A statistical model of peripheral vision predicts the Pinna-Gregory illusion

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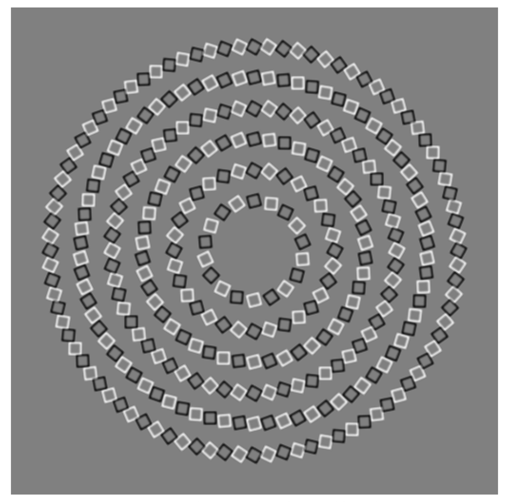
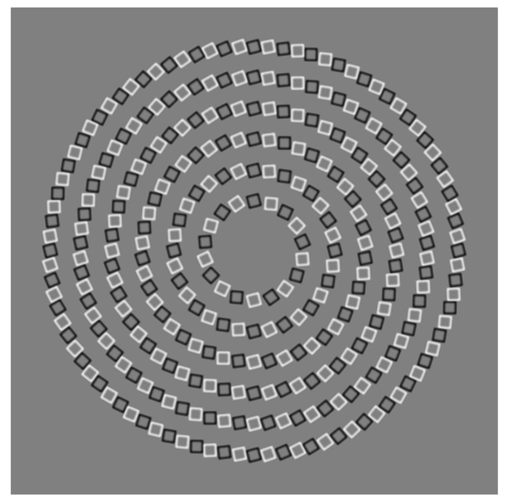
Pinna-Gregory Illusions

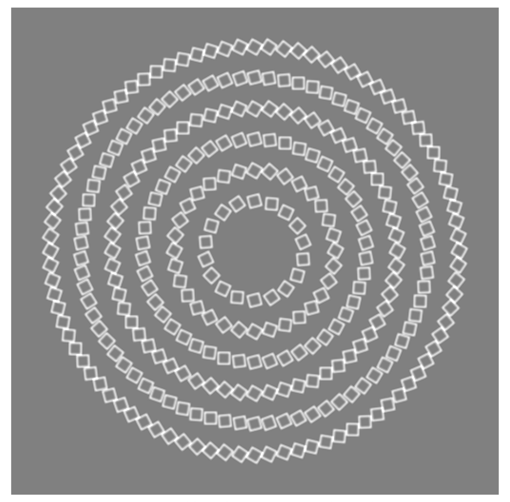

Intersecting Circles Illusion


Spiral Illusion

A subtle change in orientation of some squares leads to a significant perceptual difference.

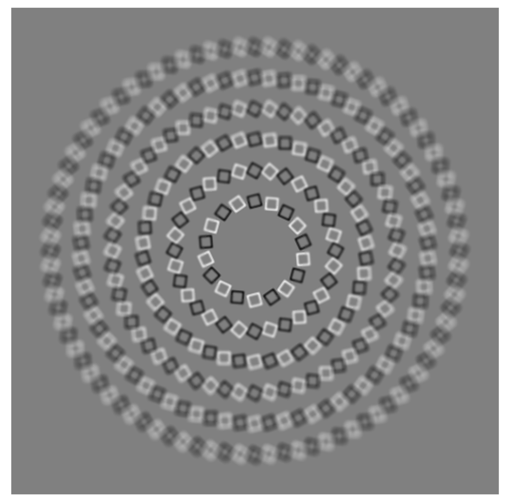
The illusion is absent at fixation, suggesting that this illusion is due to mechanisms of peripheral vision.

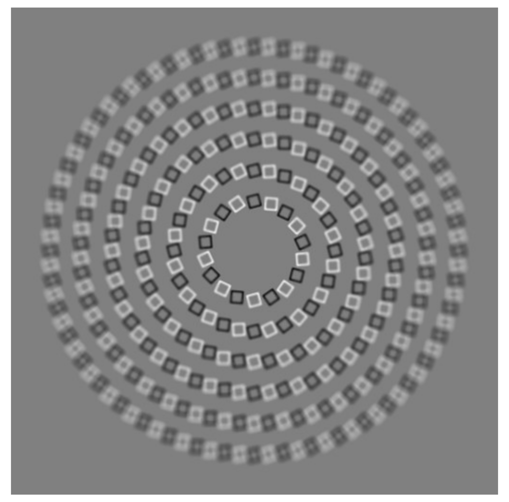
The illusion no longer holds when every square is of the same color.


