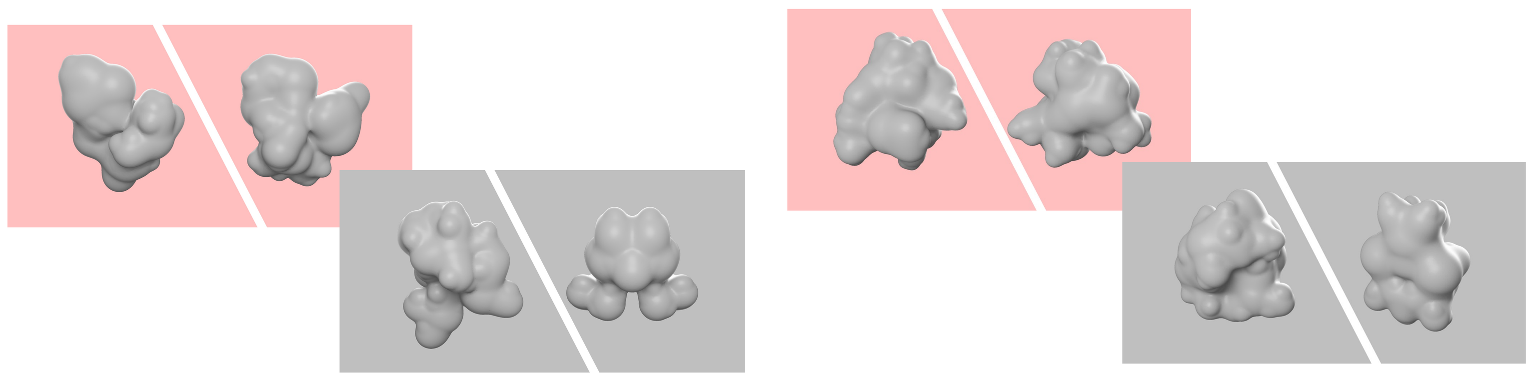
In each trial of the experiment, participants passively viewed images from 10 image pairs. The first image in each pair was presented for 500 ms, followed by the second image for another 500 ms.

