Visual analysis of shape assayed with synthetic textures

Jonathan D. Victor, Syed M. Rizvi, Mary M. Conte

Feil Family Brain and Mind Research Institute,
Weill Cornell Medical College, New York, NY 10065

26.3033
VSS 2016

Motivation

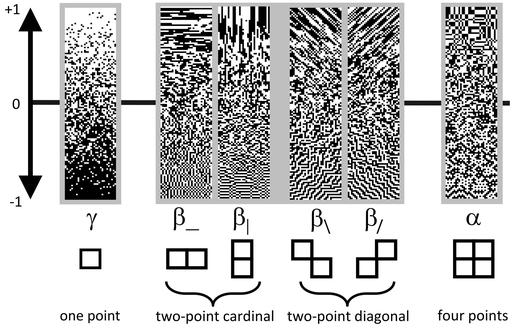
Algorithmically-defined visual textures provide a way to analyze computations performed in early vision. In this approach, image sets are synthesized to contain independent, controlled variation of several types of local features. These stimuli probe the processing of individual feature types and how they interact – something difficult to accomplish with natural images. Here we extend this strategy from elementary visual features to shape.

The starting point is our texture-based analysis of contrast, edge, and corner, in which textures of black and white checks were constructed by an algorithm that controlled one-, two-, three-, and four-point statistics in 2x2 neighborhoods. To extend this idea to elements of shape, we replace the uniformly black or white checks by tokens (tiles) containing curved segments. The tiles are designed so that where they meet, they form continuous contours.

This construction produces an image with extended shapes, whose characteristics are controlled by the underlying check-based texture. Specifically, manipulating the statistics of this underlying texture produces new textures with curvilinear contours and varying amounts of convex and non-convex shapes. These new textures are balanced for lower-level features such as the length, orientation, and curvature of individual segments.

Coordinate Axes: Standard Checks

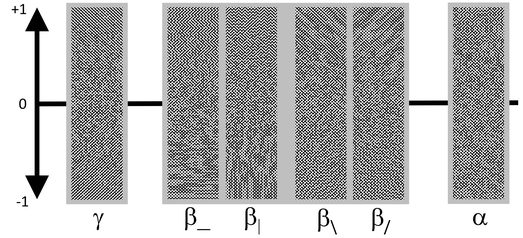
Each strip shows the textures generated by varying one coordinate across its entire range from -1 to +1. A coordinate value of 0 corresponds to a random texture.



Above: textures are generated in the standard fashion, with each check consisting of either a white or black square

Below: textures generated by substituting curved tokens for the uniform checks

Coordinate Axes: Curved Tokens



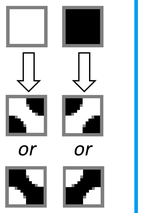
Stimuli and Methods

SUBJECTS
6 subjects
VA: 20/20, with correction if needed

CONDITIONS
288 to 320 trials per block
15 blocks per condition
4,320 trials per plane
158,400 total trials

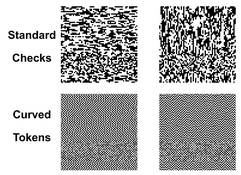
STIMULI
Check size: 14 min
Display size: 14.8 deg²
Binocular viewing at 1m
Contrast: 1.0
Duration: 120 ms, followed by 300 ms mask
Target: 16 x 64 pixels on a 64 x 64 array
Practice: approx. 50 trials per condition
Feedback during practice only

Generation of Textures with Curved Tokens



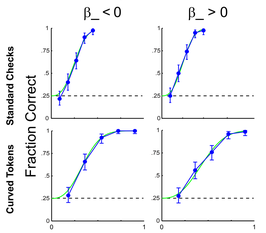
Each black or white check is replaced by one of two curved tokens. Tokens are chosen so that contours continue without interruption across check boundaries.

Sample Stimuli



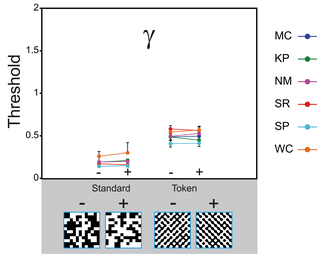
Example stimuli for the segmentation task. Targets could appear near any of the four edges (here, bottom). The textures used for the target (here, random) could be interchanged.