No Illusion Perceived

Can only lower spatial resolution in periphery explain it?

Answer: No, it's not sufficient.





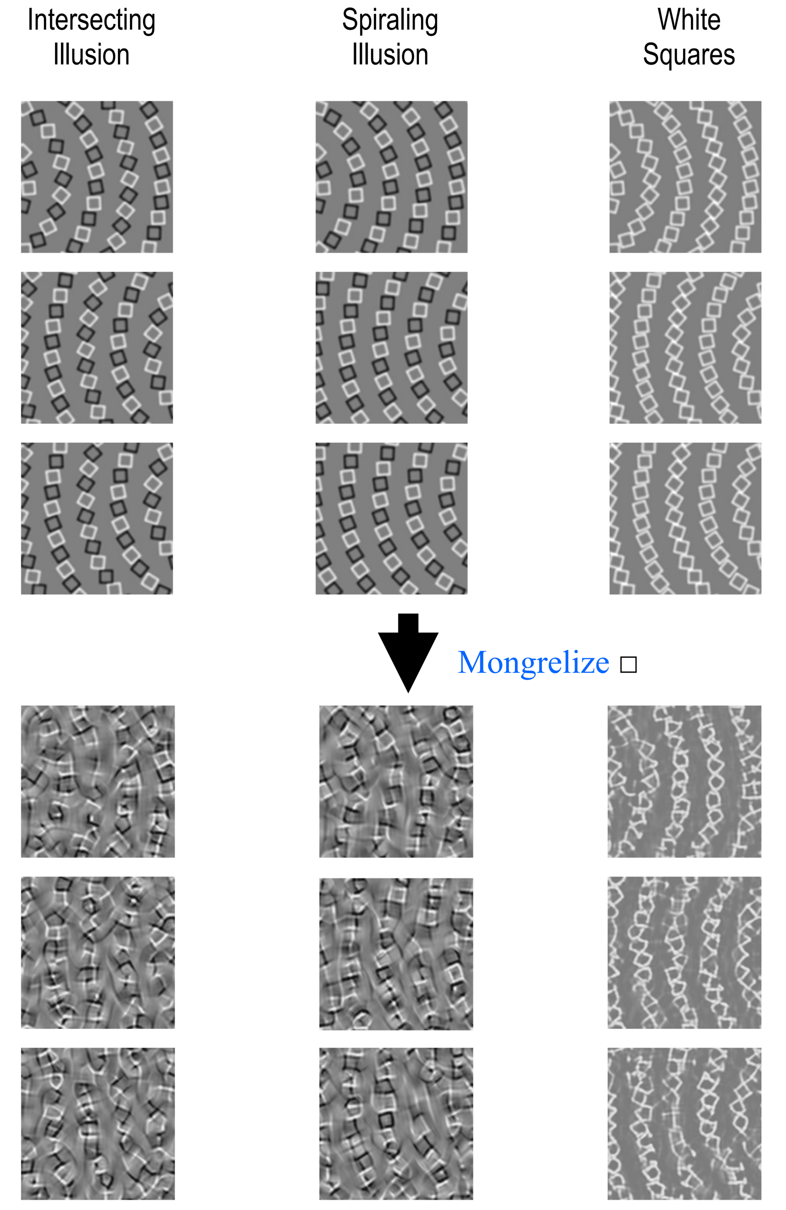
- ♦If peripheral blur were sufficient we would be able to trace (i.e., with a finger or a pen) spirals or intersecting circles in the simulated image.
- ♦We do not observe any of those characteristics (even at other levels of peripheral blur).

