The role of local image statistics in separating figure from ground

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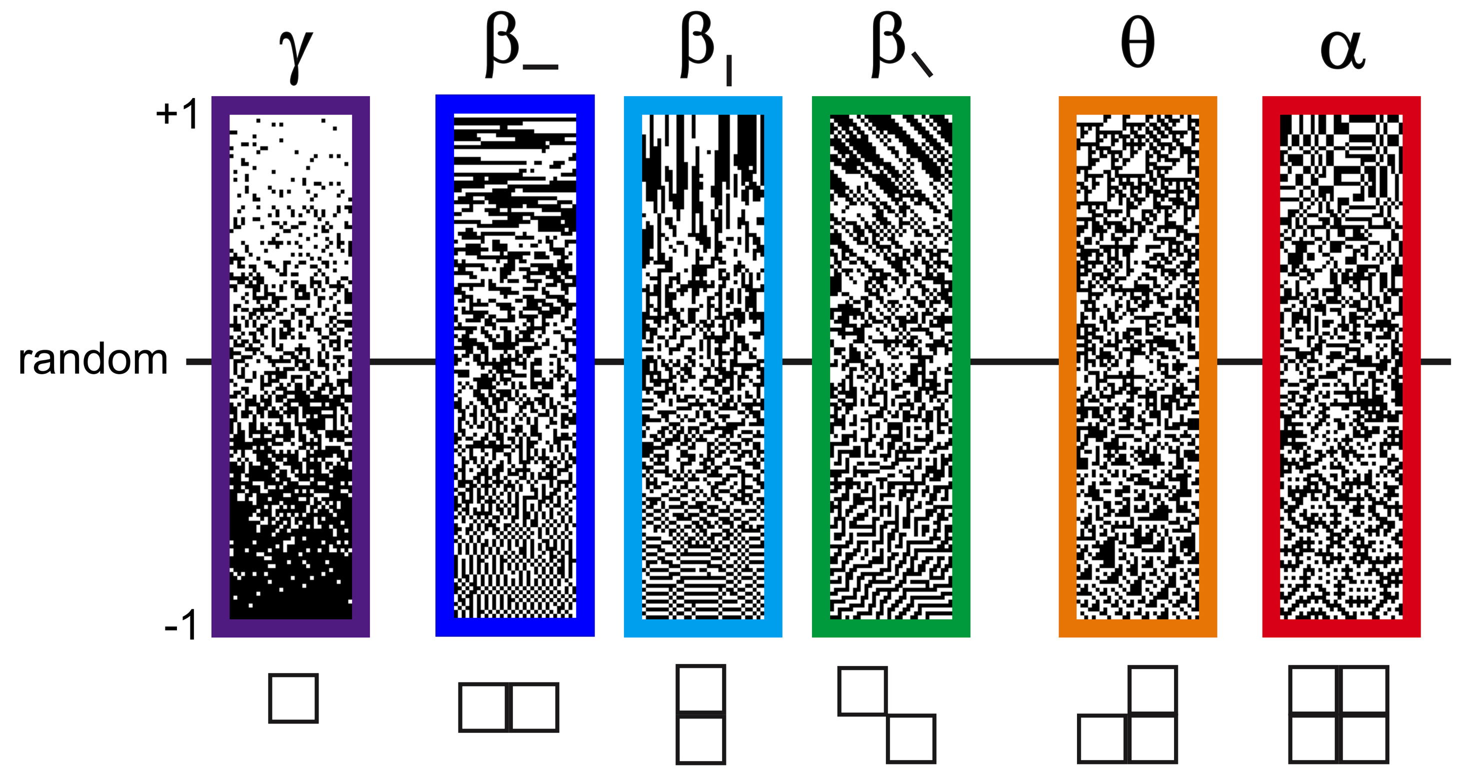
Motivation

Separating figure from ground is a crucial step in early visual processing. In complex, textured images, local analysis of image statistics provide several kinds of cues: the statistics within the figure, the statistics within the ground, and the differences between them. Here, we attempt to separate these roles.

