Task-dependent modulation of similarity judgments

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Introduction

Representations of visual information can often be described by perceptual spaces: constructs in which stimuli or features correspond to points, and their pairwise distances correspond to perceived dissimilarity.

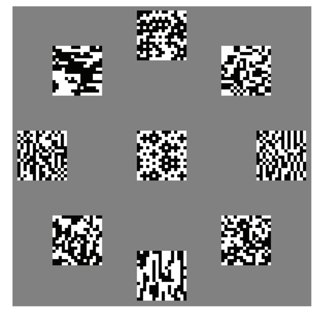
However, a perceptual space built on threshold measurements need not predict suprathreshold similarity judgments.

Here, we ask whether the geometry of suprathreshold perceptual spaces can be modulated by task.

We use a domain of visual textures to ask this question, since the perceptual space built on threshold judgments has a simple and well-characterized geometry.

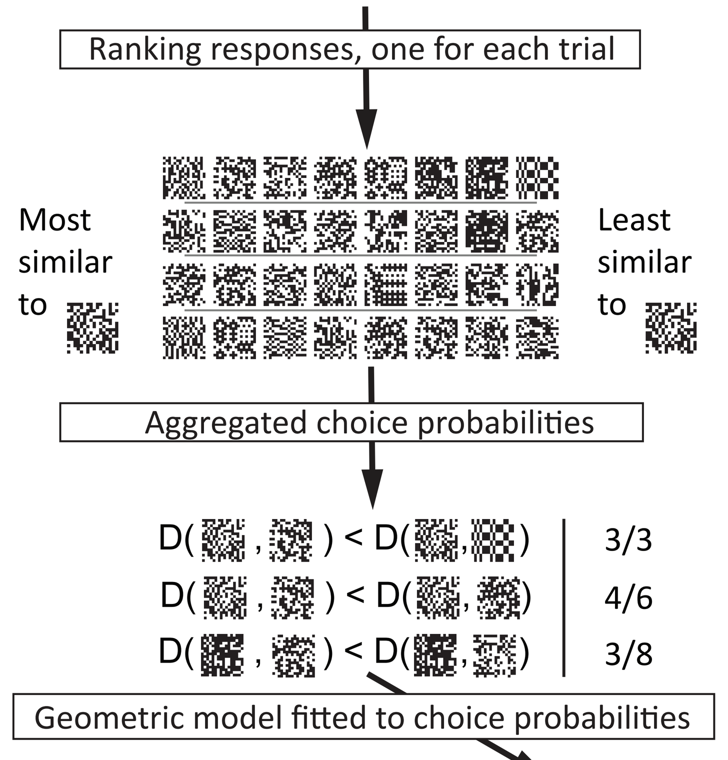
Methods

Sample Trial

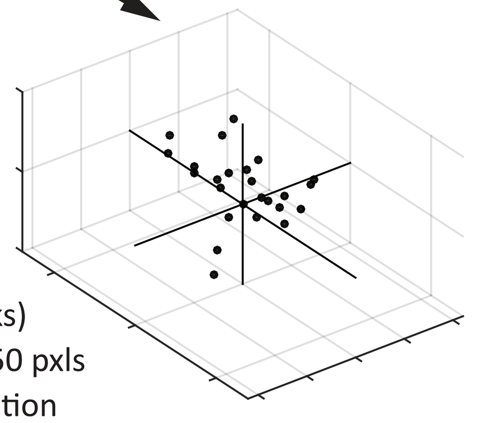


Standard Task: *Rank stimuli in order of their similarity to the central stimulus*

Brightness Task: *Rank stimuli in order of their similarity to brightness of the central stimulus*



Waraich, S. A., & Victor, J. D. (2022) JoVE, 35311825.