Psychometric Functions



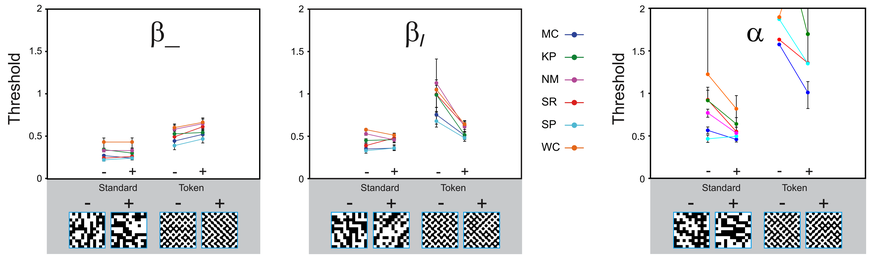
Psychometric functions along the β_ -axis. Error bars indicate 95% confidence limits via bootstrap. The smooth curves are fits to Weibull functions. Upper panels: textures consist of standard checks. Lower panels: textures consist of curved tokens. S: SP

Coordinate Axes

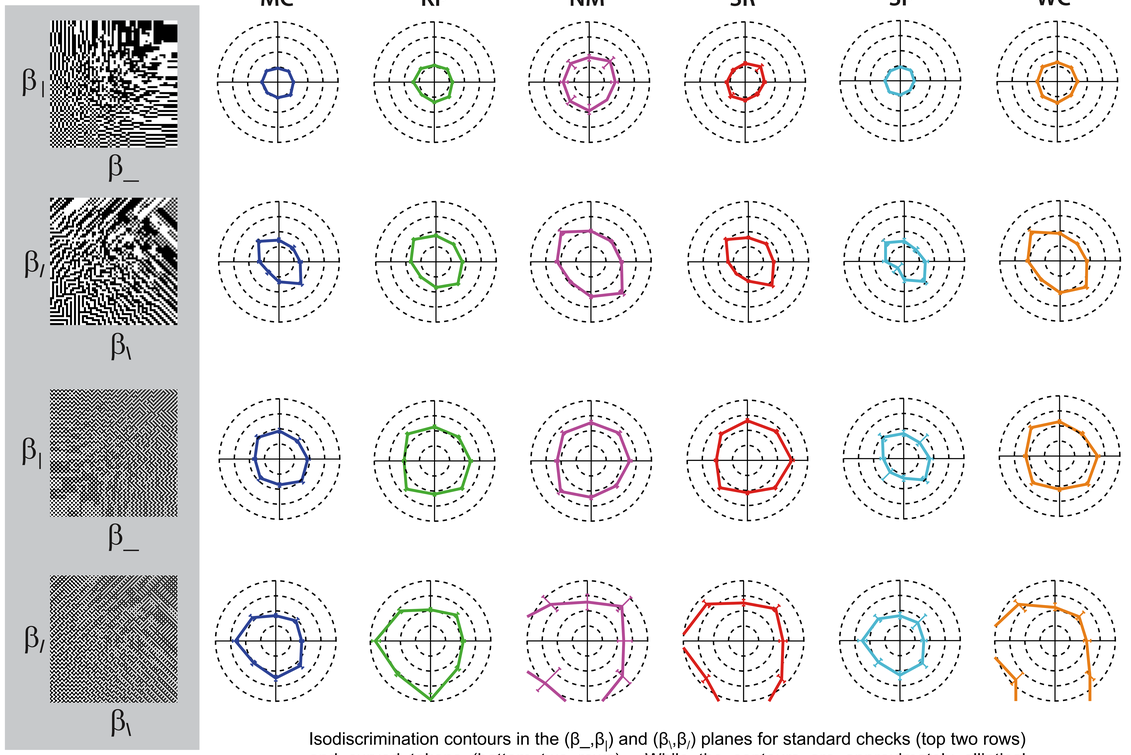


Thresholds along several coordinate axes for standard textures and textures consisting of curved tokens. Samples illustrate approximate thresholds (fraction correct = 0.625).

For β and α, thresholds depend not only on order and sign of correlation, but also, on whether curved tokens combine to form convex shapes. For standard checks, thresholds for β_ are independent of correlation sign, but for curved tokens, thresholds for β_ are lower for negative correlations. A contrasting interaction is seen for β/. Thresholds greater than 2 are not plotted.



Coordinate Planes: Isodiscrimination Contours



Isodiscrimination contours in the (β_,β|) and (β\,β/) planes for standard checks (top two rows) and curved tokens (bottom two rows). While the contours are approximately elliptical (consistent with quadratic cue combination) for tokens consisting of standard checks, there are systematic deviations from elliptical shapes for the curved-token textures.

Conclusions

- We demonstrate algorithms for the generation of textures that are balanced for lower-level features such as length, orientation, and curvature of contours, but differ in the shapes they contain.
- Thresholds for texture segmentation based on shape, consistent across 6 observers, depend on both the order of correlation, and whether convex shapes are formed.
- Sub-threshold combination of shape cues is present, but in contrast to results for simpler cues, it is not quadratic.

References

Victor, J.D. and Conte, M.M. (2012) Local image statistics: maximum-entropy constructions and perceptual salience. J Opt Soc Am **29**, 1313-1345.

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

Support: EY7977