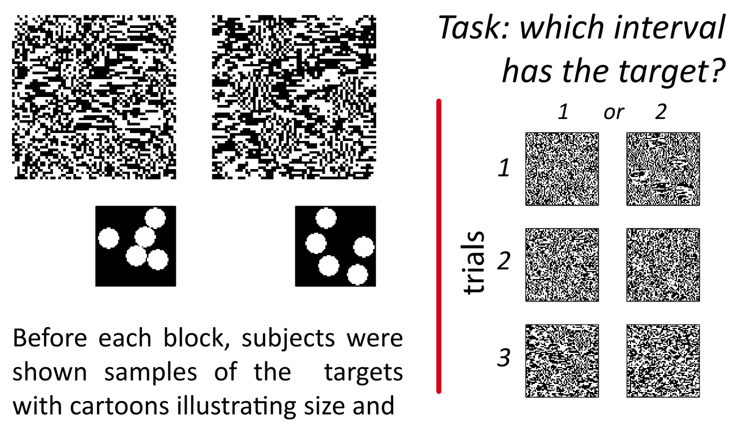
Methods



Stimulus Domains

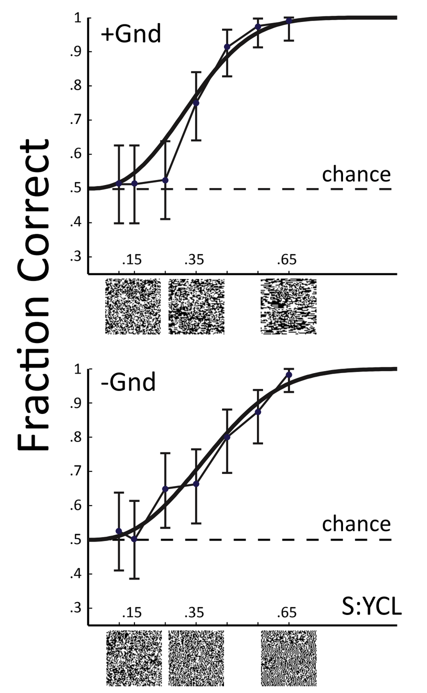
Local image statistics. Each strip shows the textures generated by varying an image statistic over its range, from -1 to +1. The first-order statistic determines the fraction of white vs. black checks. Second-order statistics determine correlations between pairs checks that are adjacent horizontally, vertically, or diagonally. Third- and fourth-order statistics determine the parity of checks in regions containing 3 and 4 checks, respectively. In all cases, the random texture corresponds to a correlation of 0.

Sample Trials and Task



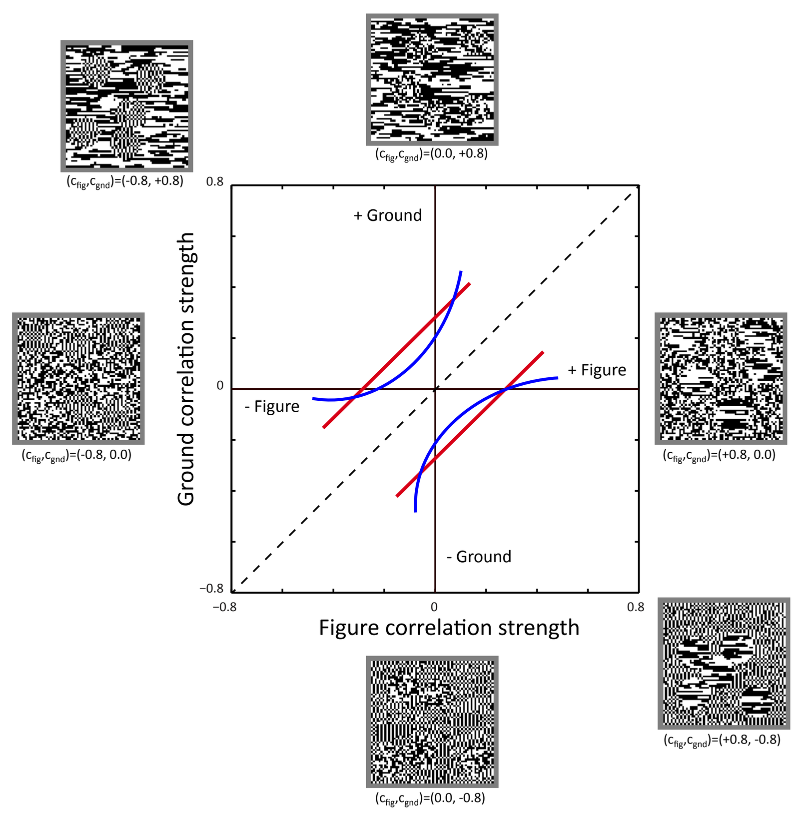
Before each block, subjects were shown samples of the targets with cartoons illustrating size and location of circles. These examples are drawn from two blocks that probe the β_ plane. **Left:** circles are defined by positive horizontal correlation; background is random. **Right:** circles are defined by negative horizontal correlation; background by positive horizontal correlation.