Details

Subjects: 4F, 1M, VA: 20/20

Viewing Distance: 57 cm

Texture Size: 4 deg (16 x 16 checks)

Display: 24 deg diam.; 1680 x 1050 pxls

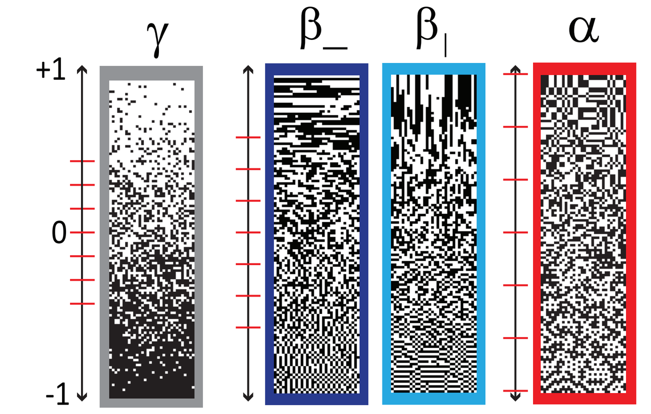
8 conditions: 25 stimuli per condition

10 sessions/condition: 1000 trials

28,000 pairwise comparisons per condition per subject

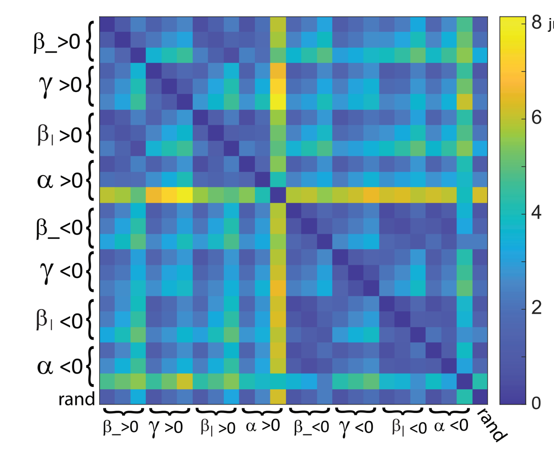
Data fit to models of 1 to 7 dimensions

Support: NIH EY7977

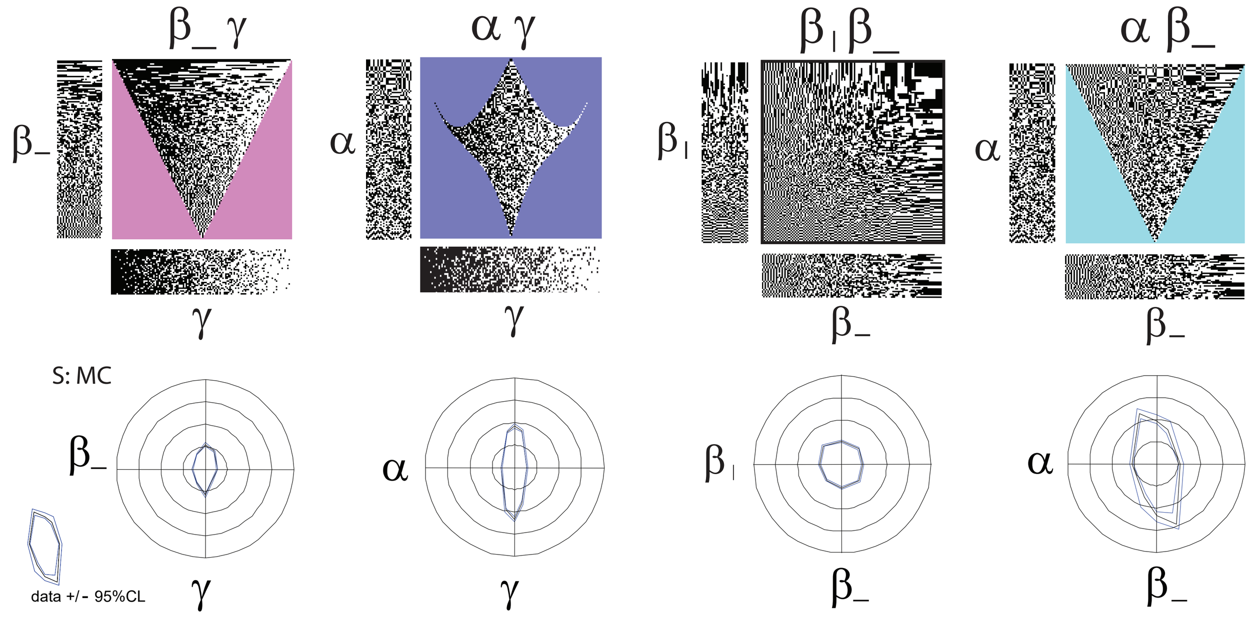


Four independent texture parameters: luminance (γ), horizontal and vertical pairwise correlations (β_ and β|), and local fourth-order correlations (α). Each parameter ranges from -1 to 1, with the random texture at 0.

