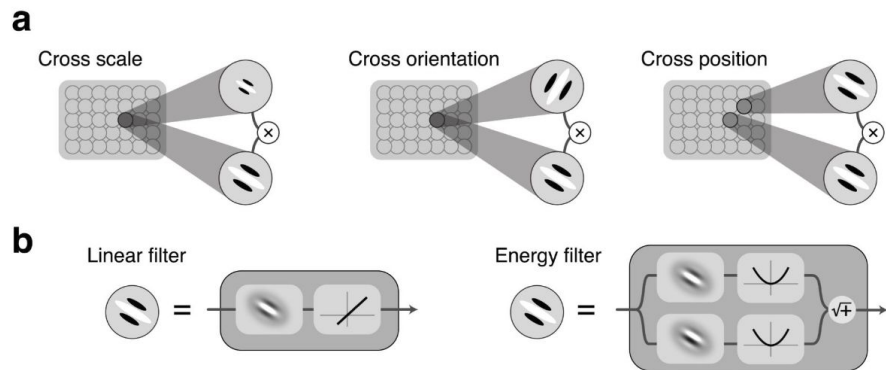# Task-dependent contribution of higher-order statistics to natural texture processing

Daniel Herrera-Esposito, Ruben Coen-Cagli

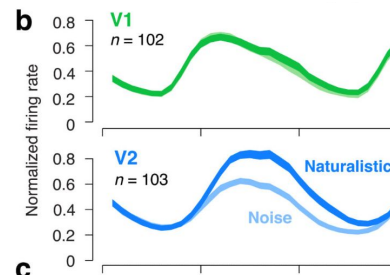UNIVERSIDAD DE LA REPÚBLICA URUGUAY

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Albert Einstein College of Medicine

Background:

- Portilla-Simoncelli model is a set of summary statistics
- It is an influential model of vision

Balas, Nakano, Rosenholtz. 2009 JOV

Ziemba, Freeman, Simoncelli, Movshon. 2013 Nat Neuro
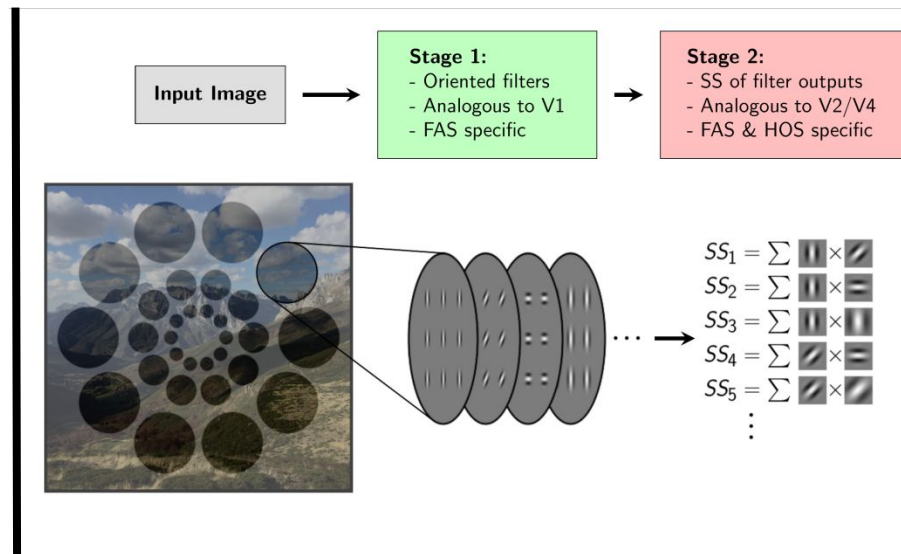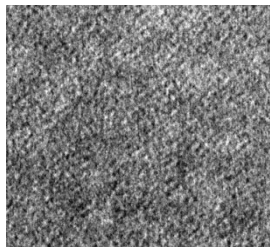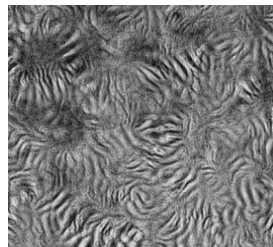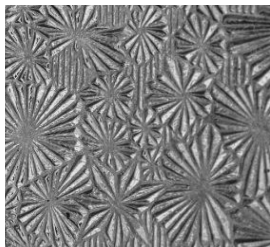
Background:

- Portilla-Simoncelli statistics can be divided into **spectral statistics** and **higher-order statistics (HOS)**
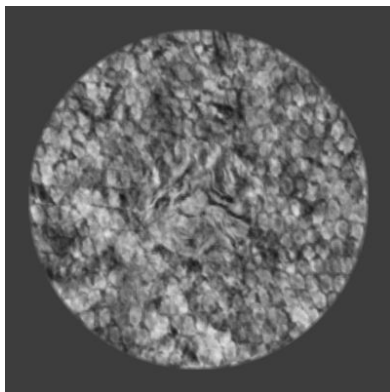
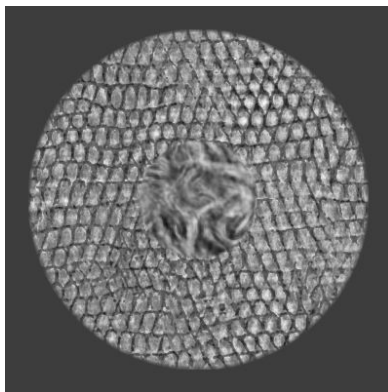Original   HOS+Spectral   Spectral

Background:

- Humans mostly ignore differences in HOS for naturalistic texture segmentation

HOS difference

HOS & Spectral difference

In line with previous work:

Hermundstadt et al. 2014 eLife
Tesileanu et al. 2020 eLife
Tkacik et al. 2010 PNAS
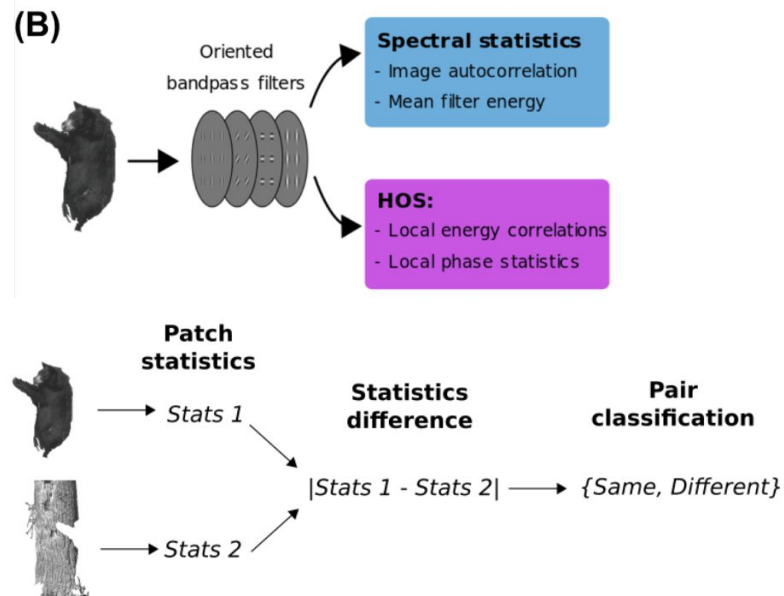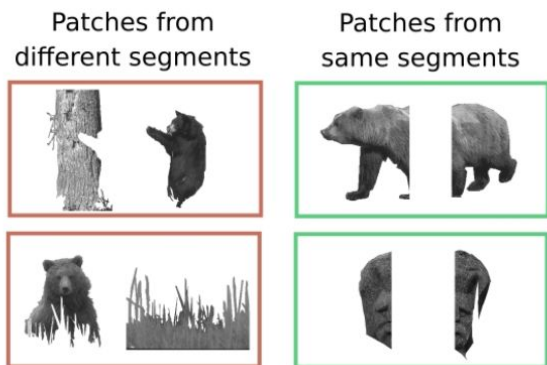Victor et al. 2013 JOV
Zavitz et al. 2014 JOV

Herrera-Esposito, Coen-Cagli, Gomez-Sena. (2021) JOV

Background:

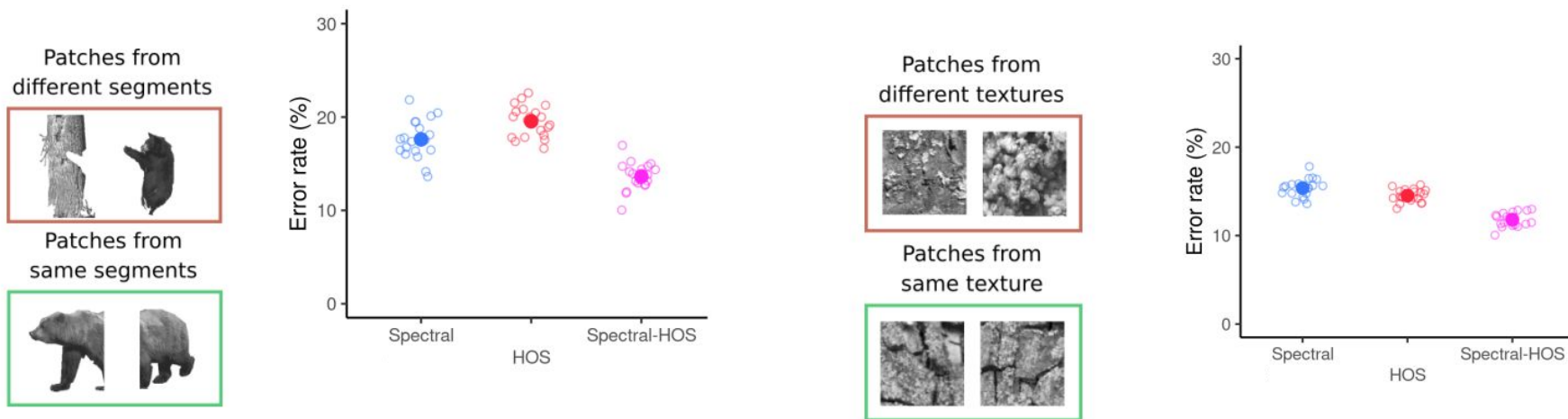- **Hypothesis:** HOS are not very useful for natural image segmentation

Background:

- **Hypothesis:** HOS are not very useful for natural image segmentation

Berkeley Segmentation Dataset. (Martin et al. 2001 ICCV)

Background:

- Spectral and HOS are redundant for a scene and for a texture segmentation task

Herrera-Esposito, Gomez-Sena, Coen-Cagli . (2021) Vision Research

Question:

- HOS are important for texture perception (abundant evidence)

- Why are HOS important for texture perception but not segmentation?

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Question:

- HOS are important for texture perception (abundant evidence)

- Why are HOS important for texture perception but not segmentation?

- **Hypothesis:** There is a task-dependent usefulness of HOS for texture processing
 - HOS are useful for some texture tasks in natural images
  - Humans do use HOS for these tasks
  - For example, classification

Approach:

- We trained texture classifiers using different statistics

- 11 image datasets, with 4 kinds of classification:
Instance, Material, Perceptual, Scenes