Weibull Functions



Example psychometric functions along the β_ axis (560 trials per curve, 80 trials per data point). **Upper panel:** positive correlation in ground; **lower panel:** negative correlation in ground. Smooth curves are Weibull function fits to fraction correct data; error bars indicate 95% confidence limits via bootstrap. Threshold is taken as the texture contrast at which fraction correct is 0.75. S: YCL.

Possible Outcomes



The locus of thresholds indicates how figure and ground statistics combine to determine the threshold for figure-ground separation. Parallel lines at a slope of 45 deg indicate that threshold is determined by texture contrast, i.e., a figure-ground difference. Hyperbolic loci suggest that threshold is determined by a quadratic discriminant.

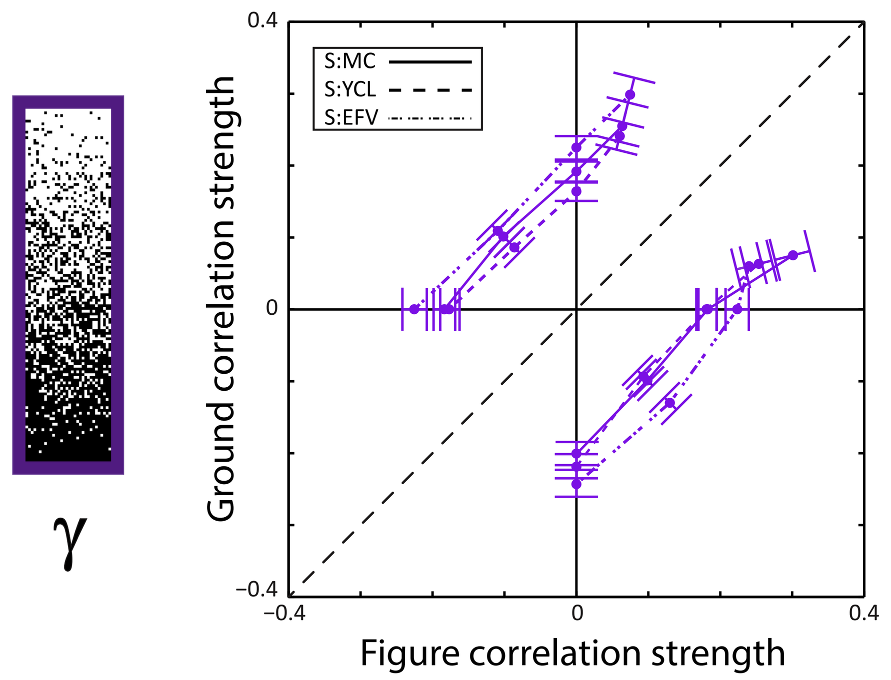
Details

Subjects
Ss: 3F
VA: 20/20

Conditions
2-AFC design
140 trials/block
32 blocks/condition
80,640 total trials
Practice: 1 hr/subject
Feedback: practice only

Stimuli
Contrast: 1.0
Check size: 9.8 min
Display size: 10.5 deg^2
Luminance: 81 cd/m^2
Binocular viewing at 1 m
Duration: 500 ms intervals followed by 500 ms mask
Target structure: 5 circles randomly-positioned; 25% of stimulus area

Results



For first-order statistics, thresholds for figure-ground separation were closely approximated by two parallel lines at a slope of 45 deg. This indicates that thresholds depended only on the absolute value of the difference between figure and ground, and not on the sign of the statistic in either region.

