The Salience of Lower-Order Features in Highly Self-Similar Wallpaper Groups

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Introduction

- Symmetry detection may be a fundamental property of the human visual system; most prior research has focused on mirror symmetry.
- There are four fundamental symmetries in 2D – translation, reflection, glide reflection, and rotation. Their combination results in 17 distinct "wallpaper groups".
- Clark et al. (2011) used a sorting task to explore perceptual features observers detect in wallpapers.
- Five groups showed high self-similarity, implying an important role in perceptual space.
- We explored whether there are sub-categories within the five self-similar wallpaper groups.

Methods

- Sample images normalized for contrast and spatial frequency were generated for each wallpaper group (Fig 1).
- Adult participants (n=11) sorted 20 exemplars from each wallpaper group into subgroups using self-chosen criteria.
- Calculated mean Jaccard index [0,1] for each exemplar to assess perceptual similarity between exemplar pairs.
- Higher mean Jaccard == more "typical" (Fig 1).
- Fit linear mixed effects models using *lme4* in R with random effects for exemplars and observers.

Methods: Jaccard Index

$$J = \frac{c}{a + b + c}$$

a = # subsets containing exemplar A
b = # subsets containing exemplar B
c = # subsets containing both exemplars
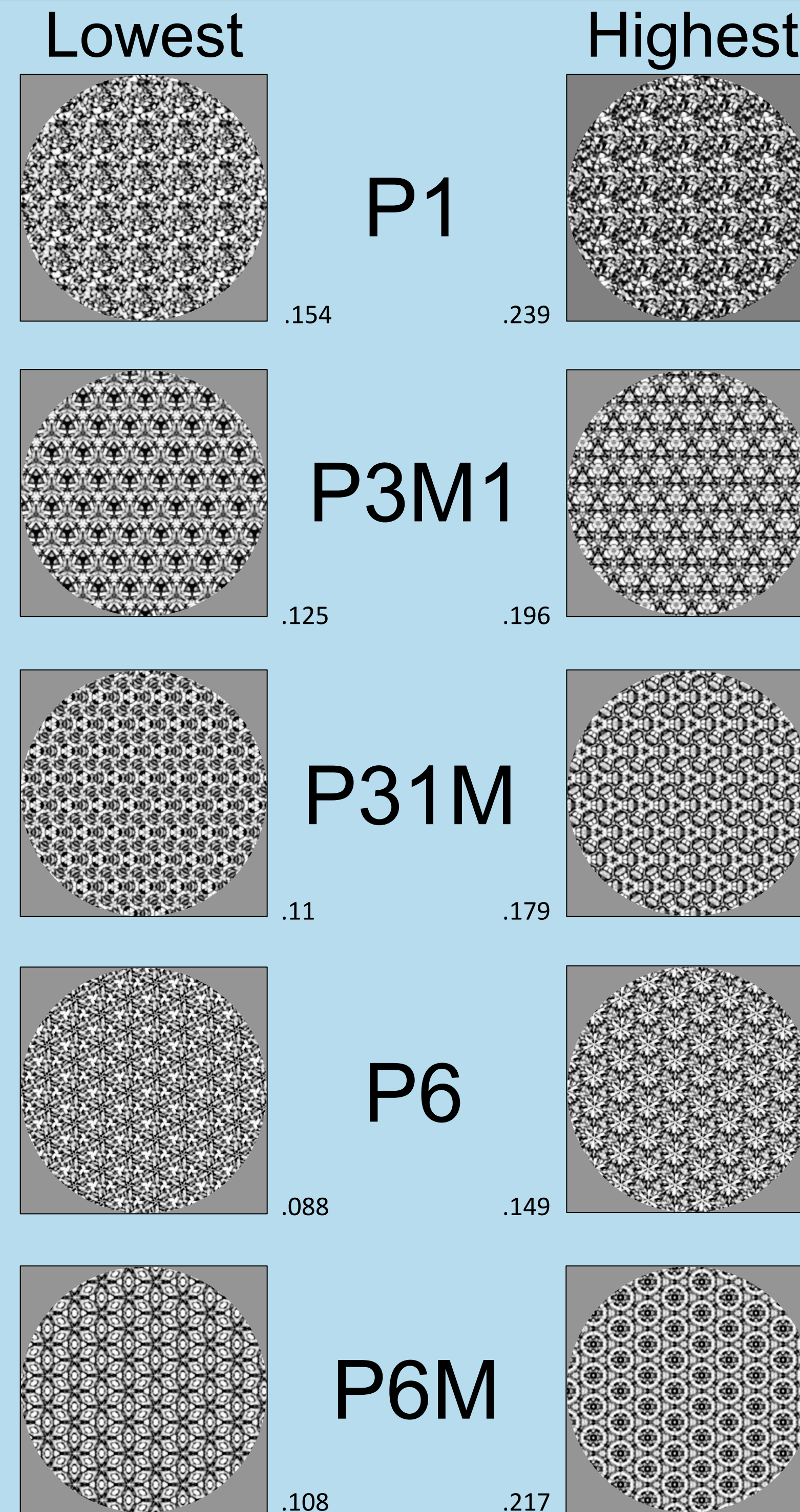
Results: Representative Exemplars