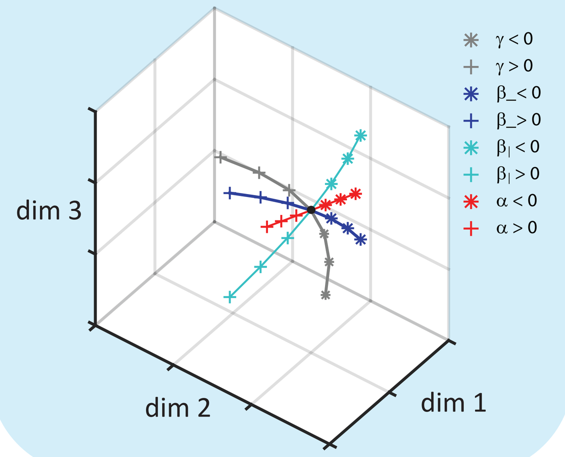
red tickmarks indicate stimulus values used in each experiment



Discrimination thresholds in a 4-parameter space of textures

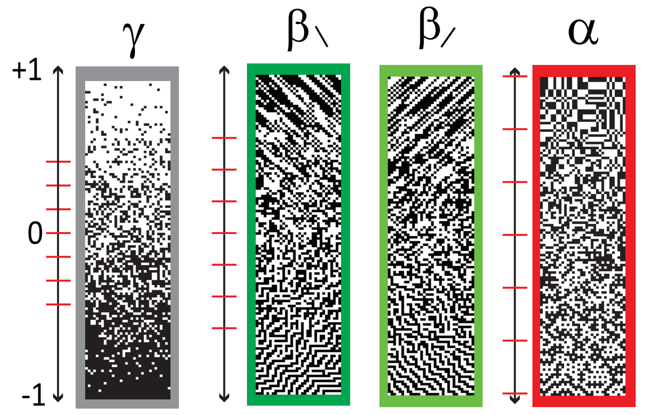


Threshold Model



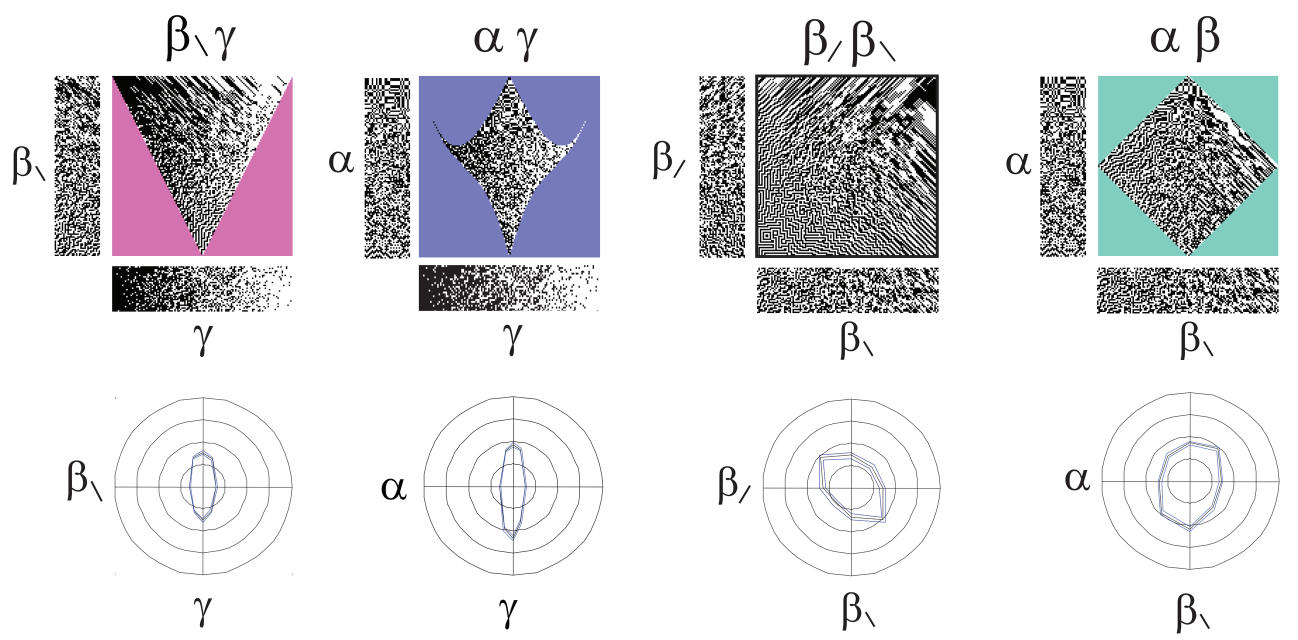
1 grid spacing = 2 jnd

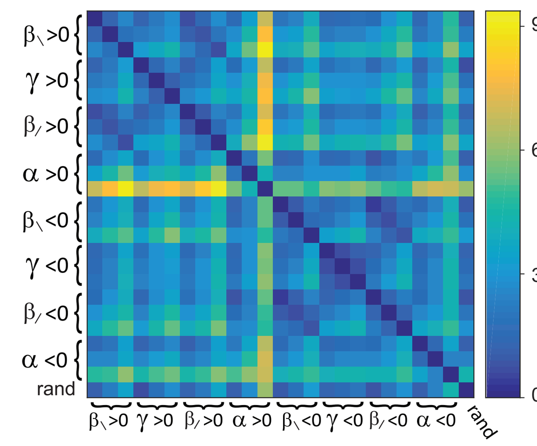
Threshold isodiscrimination contours are elliptical in every texture plane. This implies a Euclidean perceptual distance, which is summarized by the heatmap. These distances then determine a perceptual space, the "threshold model", via multidimensional scaling. A projection into the first three principal components is shown.