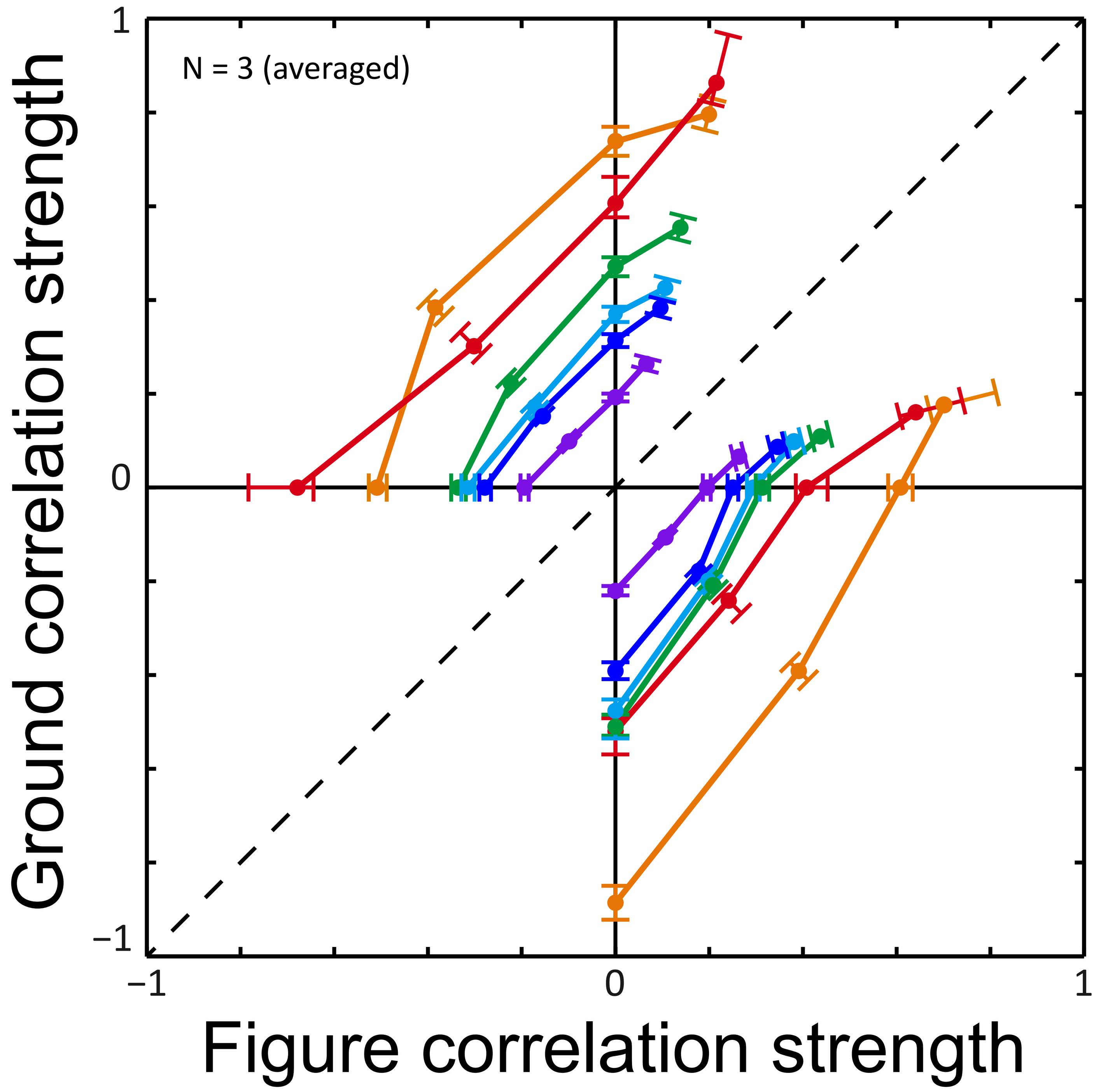
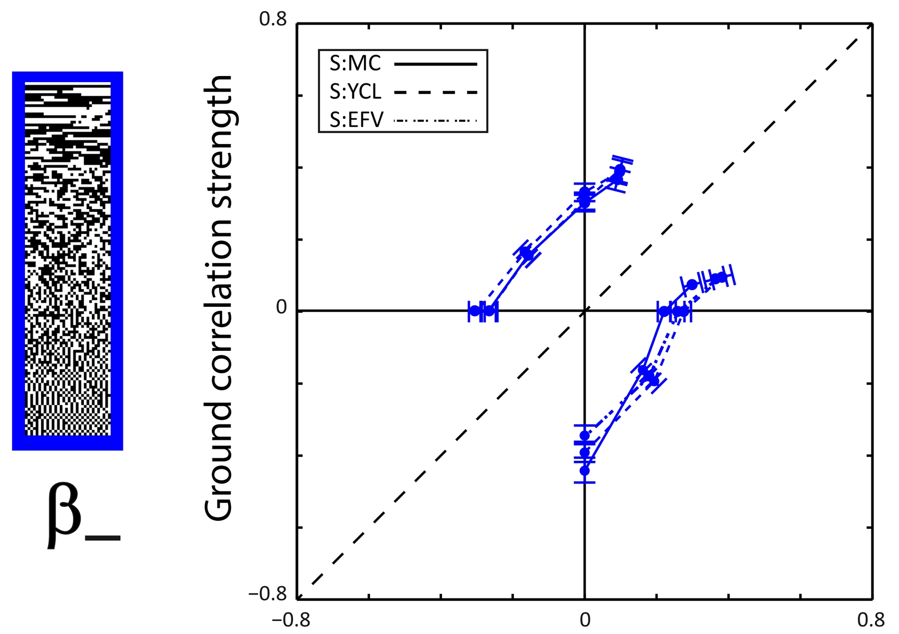
