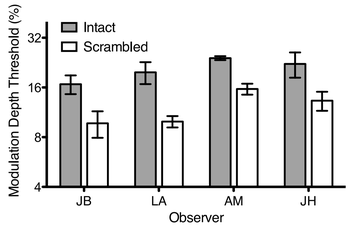
Segmentation of Boundaries Defined by Natural and Naturalistic Textures

Elizabeth Arsenault, Curtis Baker

McGill Vision Research Unit McGill University, Montreal, Canada

Introduction

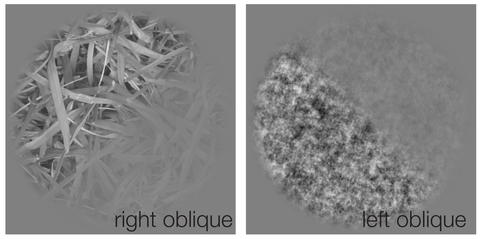
Higher-order statistics impair segmentation of contrast defined boundaries in natural textures.[1]



Can conventional models capture how texture structure affects segmentation?

Methods

Human psychophysics, model simulation

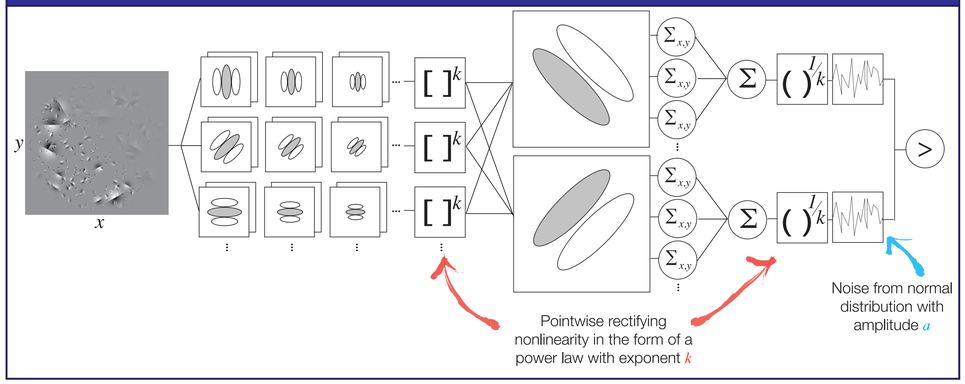


2AFC: Right- or left-oblique?

75%-correct modulation-depth threshold

What texture properties affect threshold?

Model



Fitting

Exhaustive search over parameter space:
k = [0.25 0.5 1 2 3]
a = [10 ... $10^{14.75}$].

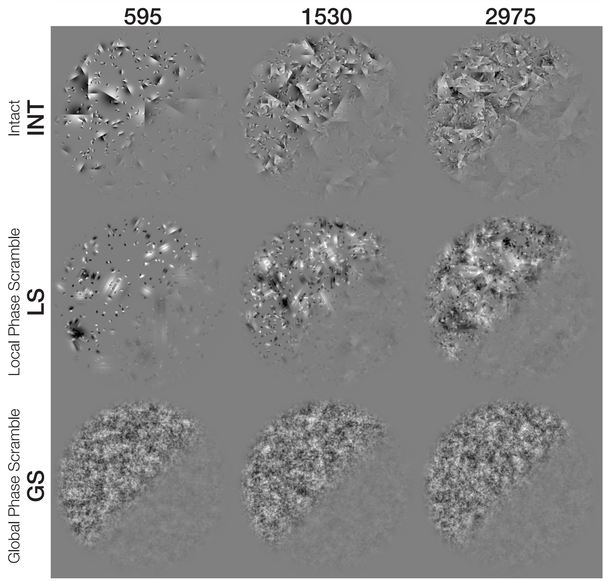
SSE computed between human and simulated orientation & contrast modulation thresholds (N = 14) for each combination of parameters:

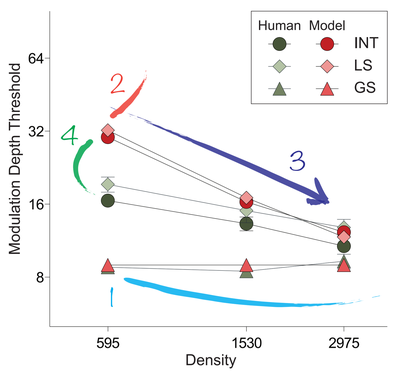
$$SSE = \sum_i (\log h_i - \log m_i)^2$$

Model was evaluated at optimal values of a and k.