Another set of four independent texture parameters, partially overlapping with the set above: luminance (γ), diagonal pairwise correlations (β\ and β/), and local fourth-order correlations (α). Again, each parameter ranges from -1 to 1, with the random texture at 0.

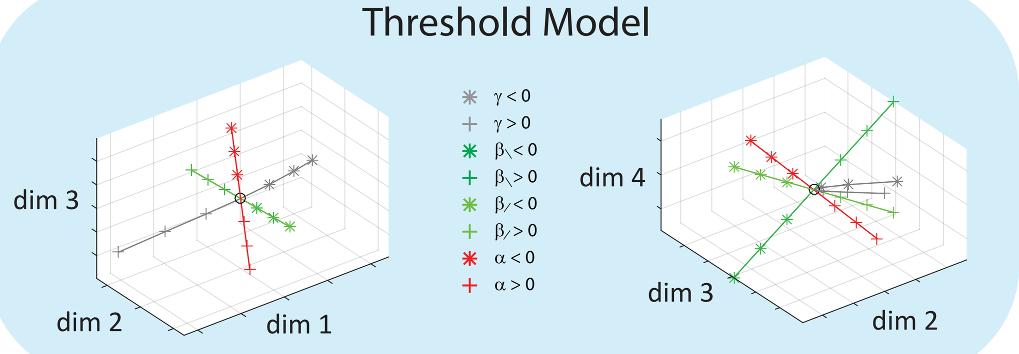
Discrimination thresholds in another 4-parameter space of textures





Threshold isodiscrimination contours are again elliptical, implying a Euclidean perceptual distance and determining a threshold model via multidimensional scaling. Two projections onto the principal components are shown, since the β\ and β/ -axes overlap in the first three dimensions.