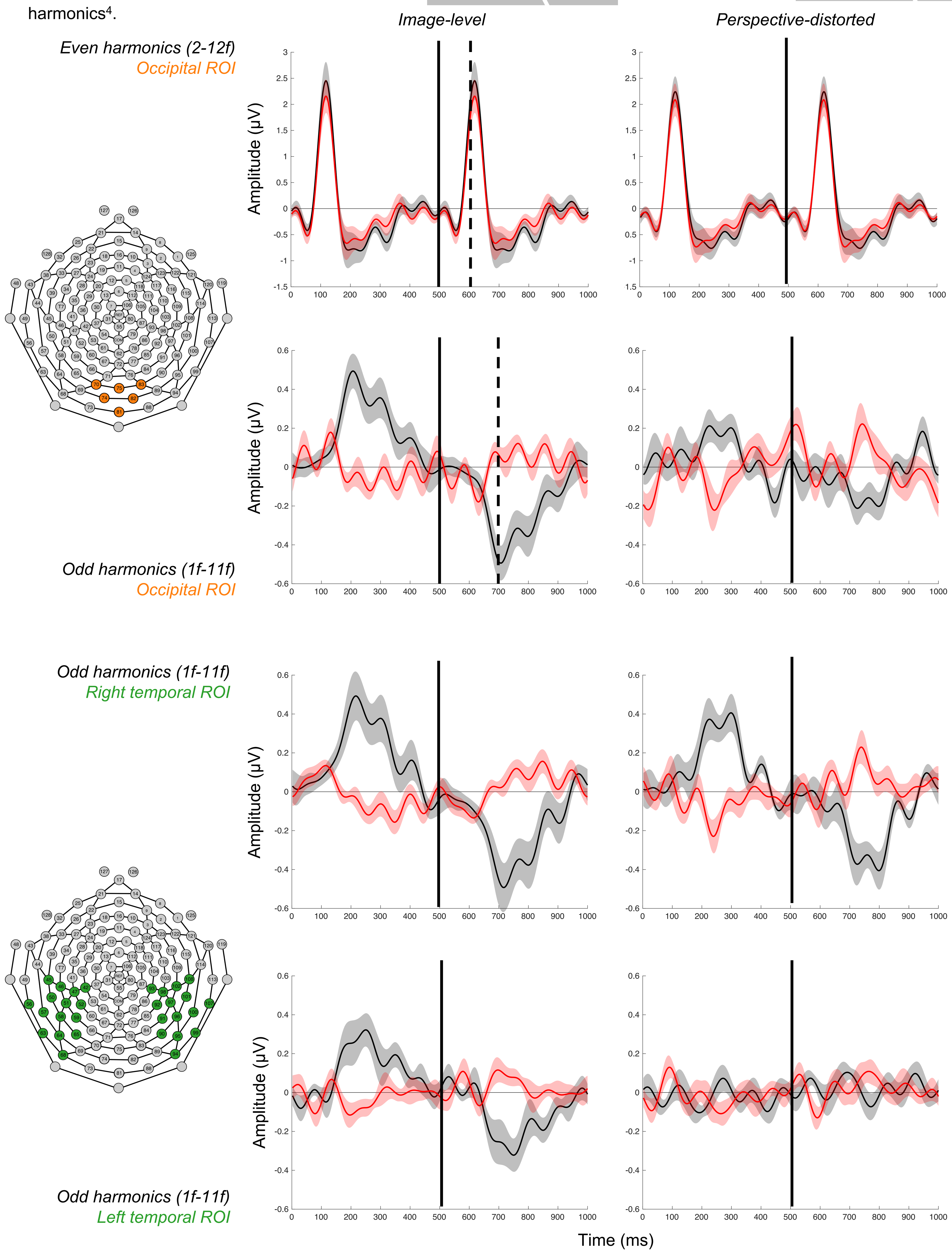
For both image-level and perspective-distorted image sets, we ran separate conditions for asymmetrical-symmetrical image pairs, and for image pairs where both images were asymmetrical, resulting in a total of four conditions.

We used high-density EEG (128 channels) to measure SSVEP responses. Our paradigm allow us to filter brain responses according to the harmonics of the stimulation frequency.

Results: Waveforms

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. The symmetry response should be isolated in the odd harmonics[4].





Results: Topographies

Odd harmonics

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

The symmetry response can be observed as the difference between the topographies produced by the *symmetry* conditions and the *control* conditions.

Image-level symmetry elicits strong responses in a broad regions including sites associated with occipital and left- and right temporal cortex.