Visual Representation as Collection of Statistics

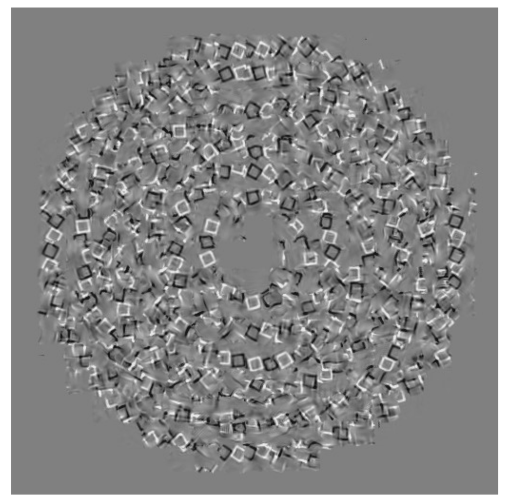
[Balas, Nakano, Rosenholtz] (See Rosenholtz's talk, Sunday 6pm!)

- ♦Peripheral stimuli are represented as joint statistics of complex wavelet coefficients.
- ♦Visualize the statistical representation by synthesizing an image to match the same statistics. (□ A process we term mongrelizing).
- ♦Use existing texture analysis and synthesis techniques from computer graphics [Portilla, Simoncelli, 2000] to capture statistical representation and to visualize it.
- ♦This representation and visualization technique has been shown to do well in predicting difficulty in both crowding and visual search.
- ♦Marginal statistics alone cannot differentiate the spiral and intersection illusions, which further motivates our representation using joint statistics of complex wavelet coefficients.
- ♦We apply this technique to visualize the statistical representation of this illusion.

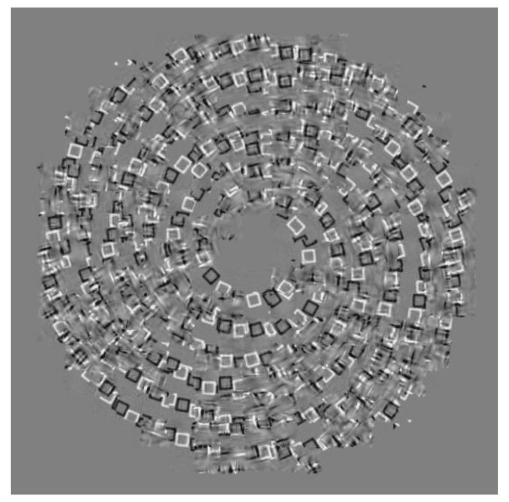
Enforce local pooling region statistics from illusion



Visualize the statistical representation

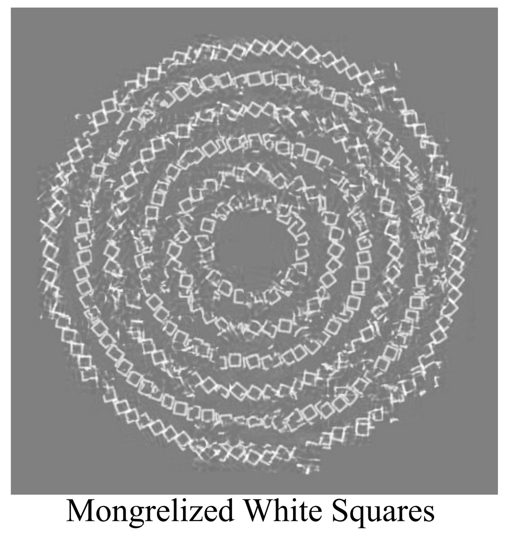

Mongrelized Intersection Illusion

There are "crossings" between rings in an almost chaotic manner, similar to our perception of the illusion.


Mongrelized Spiral Illusion

We see some actual spirals in this image — occasional smooth transitions between rings which one can trace with a finger or a pen.

We stitch together many patches (pooling regions) constrained to match the same statistics as the original stimulus.

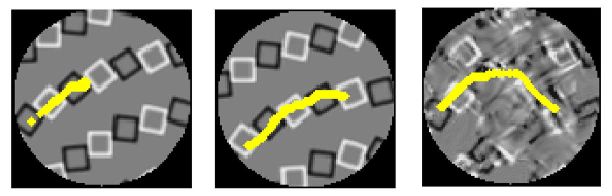

Mongrelized White Squares

For the most part, except for some stray pixels, this image consists of concentric non-crossing circles.