Threshold Model



References

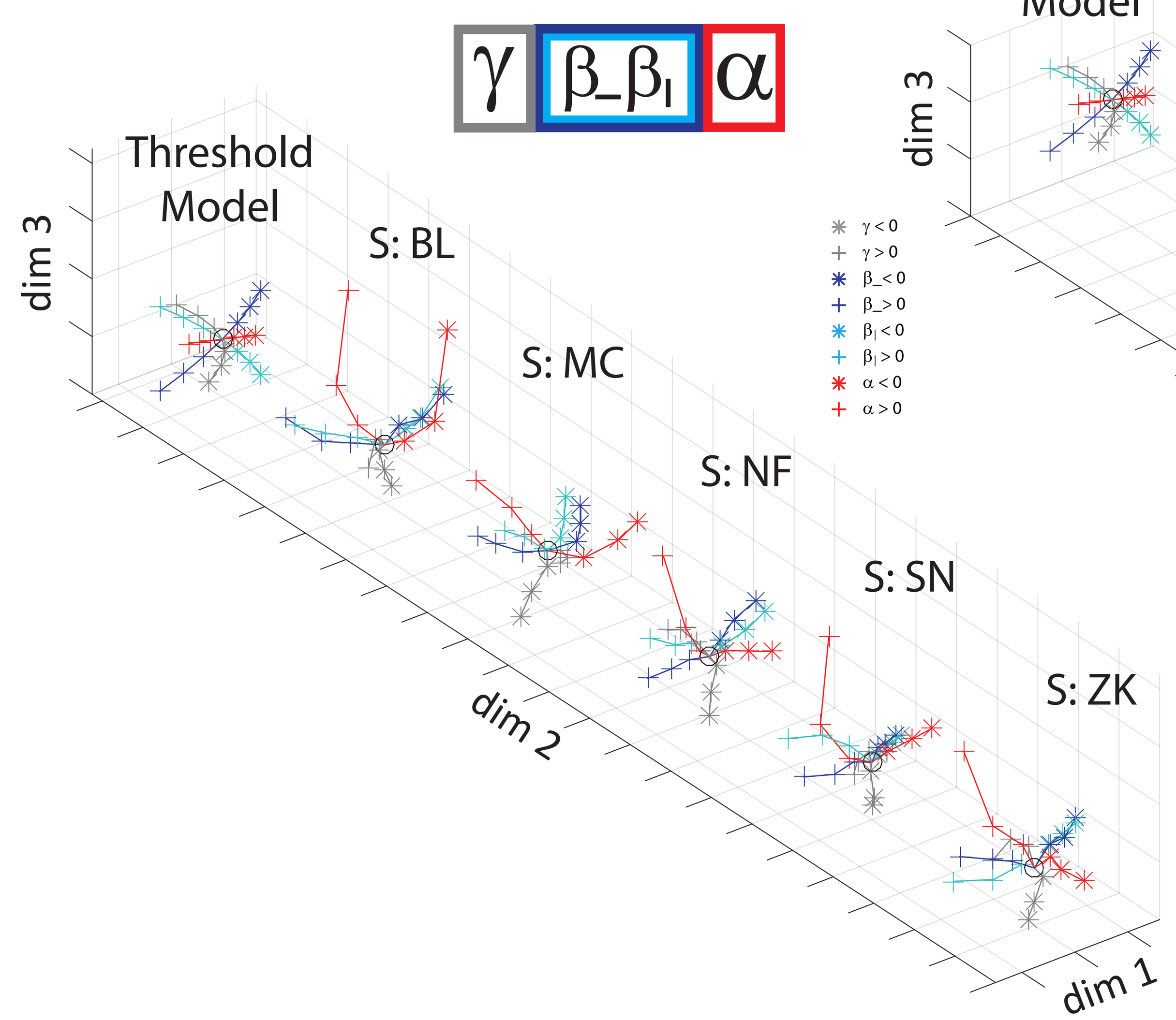
Victor, J.D., Thengone, D.J., Rizvi, S.M., and Conte, M.M. (2015). A perceptual space of local image statistics. Vis. Research 117, 117-135.

Waraich, S.A. & Victor, J.D. (2022). A psychophysics paradigm for the collection and analysis of similarity judgments. J Vis Exp, doi:10.3791/63461.