Lowest   Highest

P1   .154   .239

P3M1   .125   .196

P31M   .11   .179

P6   .088   .149

P6M   .108   .217

Figure 1. The exemplars from each wallpaper group with the lowest and highest calculated mean Jaccard index.
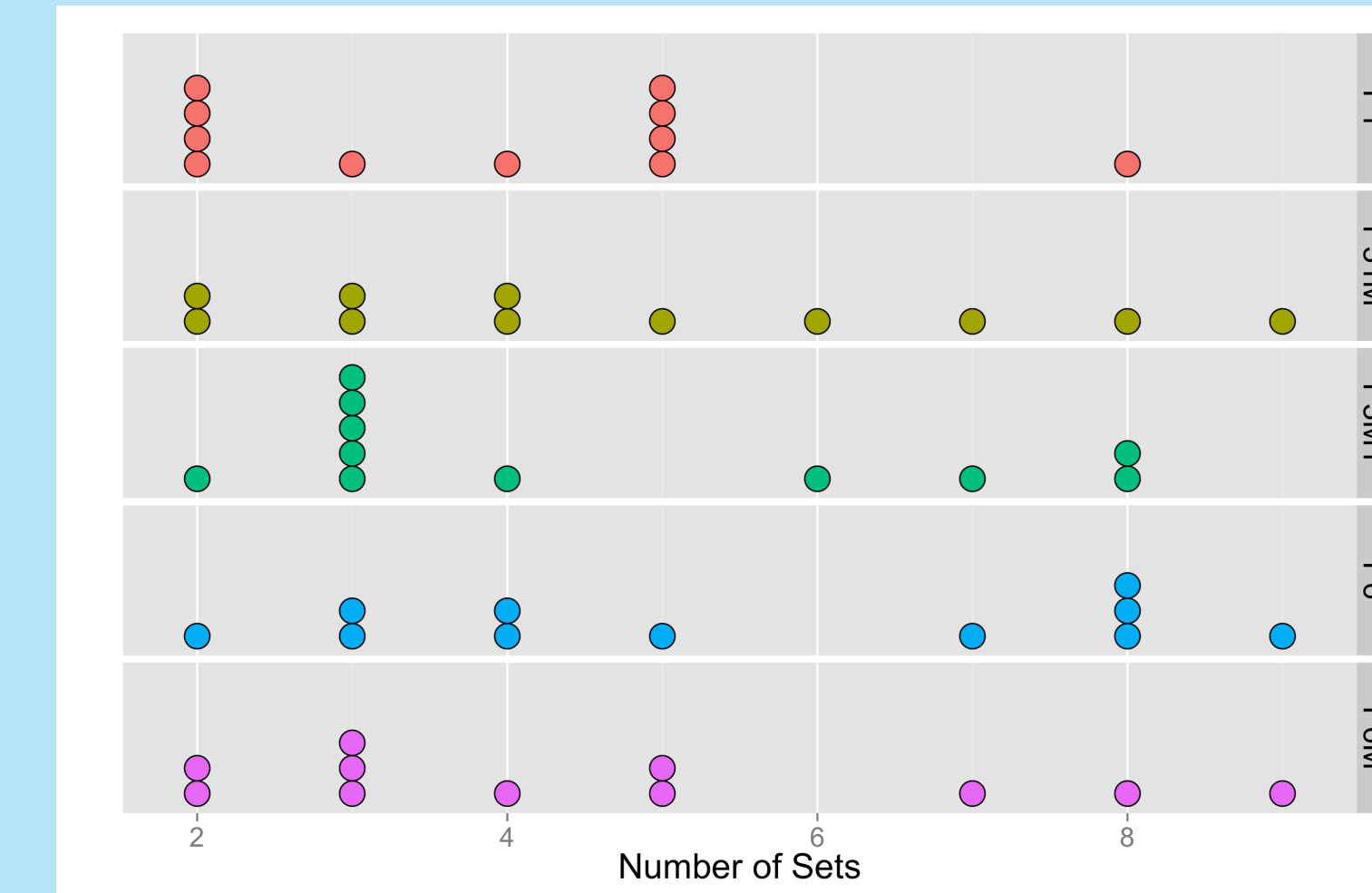
Results: Numbers of Sets