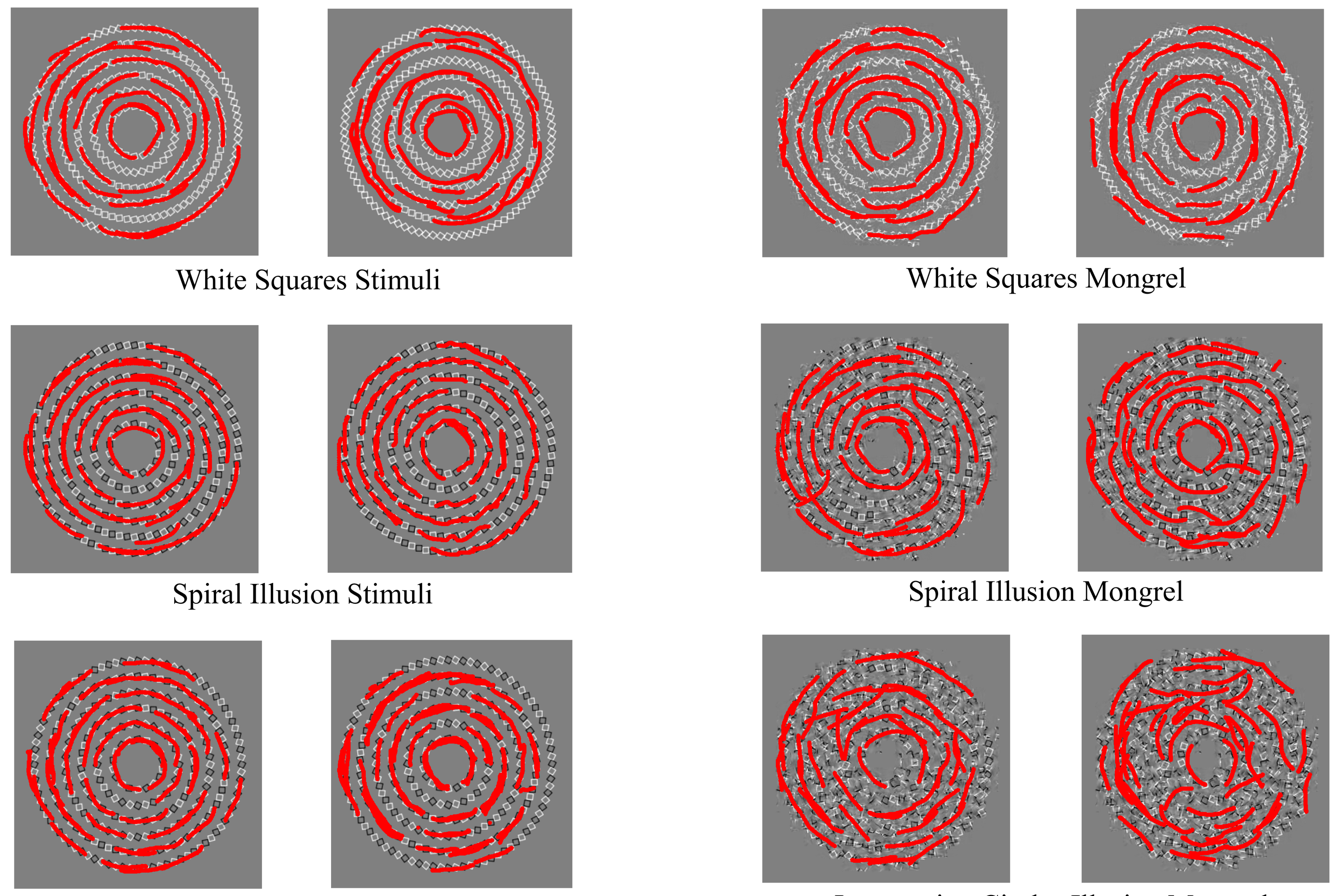
How do we test our hypothesis?

Subjects mark one small patch at a time to minimize confounding factor of still seeing the illusion while marking the image.

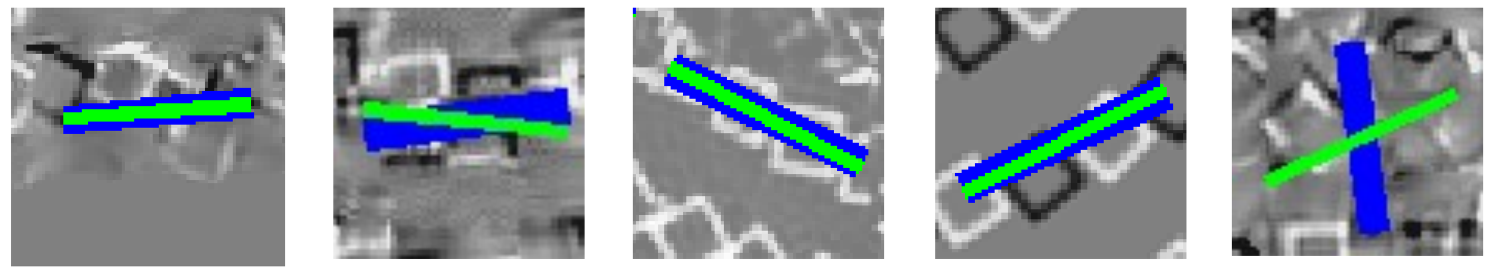
Task: Mark (using a pen input device or a mouse) a contour in patches taken from the original stimuli and their corresponding mongrels (50 patches in each stimulus or mongrel).