Conditions & Results

CONTRAST MODULATION





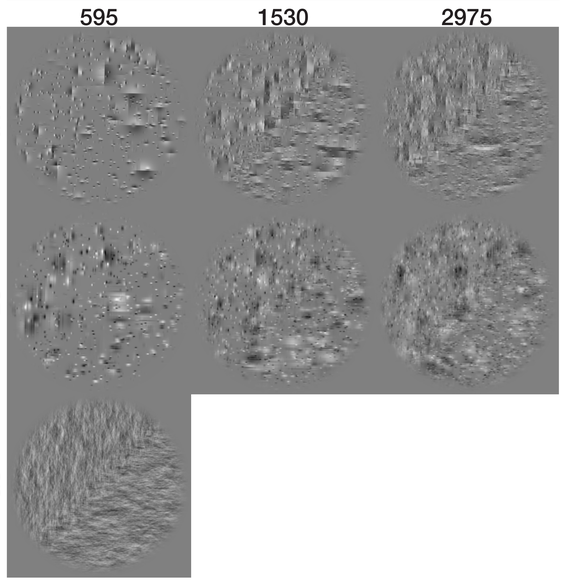
(1) The model predicts thresholds well in the absence of structure.

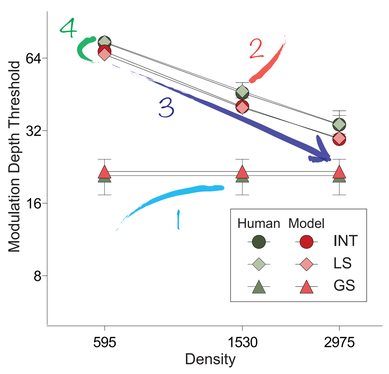
(2) Both model and human show little sensitivity to local structure.

(3) The model predicts the effect of density.

(4) Model overestimates INT and LS thresholds at low densities.

ORIENTATION MODULATION





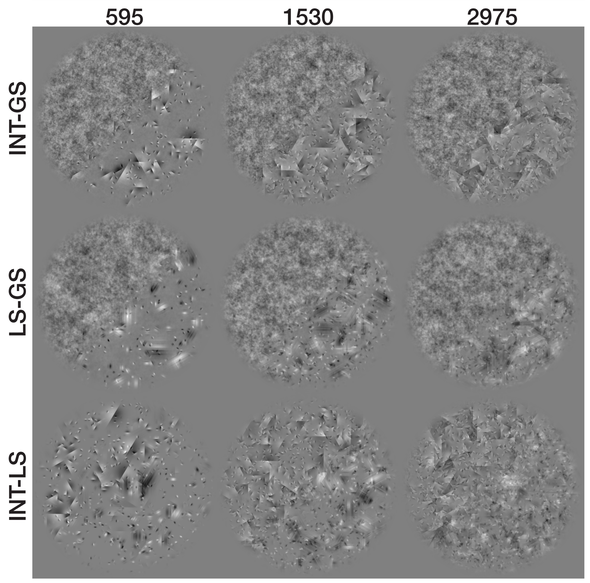
(1) The model predicts thresholds well in the absence of structure.

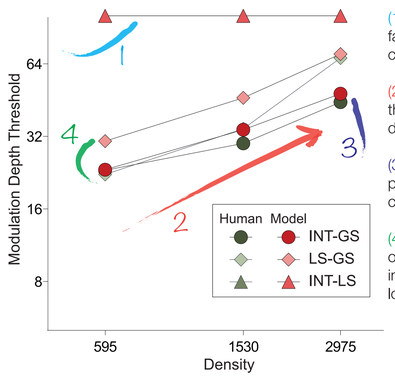
(2) Both model and human show no sensitivity to local structure.

