Disparity and Luminance Preference are Correlated in Macaque V1, Matching Natural Scene Statistics.

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The Statistics of Natural Images

- have helped us to understand how images are represented in the brain.
- More than images alone is necessary to understand inference.

Today’s Talk:

- Some findings from the statistics of natural 3D scenes
- We show how the macaque visual system exploits these trends to better infer depth from images
Acquiring a Co-Registered Range & Color Image Database

Riegl LMS-Z360

Color Image

Range Image
Da Vinci Correlation

• Correlation between log-intensity and log-distance: \( r = -0.23 \)

• Among bodies equal in size and distance, that which shines the more brightly seems to the eye nearer. - Leonardo da Vinci

• Later, psychologists verify this rigorously.

• The correlation is thought to arise from shadowing: concave surfaces and object interiors tend to be more shadowed than convex surfaces.

• This effect is especially obvious in:

Foliage:

Da Vinci Correlation

- Correlation between log-intensity and log-distance: \( r = -0.23 \)
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- Later, psychologists verify this rigorously.
- The correlation is thought to arise from shadowing: concave surfaces and object interiors tend to be more shadowed than convex surfaces.
- This effect is especially obvious in:

Piles of objects:

Da Vinci Correlation

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• *Among bodies equal in size and distance, that which shines the more brightly seems to the eye nearer.* - Leonardo da Vinci

• Later, psychologists verify this rigorously.

• The correlation is thought to arise from shadowing: concave surfaces and object interiors tend to be more shadowed than convex surfaces.

• This effect is especially obvious in:

  Folds in fabric:
Da Vinci Correlation

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- This effect is especially obvious in:

Folds in anything:
Da Vinci Correlation

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• Among bodies equal in size and distance, that which shines the more brightly seems to the eye nearer. - Leonardo da Vinci

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• The correlation is thought to arise from shadowing: concave surfaces and object interiors tend to be more shadowed than convex surfaces.

• This effect is especially obvious in:

  Folds in anything:
Two Pixel Statistics

Probability that closer pixel is also brighter

Expected value of $\Delta\text{depth}$ given $\Delta\text{luminance}$

- Probability
  - Distance between pixels

- $\Delta\text{depth}$ (meters)
  - $\Delta\text{luminance}$
Single Cell Recording Experiment

Light Polarity

Dark Polarity

0 1 0 2 0 3 0 4 0 5 0 6 0 7 0 -0.8 -0.4 0.0 0.4 0.8
Horizontal Disparity (°)
Firing Rate (sps)

0 1 0 2 0 3 0 4 0 5 0 6 0 7 0 8
Firing Rate (sps)

0.0 10.0 20.0 30.0 40.0 50.0
Contrast (%)

0.0 0.4 0.0 0.4 0.8
Near-to-Far
Horizontal Disparity (°)

0 1 0 2 0 3 0 4 0 5 0 6 0 7 0 8
Firing Rate (sps)
Correlation between brightness and disparity preferences of V1 cells

48 V1 cells:

\[ R = -0.39 \] (correlation value)
\[ p = 0.01 \] (statistical significance)
Near cell that prefers white, responding to white & black discs

![Graph showing firing rate over time for black (B) and white (W) stimuli.](image-url)
Brightness Selectivity Is Delayed
Why this is important:

• Shows that the study of natural scene statistics can predict neural behavior in the brain.

• Shows that V1 is either directly involved with multiple-cue depth inference, or receives feedback from areas that are.

• Opens up a new avenue for exploring how the visual system performs inference under ambiguity.
Thank You!

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Rural vs Urban Images

Probability that closer pixel is also brighter

Expected value of $\Delta$depth given $\Delta$luminance

Distance between pixels

$\Delta$depth (meters)

$\Delta$luminance
Two Pixel Statistics

Probability that closer pixel is also brighter

Expected value of $\Delta \log(\text{depth})$ given $\Delta \log(\text{luminance})$

Distance between pixels

$\Delta \log_2(\text{luminance})$
## Other Brightness Metrics

<table>
<thead>
<tr>
<th>Metric</th>
<th>R (Correlation)</th>
<th>p (Significance)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \frac{W-B}{W+B} )</td>
<td>-0.39</td>
<td>0.01</td>
</tr>
<tr>
<td>( \frac{(W-G)-(B-G)}{</td>
<td>W-G</td>
<td>+</td>
</tr>
<tr>
<td>( \frac{\sum W - \sum B}{\sum W + \sum B} )</td>
<td>-0.39</td>
<td>0.01</td>
</tr>
<tr>
<td>( \frac{W-B}{</td>
<td>W-B</td>
<td>+2\sqrt{\frac{SSE}{n-m}}} )</td>
</tr>
<tr>
<td>Center of Mass</td>
<td>-0.28</td>
<td>0.06</td>
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</tbody>
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Example Luminance Stimulus
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