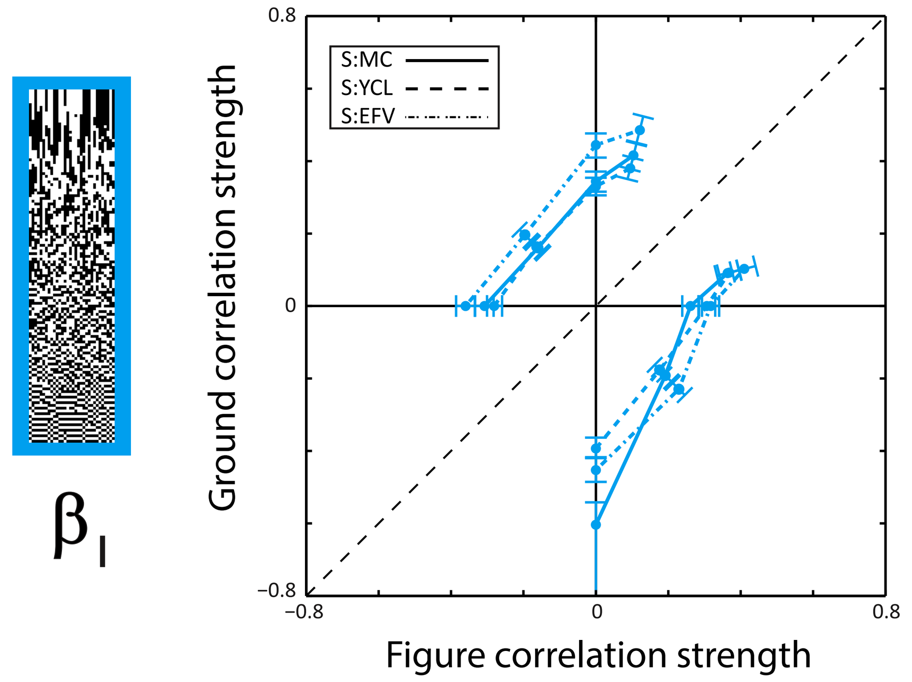
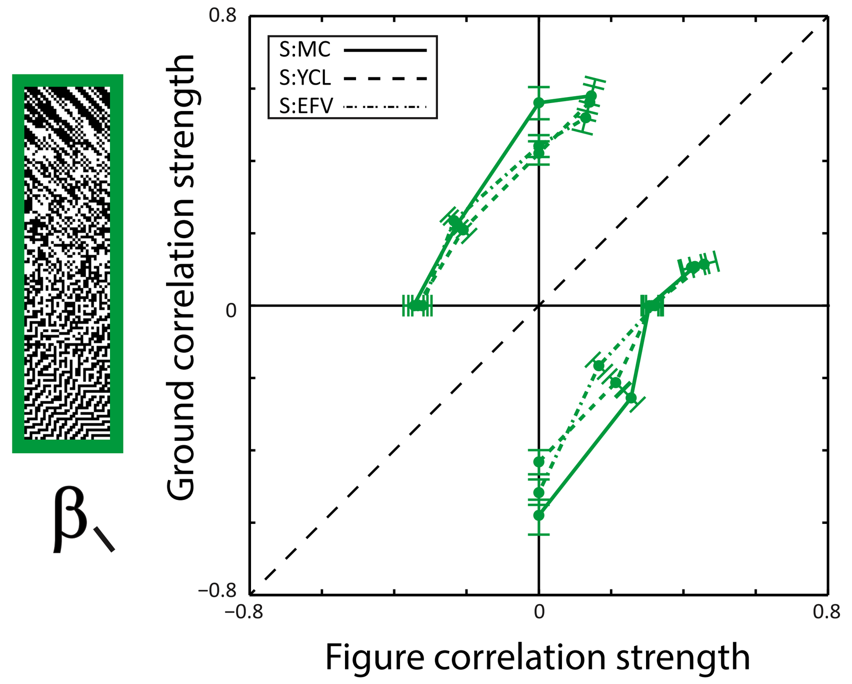