(3) The the effect of density on thresholds is well-predicted.

(4) Model slightly underestimates thresholds at all densities in the INT and LS conditions.

STRUCTURE MODULATION





(1) Both model and human fail to segment INT-LS condition reliably.

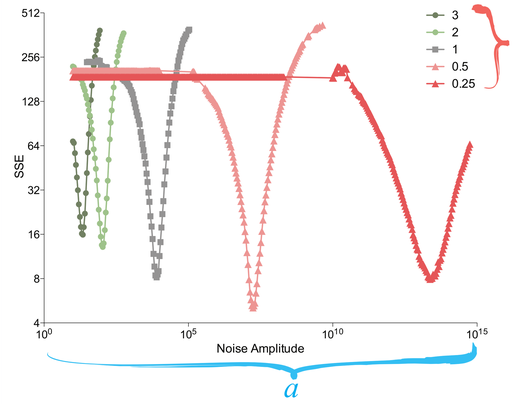
(2) Model and human thresholds increase with density.

(3) The model predicts performance in the INT-GS condition well.

(4) The model overestimates thresholds in the LS-GS condition at low densities.

Model Behaviour

SIMULATION ERROR

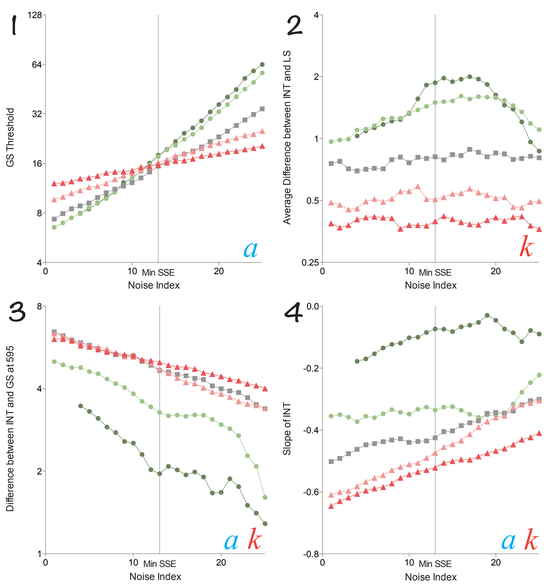


Expansive, rectilinear, and compressive power law exponents.

Error is minimized with k = 0.5 and a = $10^{7.25}$

At lower values of k, signal mean and variance were much higher, so a higher noise amplitude was required to impact performance.

EFFECTS OF PARAMETERS



(1) The difficulty of the globally scrambled condition depends exclusively on **noise amplitude**.

(2) The difference between the intact and locally scrambled conditions depends mainly on the **power law exponent**.

(3) The difference between the intact and globally scrambled conditions at low densities, and **(4)** the slope of the intact performance over density depend on both **power law exponent** and **noise amplitude**.

Conclusions

- An FRF model is capable of capturing many of the effects of higher-order statistics
- An intermediate compressive nonlinearity provides the best fit to human data
- Decision noise does not simply scale model performance

Discussion

- Compressive nonlinearities might emulate the effects of neuronal suppression[2]
- Sublinear summation may be a general property of early visual processing[3]

References:
(1) Arsenault, Yoonessi & Baker (2011). "Higher-order texture statistics impair contrast boundary segmentation" *Journal of Vision*.
(2) Mineault, Khawaja, Butts & Pack (2012). "Hierarchical processing of complex motion along the primate dorsal visual pathway" *PNAS*.
(3) Vu, Ravikumar, Naselaris, Kay, Gallant & Yu (2011). "Encoding and decoding V1 fMRI responses to natural images with sparse nonparametric models" *The Annals of Applied Statistics*.

This research was funded by an NSERC grant (OPG0001978) to CB.