# A distinctive role for orientation in figure-ground separation

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Jonathan D. Victor and Mary M. Conte

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

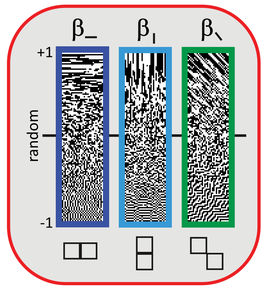
## Motivation

Figure-ground separation can be driven by many cues, including luminance, contrast, and orientation. In natural scenes, these cues are intertwined. To analyze their roles, we use synthetic textures in which these cues could be separately manipulated. We then asked whether figure-ground separation is driven simply by the difference between figure and ground, or rather, whether the compositions of figure and ground also play a role. Here, we focus on textures defined by their second-order statistics, as these contain both contrast and orientation information.

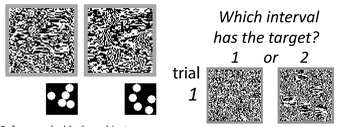
## Methods

### Stimulus Domains

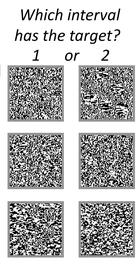
Each strip shows the textures generated by varying a second-order image statistic over its range, from +1 to -1. These statistics determine correlations between pairs of checks that are adjacent horizontally, vertically, or diagonally. In all cases, a random texture corresponds to a correlation of 0.




### Sample Trials and Task



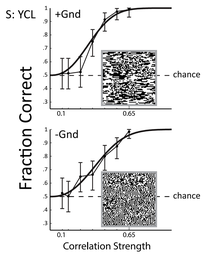
Before each block, subjects were shown samples of the targets with cartoons illustrating size and location of circles. These examples are drawn from the β_ plane. **Left:** circles are defined by positive horizontal correlation; background is random. **Right:** circles are defined by negative horizontal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




### Testing Details

**Subjects**: 3F; VA = 20/20 **Conditions**: 2-AFC design with 140 trials/block, 32 blocks/condition (**120,960** total trials), Practice: 1 hr/subj, feedback only with practice. Binocular viewing at 1 m. **Stimuli**: Contrast: 1.0, Check size: 9.8 min; Display size: 10.5 deg, luminance: 81 cd/m², Trial duration: two 500 ms intervals followed by a 500 ms mask, Target structure: 5 circles randomly-placed = 25% of stimulus area.

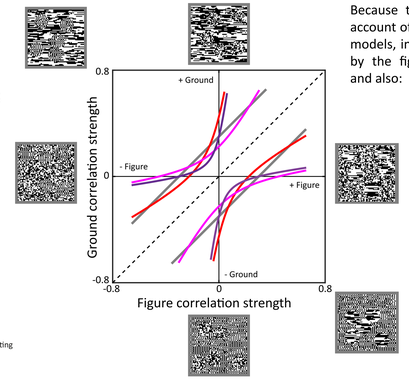
### Weibull Functions




Psychometric functions on the β_ axis (560 trials/curve; 80 trials/data point. **Upper**: positive correlation in ground; **lower**: negative correlation in ground. Smooth curves are Weibull function fits to fraction correct data; error bars are 95% confidence limits. Threshold is taken as the texture contrast at which fraction correct is 0.75.

### Modeling Possible Outcomes

The locus of thresholds indicates how figure and ground statistics combine to enable figure-ground separation. A simple model is that threshold is determined by the texture difference between figure and ground. This corresponds to thresholds that lie on **parallel 45 deg lines.**




Because this model was an incomplete account of our data, we considered other models, in which threshold is determined by the figure-ground texture difference and also:

the figure texture, yielding an asymmetric hyperbola skewed towards the figure axis

the ground texture, yielding an asymmetric hyperbola skewed towards the ground axis

figure and ground textures, playing equal roles, yielding a hyperbola symmetric about the diagonal

*Note that the influences of the figure-ground texture difference and the components can be distinguished because the model assumes quadratic cue combination.*

*Related Work:*

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. http://www-users.med.cornell.edu/~jdvicto/vitgrz15.html