Figure 2. Observers sorted exemplars into different numbers of sets, $\chi^2(4)=9.7$, p<.05; P1<P6
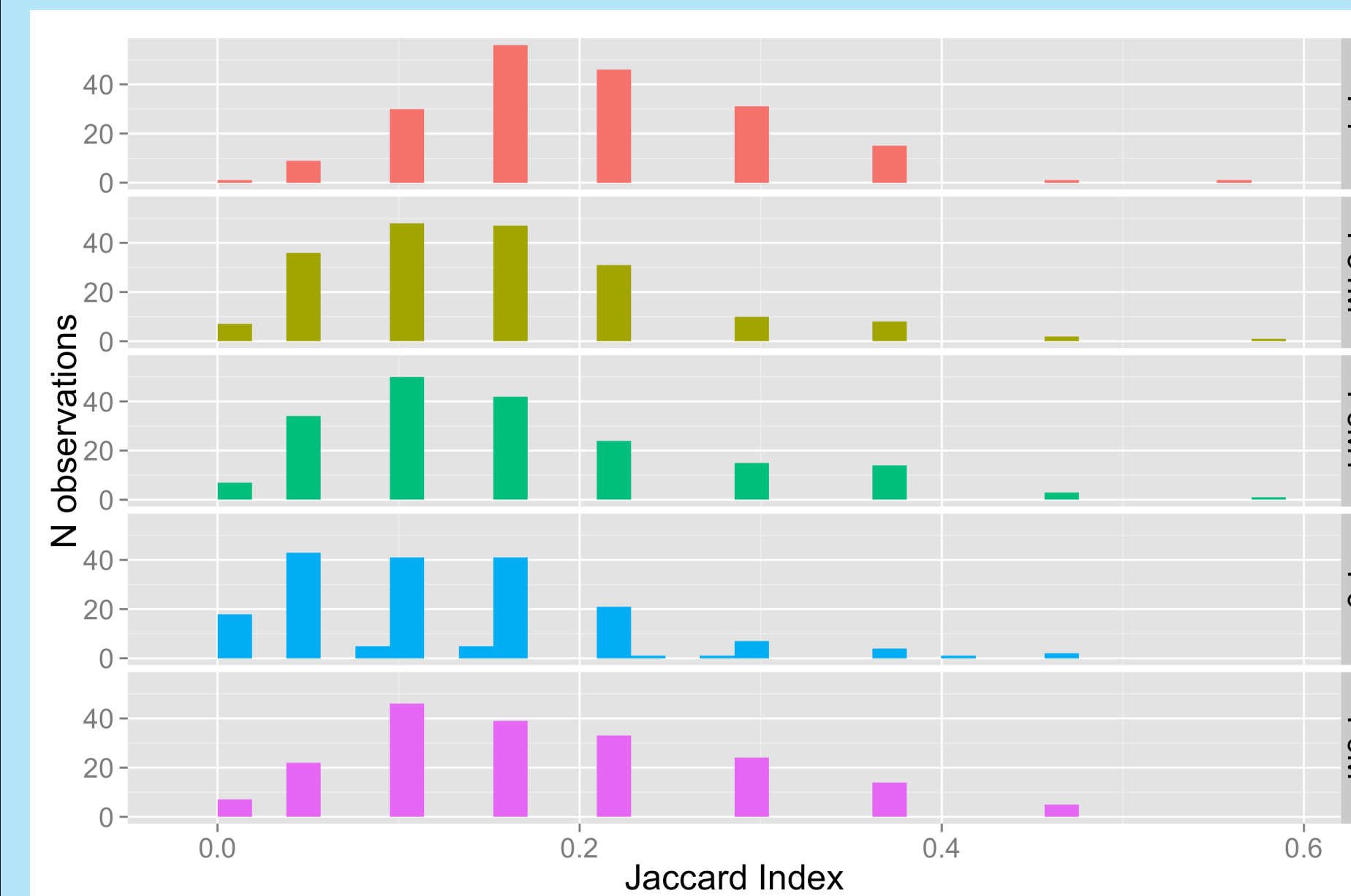
Results: Jaccard Indices

Figure 3. Mean Jaccard indices differ by group, $\chi^2(4)=93.4$, p<.0001. P1 is greater than P3M1 and P6; P6M greater than P6M.

Conclusions

- P1 exemplars more self-similar – fewer sets (Fig 2) and higher mean Jaccard indices (Fig 3) – than other groups.
- P6M more self-similar than P6 (Figs 2 & 3).
- Translational symmetry alone (P1) perceptually salient.
- Reflection symmetry increases perceived self-similarity (P6M > P6).
- Increasing degree of rotation symmetry (P6* vs. P3*) does not increase perceived self-similarity.
- Detection of self-similarity influenced by emergent global geometric structures (e.g. large geometric forms, striations, grid patterns).
- Future studies could explore factors suggested to influence the salience of characteristic geometric structures within wallpaper groups.

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