- Log-odds ratio (LOR) as a measure of HOS usefulness:
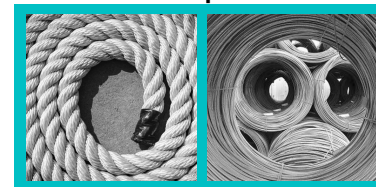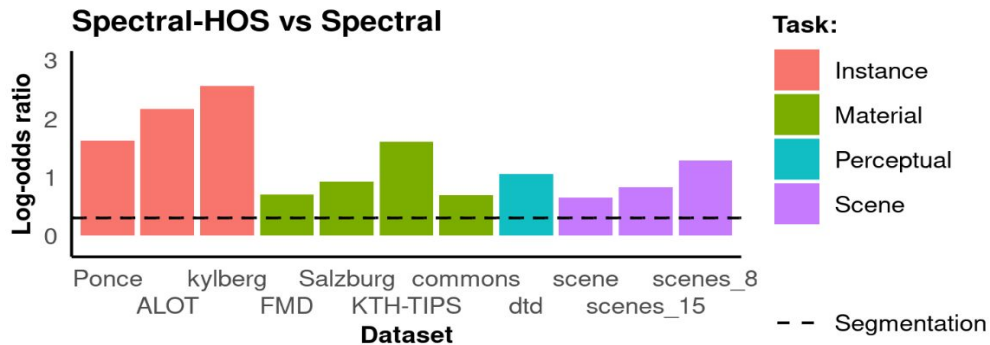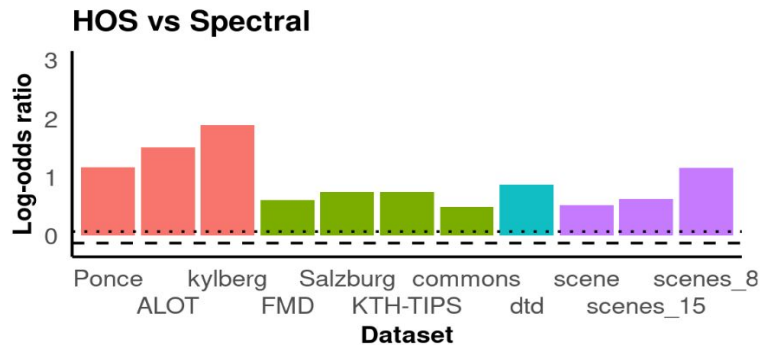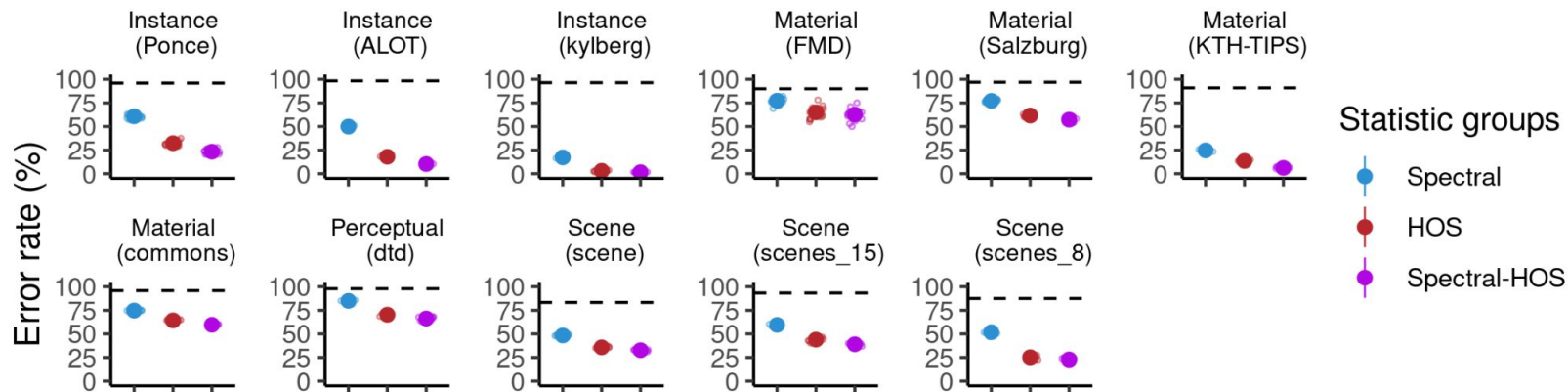 - LOR~0 ➡ HOS not useful
  - LOR>0 ➡ HOS useful
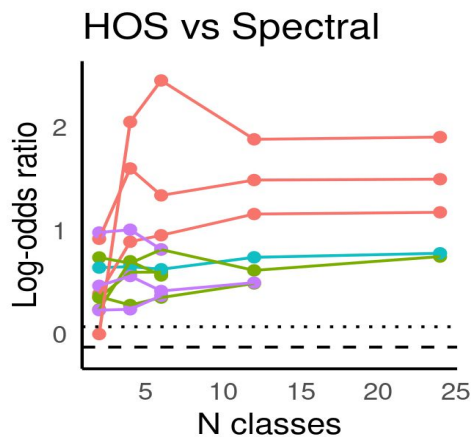
Instance
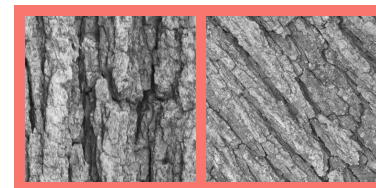
Material