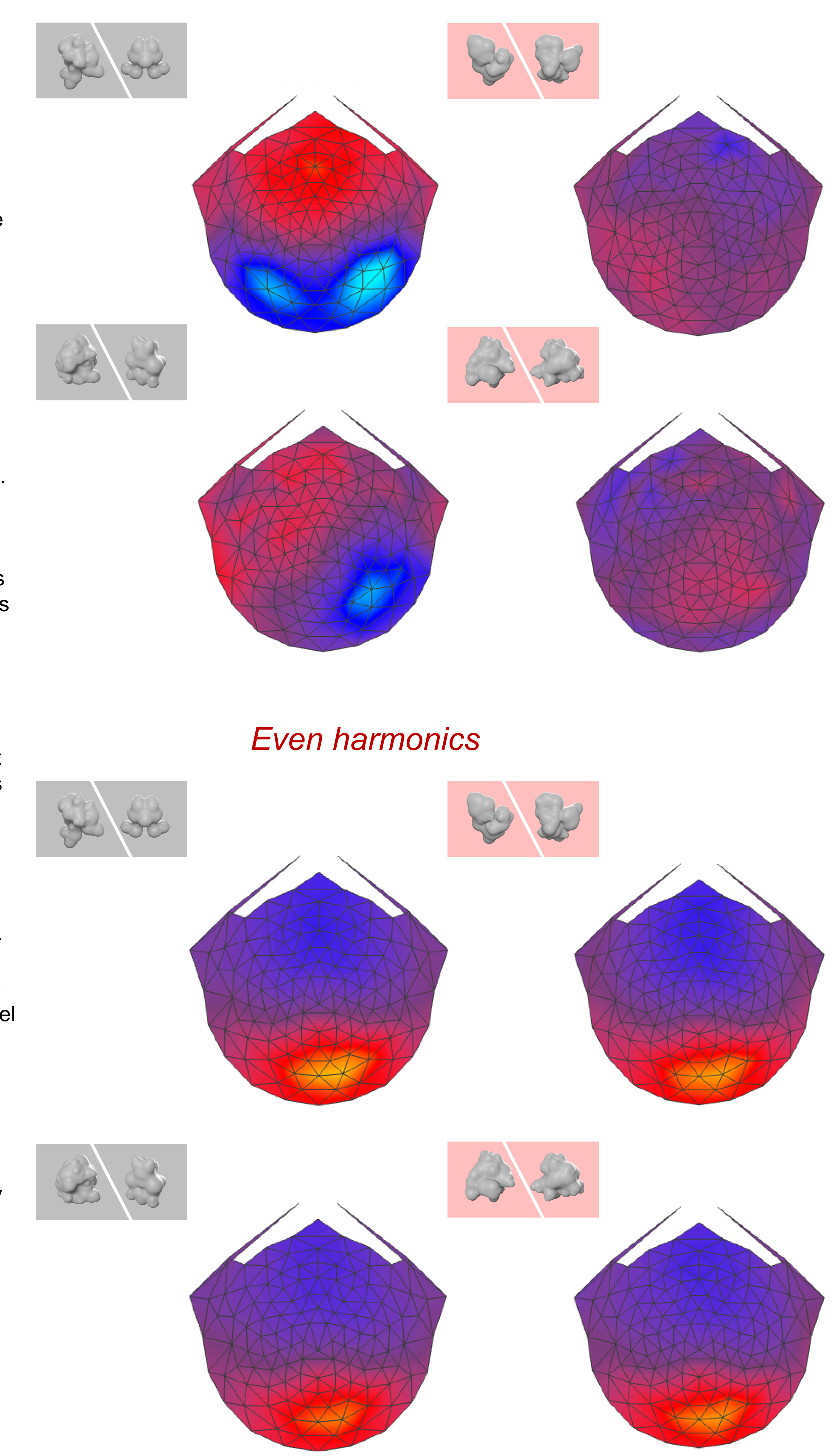
For perspective-distorted symmetry, the response is clearly right-lateralized, and is weak in the posterior locations associated with occipital cortex.

For even harmonics, topographies are very similar across conditions, and do not exhibit systematic differences between the *symmetry* conditions and the *control* conditions.

Our results show that during passive viewing, perspective-distorted symmetry can elicit SSVEPs that are comparable to those elicited by image-level symmetry, but only in more anterior scalp regions likely driven by activity in temporal cortex.

Responses to perspective-distorted symmetry are highly lateralized to the right hemisphere.

Future research will be necessary to determine how task- and viewing conditions influence responses to symmetries in these novel, naturalistic stimuli.



References

1. Treder, MS. Behind the Looking-Glass: A Review on Human Symmetry Perception. *Symmetry*, **2**(3) (2010).
2. Keefe BD, *et al.* Emergence of symmetry selectivity in the visual areas of the human brain: fMRI responses to symmetry presented in both frontoparallel and slanted planes. *Human brain mapping* **39**, 3813-3826 (2018).
3. Makin ADJ, Rampone G, Bertamini M. Conditions for view invariance in the neural response to visual symmetry. *Psychophysiology* **52**, 532-543 (2014).
4. Kohler, PJ, Clarke, A, Yakovleva, A, Liu, Y, & Norcia, AM. Representation of Maximally Regular Textures in Human Visual Cortex. *Journal of Neuroscience*, **36**(3), 714–729 (2016).