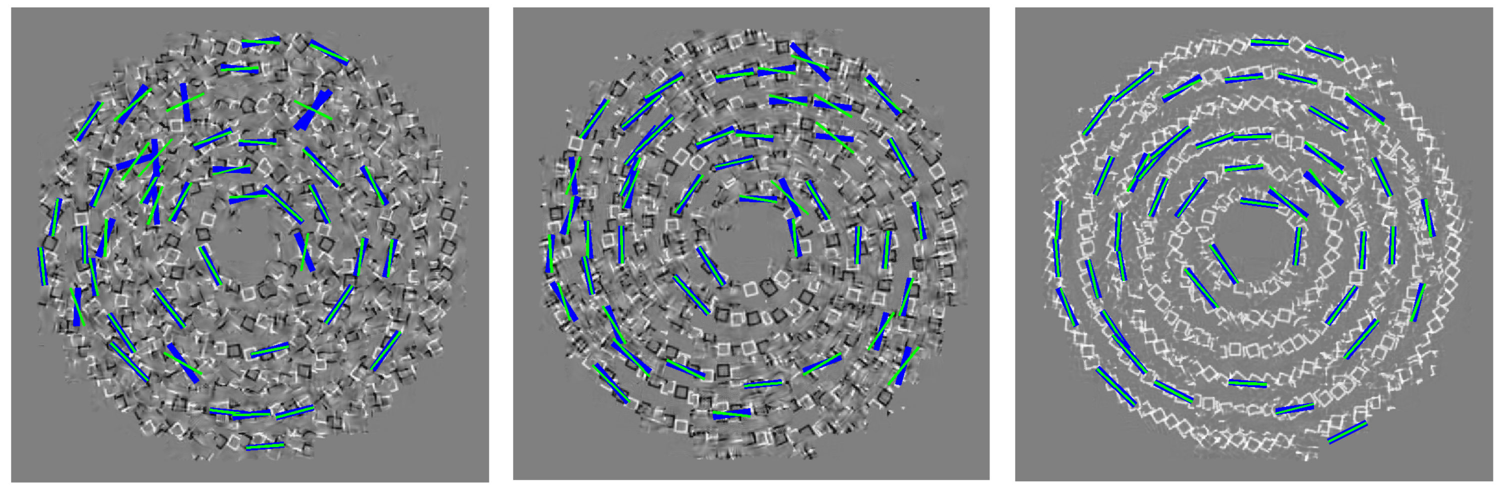
Some sample markings overlaid onto the stimuli and mongrels


White Squares Stimuli — White Squares Mongrel
Spiral Illusion Stimuli — Spiral Illusion Mongrel
Intersecting Circles Illusion Stimuli — Intersecting Circles Illusion Mongrel

Quantifying our qualitative impressions



- ♦Perfectly marking the original stimuli would result in markings that are sectors from the ideal circle, which is centered in the middle of the image.
- ♦For each patch that a subject marked, we compute the angular deviation of the **estimated tangent of that marking (blue)** to the **tangent of the ideal circle (green)**.