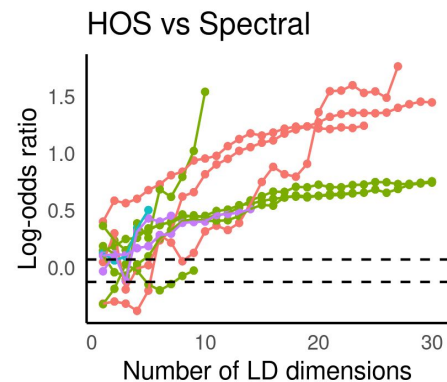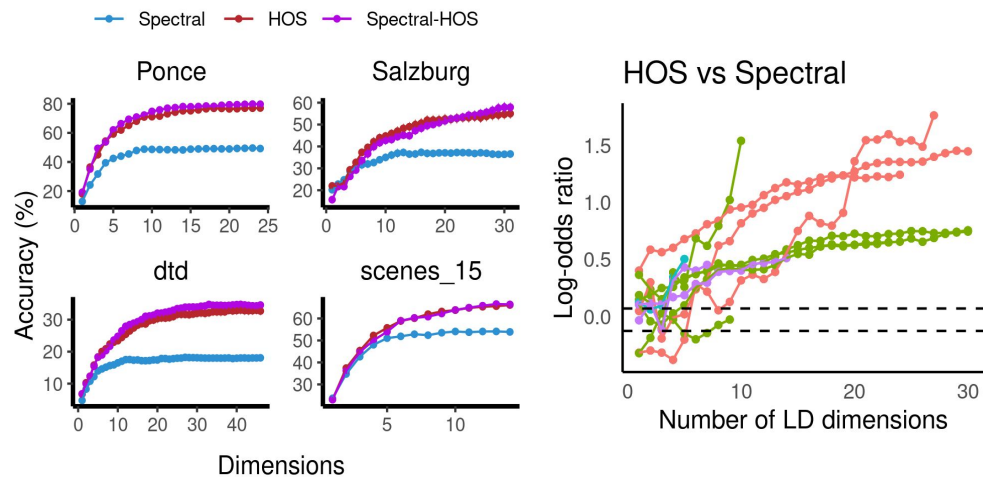Perceptual

Scenes

Results:

Results:

It is not (exclusively) due to larger number of classes in classification
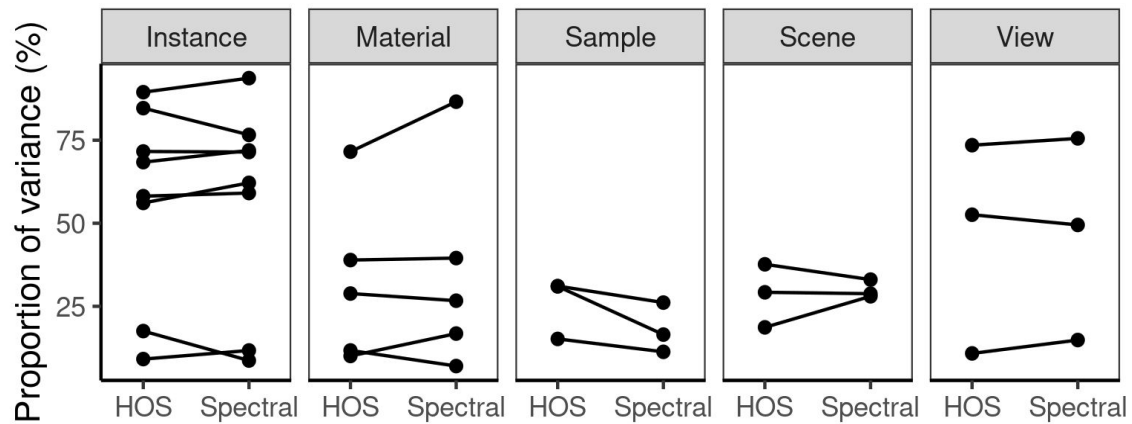

The advantage of HOS for classification depends on the number of dimensions

Results:

Both statistics are similarly susceptible
to sources of variability

Conclusions:

- The advantage of HOS over spectral statistics for image processing is task-dependent

- The use of HOS by humans may follow their task-dependent usefulness in natural images

- Even fine task differences can affect feature usefulness

- HOS have more useful dimensions for classification… But it is still unclear (work in progress) 1) why HOS are better for classification, and 2) why they are not better for segmentation

Task ── Instance ── Material ── Perceptual ── Scene

HOS subsets alone

HOS performance explained (%)

Orientation Phase Scale Space

Spectral + HOS subsets

HOS performance explained (%)

+ Orientation + Phase + Scale + Space

Full model - HOS subsets

HOS performance explained (%)

- Orientation - Phase - Scale - Space