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February 3rd, 2021

Dear PNAS Editors,

Symmetries are present at many scales in images of natural scenes, due to a complex interplay of physical forces that govern pattern formation in nature. Symmetrical patterns have been created and appreciated by human cultures throughout history and since the gestalt movement of the early 20th century, symmetry has been recognized as important for visual perception.

Here we present a new approach to studying the role of symmetry in vision, using *wallpaper groups*. The wallpaper groups are regular textures that form 17 distinct combinations of symmetries in the 2D plane, and thus represent the complete set of symmetries in images. We expand on prior work on symmetry in vision and neuroscience by investigating representations of the entire set of wallpaper groups in human visual cortex, using brain imaging (Steady-State Visual Evoked Potentials measured using high-density EEG) and psychophysical measurements (symmetry detection thresholds). In accordance with best practices of Open Science, the Supplementary Materials include all of the data and code required to run our analyses, as well as additional helpful figures and tables (see: https://osf.io/f3ex8/).

We frame our findings in terms of a series of hierarchical relationships among the wallpaper groups that have been established by mathematical group theory. Our main finding is that both psychophysical and brain imaging measures are remarkably consistent with group theory, such that groups lower in the hierarchy produce smaller response amplitudes and require longer presentation time to be accurately detected. These results show that visual cortex have comprehensive representations of symmetries in regular textures and that individual symmetry types embedded in textures are coded with a high degree of precision. We also show a robust correlation between our psychophysics and brain data, indicating that the two measurements are likely reflecting the same underlying representations in visual cortex.

The physical forces underlying the structure of objects and their surface properties are subject to fundamental constraints that generate symmetries in the visual environment. The correspondence between brain responses and group theory that we observe here is likely learned implicitly from regularities in the natural world, suggesting that the well-known principle of *efficient coding* extends to a much higher level of structural redundancy – that of symmetries in visual images. Symmetries have been widely used in human art and architecture going back to the Neolithic age. It is interesting to consider whether the aesthetic appeal of symmetry is perhaps a direct result of the coding strategy implemented by the visual system.

We look forward to hopefully embarking on a rigorous peer review process under your editorial guidance.

Sincerely,

Peter J. Kohler & Alasdair Clarke

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