Similarity Task

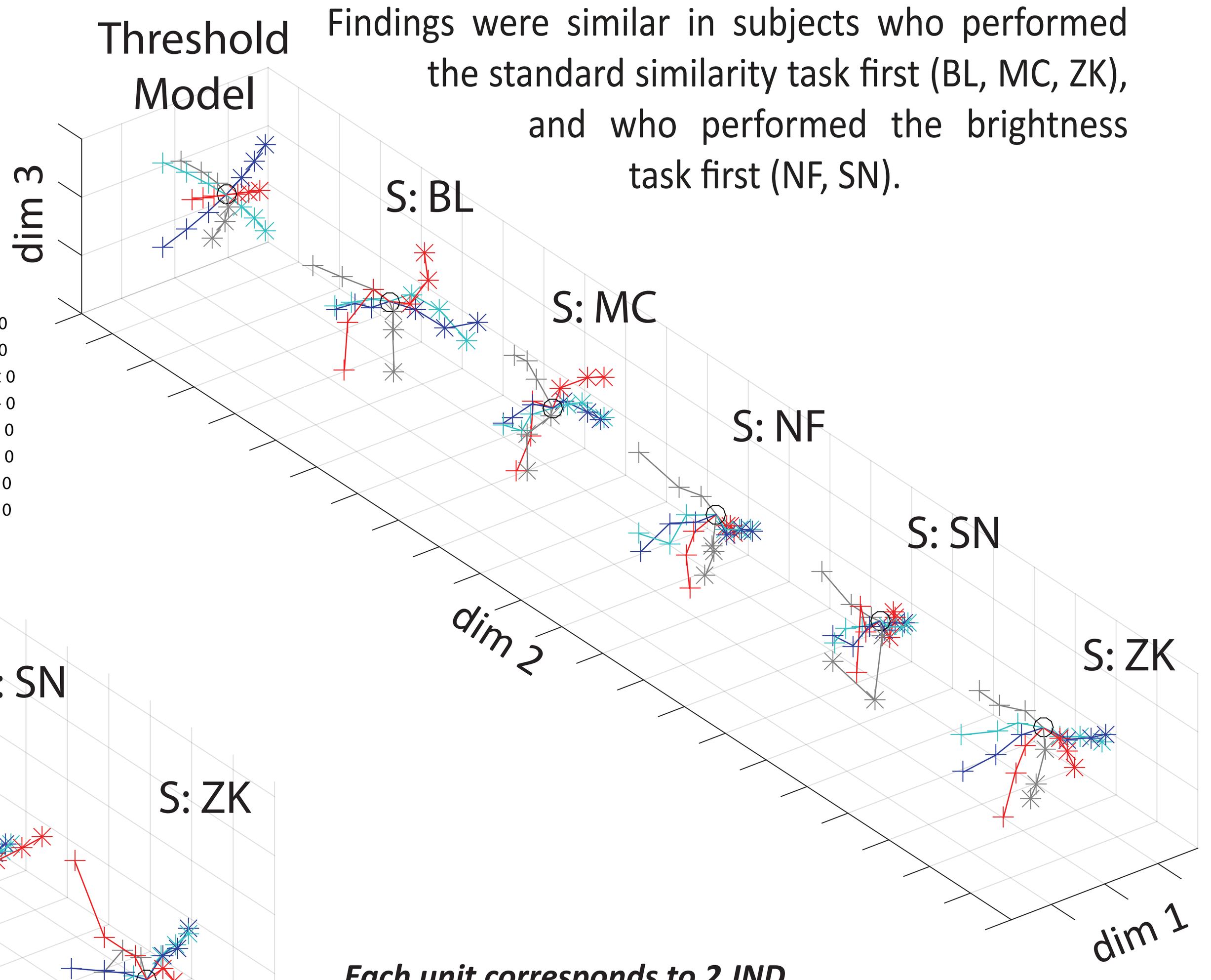
The perceptual space constructed from suprathreshold similarity judgments differed markedly from the predictions of the threshold model: all axes were curved, the β-axes crossed at a much more acute angle; and the α-axis was disproportionately elongated.

