Does perspective-distortion modulate the temporal tuning of symmetry responses in the human visual cortex?

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Background

Symmetry is a highly salient feature in both natural and man-made environments. The sensitivity to symmetry in numerous species, including bees, fish, dolphins, and humans,[1] is believed to be a cue for symmetry's involvement in viewpoint invariant representation of objects, regularity and structure in visual scenes, and mate selection.[2]

The neural mechanisms underlying symmetry have largely been pursued fMRI and ERP potentials to investigate dot patterns. However, symmetries in an animal's visual environment are often subjected to perspective distortion and do not give rise to symmetrical patterns in the image or on the retina.[3]

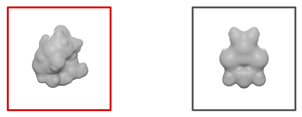
Motivation

Here, we build on previous studies showing that perspective-distortion makes symmetry responses weaker and more task-dependent[3,4] by investigating the effect of perspective-distortion on the temporal tuning of symmetry responses.

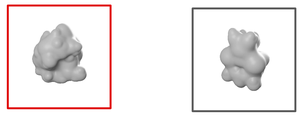
Methods

Asymmetrical and symmetrical three-dimensional novel and naturalistic objects were created in Blender and rendered into greyscale. These objects were then subsequently rotated to create two sets of images:

1. image-level symmetry conditions



2. perspective-distorted symmetry conditions



Images were paired into three groups of images:

asymmetry followed by symmetry (image-level)

asymmetry followed by symmetry (distorted)

asymmetry followed by asymmetry (image-level)

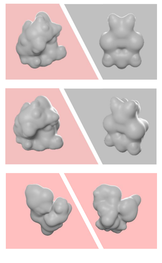
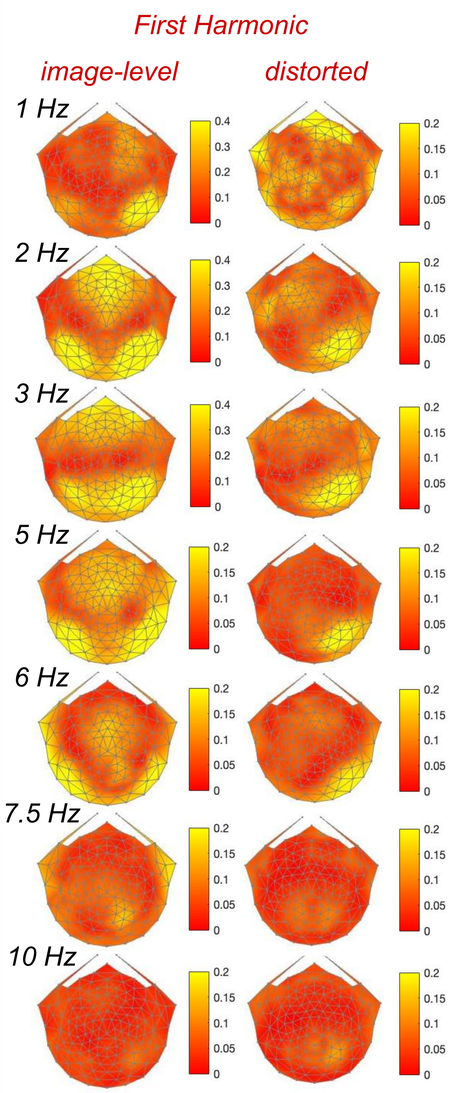
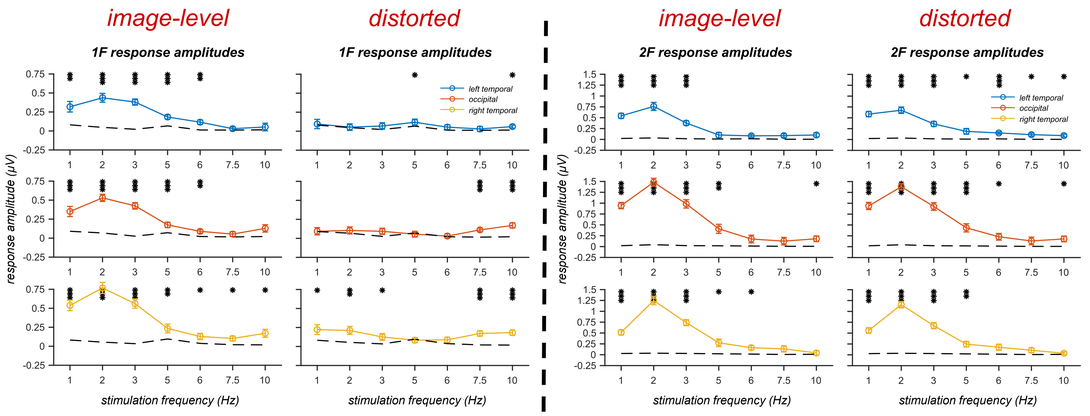