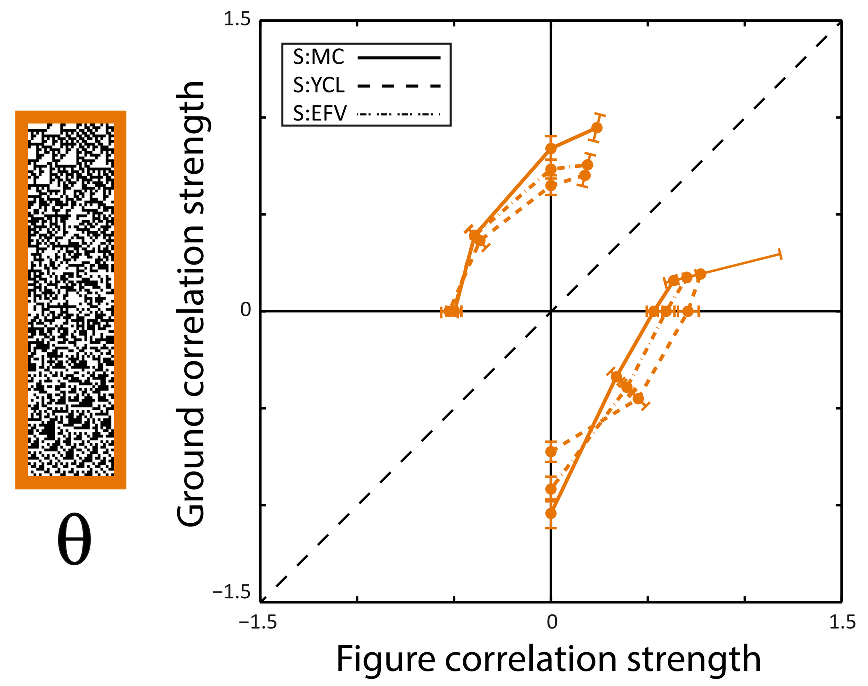
Figure-ground thresholds for first-, second-, third- and fourth-order image statistics (color-coded to adjacent plots). For each kind of statistic, loci are approximately parallel lines, indicating that thresholds are primarily driven by the figure-ground difference. Deviations are more prominent for higher-order statistics. Results are averaged across three subjects. Here and below, error bars are 95% confidence limits.