γ β_β| α

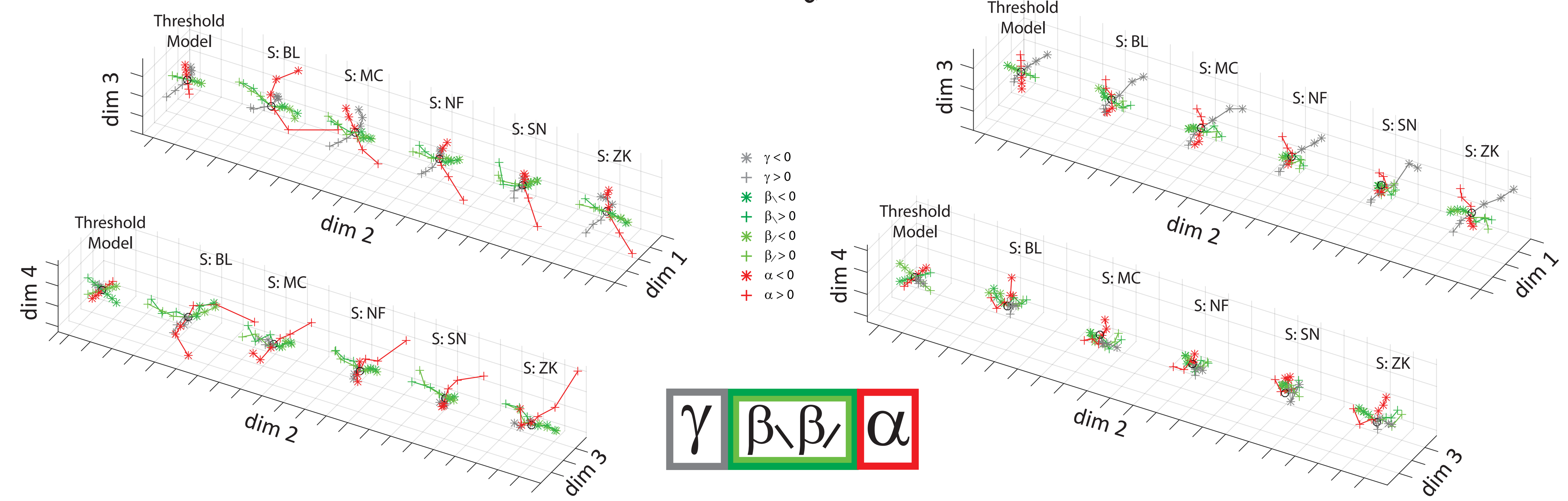


Brightness Task

When subjects were asked to judge similarity based on brightness, geometry changed: the luminance (γ)-axis was longer and less curved, and the other axes were shorter. However, the space did not collapse to a single dimension. Findings were similar in subjects who performed the standard similarity task first (BL, MC, ZK), and who performed the brightness task first (NF, SN).



Each unit corresponds to 2 JND



γ β\β/ α

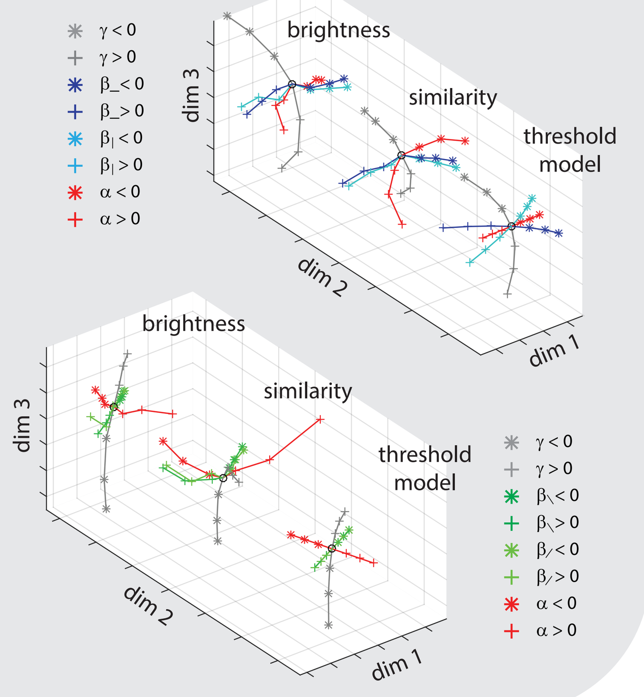
Summary and Conclusions

The perceptual representation of suprathreshold similarity differs markedly from the perceptual space that accounts for threshold discriminations.