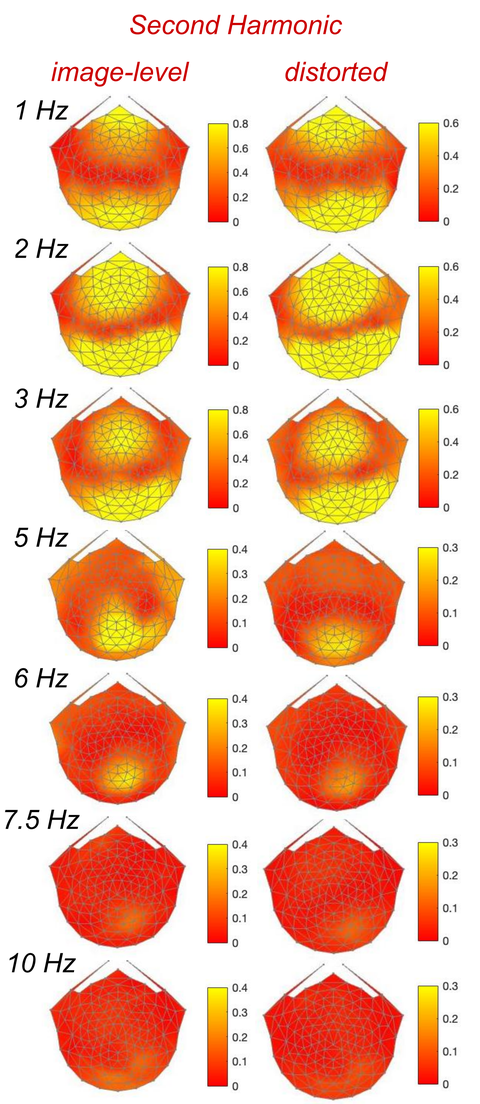
Image pairs were subjected to a deep neural network algorithm ensuring a minimum 45% (±1) match, isolating symmetry-specific responses and reducing low-level visual differences across every pair in all groups.

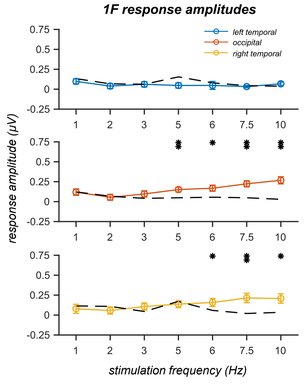
20 participants were placed facing a monitor to view the images while conducting a contrast detection. Presentation times ranged from 1000ms (1 Hz) to 100ms (10 Hz) per image pair. 128-channel high-density EEG was used to measure the SSVEP responses in all participants over two sessions, with the paradigm enabling the filtering of symmetry-specific brain responses according to the harmonics of stimulation frequency.

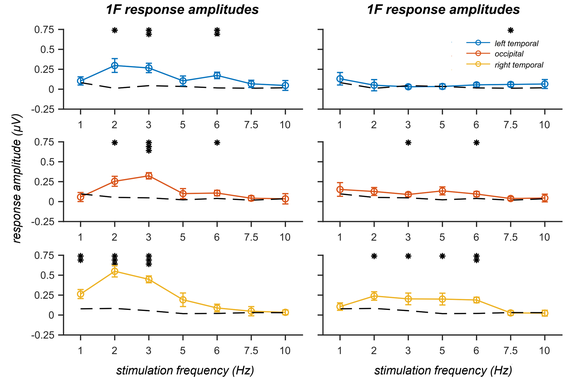
Results and Conclusion



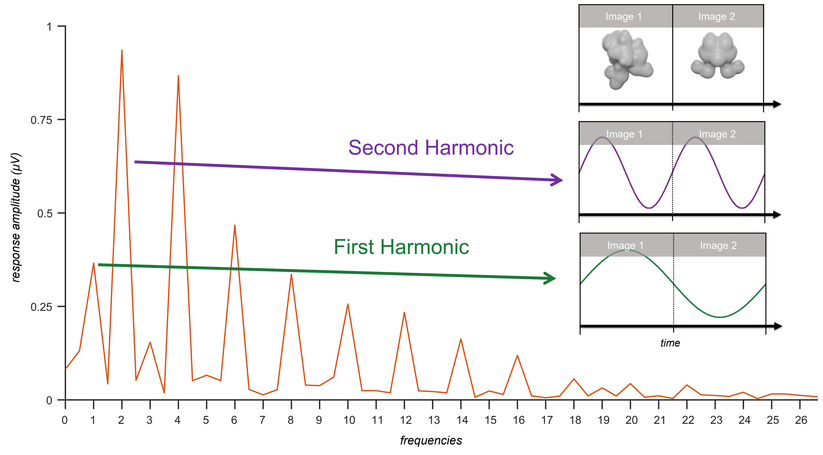


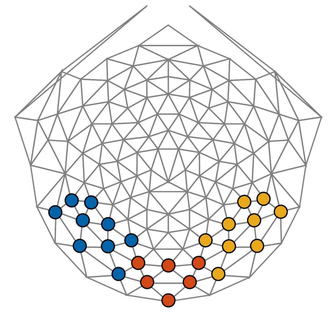






Does perspective-distortion modulate the temporal tuning of symmetry responses? Yes





Key findings:

The temporal response function for image-level and distorted symmetries differ.

Image-level symmetries peak at 2 Hz, while distorted symmetries remain steady.

References

[1] Rhodes, G., Proffitt, F., Grady, J.M. *et al.* Facial symmetry and the perception of beauty. *Psychonomic Bulletin & Review* **5**, 659–669 (1998).

[2] Audurier P, Héjja-Brichard Y, De Castro V, Kohler PJ, Norcia AM, Durand JB, Cottereau BR. Symmetry Processing in the Macaque Visual Cortex. Cereb Cortex. 2022 May 14;32(10):2277-2290.

[3] Keefe, B. D., Gouws, A. D., Sheldon, A. A., Vernon, R. J. W., Lawrence, S. J. D., McKeefry, D. J., Wade, A. R., & Morland, A. B. (2018). 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*(10), 3813–3826.

[4] Makin, A.D.J., Rampone, G. and Bertamini, M. (2015), Conditions for view invariance in the neural response to visual symmetry. Psychophysiol, 52: 532-543.