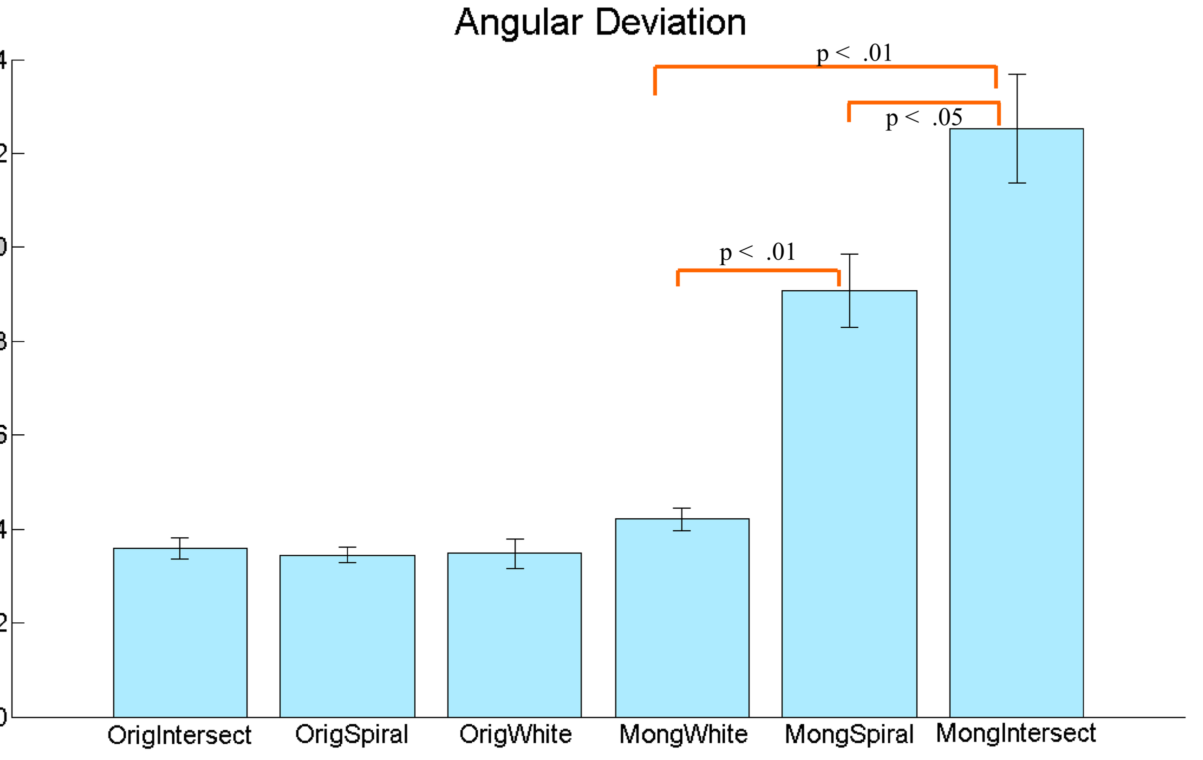


Some sample markings with angular deviation estimates overlaid

If a statistical representation underlies these illusions, we expect:

- ♦Zero (+ input device error) angular deviation for original stimuli.
- ♦Angular deviation of white squares mongrel is close to that of original stimuli.
- ♦Spiral and intersecting circles mongrels have markings that deviate significantly from concentric circles and those of the white squares mongrel.
- ♦Higher angular deviation for intersecting circles mongrel than for the spiral mongrel, because the percept for the spirals illusion is closer to that of circles than the intersecting illusion.
- ♦More large deviations (> 30° degrees) in the intersecting circles mongrel than in the spiral mongrel.

Results



Plot of mean angular deviation with standard error bars. (5 subjects marked 50 patches in each image)

p < .01 (Mongrel Spiral Illusion vs. Mongrel Intersect Illusion)

30°	Mongrel Spiral Illusion	Mongrel Intersect Illusion
% of angular deviations > 30°	3 %	12 %

Frequency of large angular deviations

- Original stimuli have little or no angular deviation, as expected.
- Angular deviation for the white squares mongrel are only marginally higher than those of the original ($p < .15$).
- The spiral and intersecting mongrels deviate greatly from the original stimuli as well as the white squares mongrel.
- The relative deviation from perfect concentric circles within mongrels is consistent with our perception: white squares mongrel seem closest to concentric circles, and intersecting circles seem farthest from concentric circles.
- The mongrel intersection illusion has significantly more large angular deviations than the mongrel spiral illusion.

- ♦**Our Hypothesis — the peripheral representation of visual structure is "statistical".**
- ♦**We demonstrated that information lost under this representation leads to an ambiguity between the concentric circles that make up the Pinna-Gregory illusion and the spiral/intersecting patterns that are perceived.**
- ♦**We therefore suggest that this illusion is a by-product of representing the periphery via a statistical code.**

Acknowledgements

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References

Pinna, B., Gregory, R.L., 2002. Shifts of Edges and Deformations of Patterns. Perception, 31, 1503-1508

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