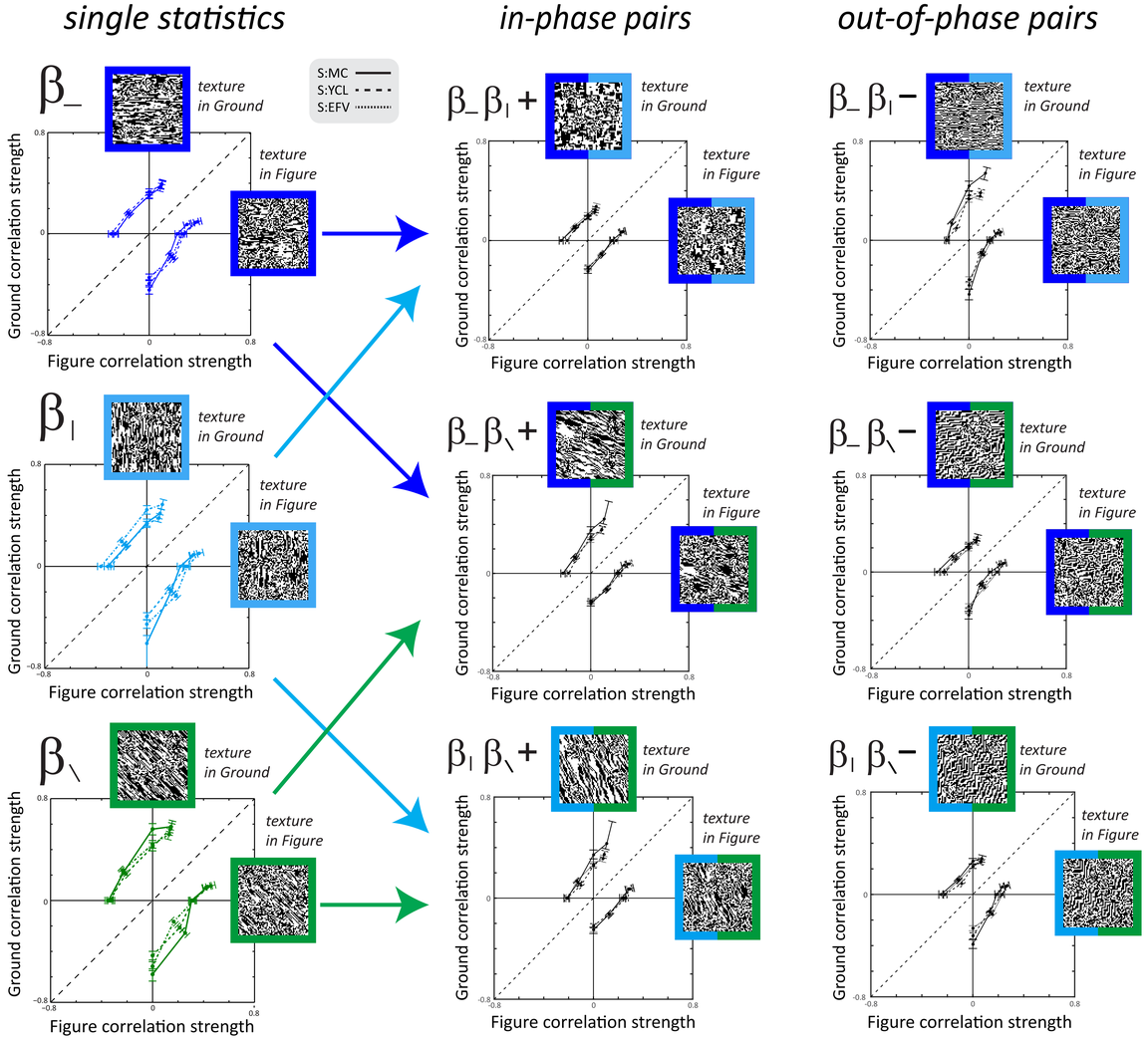
Victor, J.D., and Conte, M.M. (2019) The role of local image statistics in separating figure from ground. (Abstract) Vision Sciences Society Annual Meeting 2019. http://www-users.med.cornell.edu/~jdvicto/vps/vss19_vico.pdf

## Results

For individual image statistics, thresholds for figure-ground separation deviated from two parallel lines at 45 deg, (the behavior corresponding to a constant figure-ground difference). Thresholds were generally lower for correlations in the figure, than for correlations in the ground.

For in-phase pairs, thresholds for figure-ground separation were closer to parallel lines at 45 deg, especially for the $\beta_{-}\beta_{|}+$ combination (top), which contains un-oriented blobs

For out-of-phase pairs, thresholds deviated substantially from parallel lines at 45 deg. These textures are the most strongly oriented, with positive correlations at one orientation and negative correlations at a different orientation.




### Simple model: figure-ground differences

| | | *in-phase pairs* | | *out-of-phase pairs* | |
|---|---|---|---|---|---|
| Single Statistics | Variance Unexplained | Paired Statistics | Variance Unexplained | Paired Statistics | Variance Unexplained |
| $\beta_{-}$ | 0.31 | $\beta_{-}\beta_{|}+$ | 0.09 | $\beta_{-}\beta_{|}-$ | 0.55 |
| $\beta_{|}$ | 0.40 | $\beta_{-}\beta_{\backslash}+$ | 0.20 | $\beta_{-}\beta_{\backslash}-$ | 0.32 |
| $\beta_{\backslash}$ | 0.35 | $\beta_{|}\beta_{\backslash}+$ | 0.14 | $\beta_{|}\beta_{\backslash}-$ | 0.43 |

A model based solely on figure-ground differences fails when correlations are strongly oriented. The model fits poorly for textures that contain correlations at a single orientation ($\beta_{-}$, $\beta_{|}$, $\beta_{\backslash}$), or positive correlations at one orientation and negative correlations at another (*out-of-phase pairs*). The model fits best for blob-like textures (*in-phase pairs*).

### Models that add other cues to figure-ground difference

| Cues Added | Variance Unexplained |
|---|---|
| figure-ground difference only | 0.33 |
| figure texture | 0.10 |
| ground texture | 0.29 |
| figure and ground play equal roles | 0.29 |

## Conclusions

- Many types of second-order correlations can drive figure-ground separation.
- For correlations that are not oriented, figure-ground difference determines thresholds.
- For correlations that are oriented, figure composition interacts with figure-ground difference, yielding lower thresholds when the figure is structured.

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