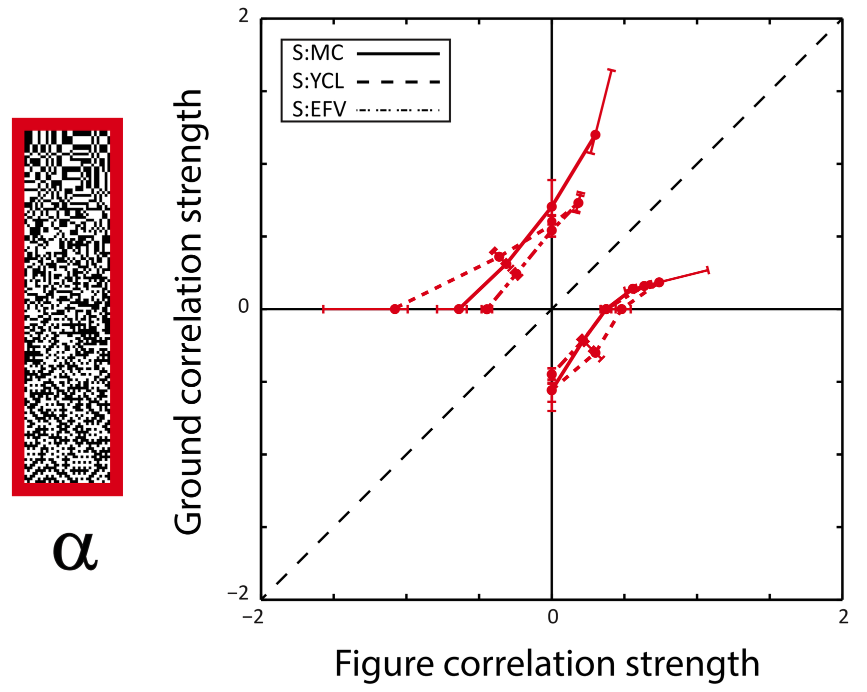




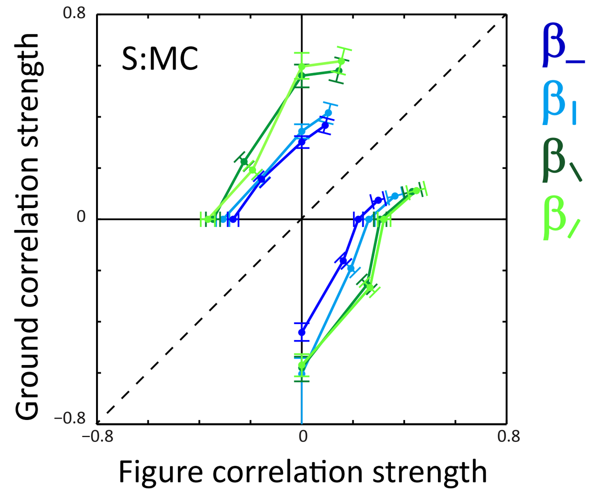


For second-order statistics, thresholds for figure-ground separation deviated somewhat from two parallel lines. The threshold for negative correlations in the ground was larger than thresholds for positive correlations in the ground, or for negative correlations in the figure.





For third- and fourth-order statistics, the deviations are more pronounced, and the threshold loci show some evidence of curvature. A hyperbolic threshold locus suggests that the figure-ground computation is based on a quadratic discriminant, rather than a texture difference.



β_ β| β\ β/ In one subject, MC, thresholds were determined for second-order statistics in all four directions (horizontal, vertical, and the two diagonals). There were differences in sensitivity to negative horizontal and vertical correlations in the ground. There were no differences between the two diagonals.

Image Statistic	Variance Unexplained
γ	0.05
β_	0.32
β|	0.40
β\	0.35
β/	0.48 *MC only
θ	0.55
α	0.25

Testing the hypothesis that threshold depends on texture contrast. This hypothesis accounts for all but 5% of the variance for γ, but leaves 25-50% of the variance unexplained for higher-order statistics. All deviations, however, are significant by the F-test, $p < 0.01$ for γ and $p < 0.001$ for all other statistics ($F_{7,8}$).

Summary and Conclusions

- Thresholds for figure-ground separation depended on the order of the image statistic: lowest for first-order, then second-order, then fourth-order, then third-order. This matched previous findings in a texture-segmentation task.
- To a first approximation, figure-ground thresholds were determined by the difference between value of an image statistic in figure vs. ground.
- For image statistics beyond first-order, consistent deviations across subjects were found: unequal sensitivities to positive vs. negative correlations, and unequal sensitivities to statistics in figure vs. ground.
- Thus, ground and figure composition, as well as figure-ground texture contrast, influence figure-ground thresholds.

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.

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