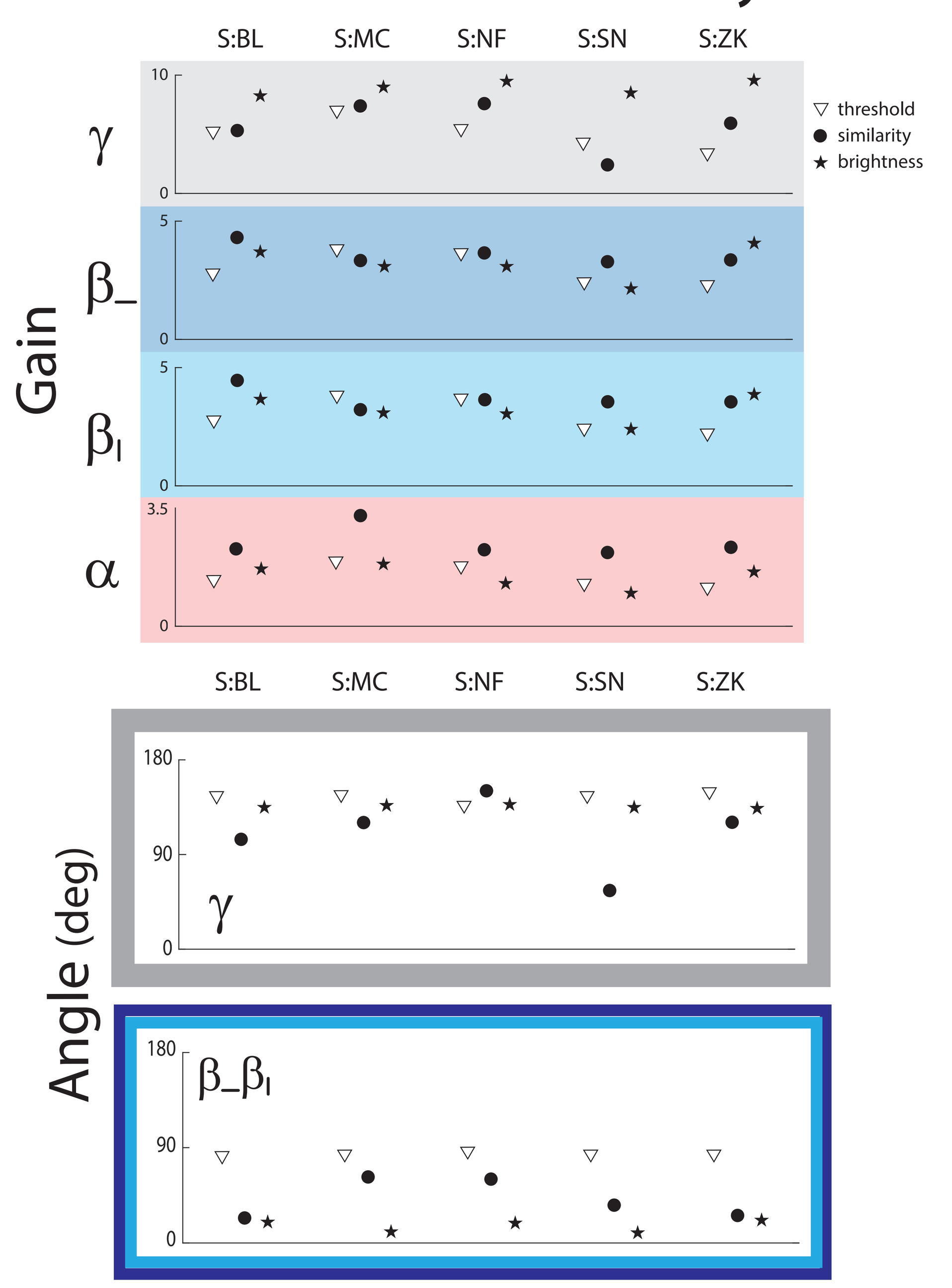
The transformation from threshold to suprathreshold spaces is nonlinear: coordinate axes in the threshold space are transformed to curved trajectories in suprathreshold representations.

When subjects judged similar brightness, the representational space changes: luminance is given a greater weight, but the space remains high-dimensional.

Consensus Spaces



Parametric Summary



Gains: For suprathreshold similarity, both second-order (the β's) and fourth-order (α) correlations have a higher impact than predicted by the threshold model, while luminance (γ) has a lower impact. For similarity based on brightness, the impact of luminance is selectively increased.

Angles: The bend of the luminance (γ)-axis at the origin is decreased (angle is closer to 180 deg) for brightness judgments, compared to similarity. The angles between the second-order (β)-axes, which are orthogonal or nearly so in the threshold model, are acute for both kinds of suprathreshold judgments.