Developmental Changes in Natural Visual Statistics

Christina DeSerio
Indiana University, Bloomington, IN, United States
Mentors: Linda Smith, Rowan Candy, Jason Gold
Hierarchy & Reverse Hierarchy of cell types & cortical areas

Feedback connections add details to explicit "vision with scrutiny"

Feedforward hierarchy underlies implicit processing for initial "vision at a glance"

High areas represent objects & categories, generalizing over position, etc.

Early explicit perception is a post-processing high-level view with spread attention. Later, attention is focused on specific low-area details.

Lower area cells respond to simple geometric forms in specific locations.

Adapted from Hochstein & Ahissar (2002)
Sleeper Effects
Maurer, Mondloch & Lewis (2007) *Developmental Science*

Early experiences tune later-developing areas of the visual system
• Dense bilateral cataracts
• Corrective surgery a few months after birth
• Normal entry-level vision by 1 to 2 years of age
• Sleeper Effects Evidenced:
  1. sensitivity to mid spatial frequencies & high spatial frequencies
  2. Holistic face processing
  3. Second-order relations (recognition of facial identity based of the spacing of features)

• Visual input during the first few months of life – before there is any sign of sensitivity to these higher order processes – is tuning up capabilities that emerge later in development.
The structure in the infant visual environment matters

We need to be considering what statistics are getting in and what statistics are influencing the development of the system.
Natural visual statistics

Theoretically viewed as the fixed and universal properties of the world.

Most common method: Low-level visual statistics (e.g. luminance, contrast, color, orientation, spatial frequency) averaged across a number of photographs taken by adults
Visual experience occurs in time and depends on the body, behavior and location of the perceiver
**Intrinsic Development**

- Immature visual system
  - Eyes
  - Brain
- Where they are placed
- Motor abilities
  - Mobility
  - Head
  - Torso
  - Body
- Grabbing/reaching
- "Interest"

**Physical Environment**

- Brightness
- Contrast
- Objectiveness

**Social Environment**

- # People
- Handled
  - Held/carried/bounced
  - Rocked
  - Driven/pushed
- Play (f-f)
Natural visual statistics: limitations

Adult perspective: photos taken and framed by adults
Solution

Developmentally indexed: Egocentric views of natural scenes
A new way of looking at natural visual statistics

**Most common method**
Low-level visual statistics averaged across number of photographs taken by adults.

**My method**
The distribution of low-level visual statistics in infant-perspective scenes obtained from body-worn cameras.
Home-view project
(with the support of the National Science Foundation)

A corpus of developmentally indexed egocentric scenes
• 75 infants (to date)
• 3 weeks to 24 months
• 4 to 6 hours of head-camera video in the home (no experimenters present, cameras on hats)
• Recorded at 30 Hz
• Over 5 million images extracted

Number images sampled at 5Hz
1- to 3-month olds: 738,788 frames
6- to 8-month olds: 1,082,233 frames
Total (both age groups): 1,821,021 frames

1- to 3-month old infants 6- to 8-month old infants
11 total (5 female, 6 male) 12 total (7 female, 5 male)
The overarching hypothesis: different statistics at different ages

1- to 3-month old infants have more...
- Faces close in view
- Ceiling, walls and high contrast things

6- to 8-month old infants have more...
- Touching objects
- Crowded scenes

Statistics in time

Figure 4. Hierarchies of visual areas. This hierarchy shows 32 visual cortical areas, shaded according to the same scheme as in Figure 2. 7 horizontal visual stages (the ventral pathway) are blue and the 25 others (also several sensory areas) are 18 of sensory areas, pericentral area 38, 17 and 18, and the temporal area remanent. These areas are connected by 187 projections, most of which have been interneurons to be reciprocal pathways.
What visual information is available to the developing system?

What is physically in front of the face and how does it change with age?
Measures & analyses

Measures
- Spatial Frequency
- Orientation
- Contrast

Analyses
- Fourier Analysis
- Subband Entropy
- Feature Congestion
- Image Segmentation
## Trial run: subjects & sampling

<table>
<thead>
<tr>
<th>Four 1- to 3-month old infants at 02Hz</th>
<th>Four 6- to 8-month old infants at 02 Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 weeks old: 2,567 JPGs</td>
<td>26 weeks old: 2,517 JPGs</td>
</tr>
<tr>
<td>7 weeks old: 2,187 JPGs</td>
<td>28 weeks old: 2,628 JPGs</td>
</tr>
<tr>
<td>8 weeks old: 2,500 JPGs</td>
<td>30 weeks old: 2,500 JPGs</td>
</tr>
<tr>
<td>11 weeks old: 2,539 JPGs</td>
<td>32 weeks old: 2,520 JPGs</td>
</tr>
<tr>
<td><strong>Total:</strong> 9,793 JPGs</td>
<td><strong>Total:</strong> 10,175 JPGs</td>
</tr>
</tbody>
</table>

Total: 19,968 frames

**Number of tested 02Hz JPGS**

~20,000 frames total

~2,500 frames *per subject*

~10,000 frames *per group*
02Hz from the 6-8 month age group
32 weeks old  2,520 frames

02Hz from the 1-3 month age group
7 weeks old  2,187 frames
Just faces

4 weeks old: 768 JPGs

32 weeks old: 637 JPGs
Clutter measures

**Feature Congestion**: visual salience of items
- Local variability in specific image features such as color, orientation, and luminance

**Subband Entropy**: amount of visual information in a display
- A measure of the efficiency with which an image can be encoded while maintaining perceived image quality (similar to the method used in JPEG image compression)

Comparing Feature Congestion measure of clutter with Wolfe, Oliva, Horowitz, Butcher, and Bompas (2002) search task

Image Segmentation

originals

numRegionsSpec = 31

k = 800

numRegionsSpec = 196

numRegionsSpec = 220

numRegionsSpec = 107

k = 5000

numRegionsSpec = 31

numRegionsSpec = 25

numRegionsSpec = 36
numRegionsSpec = 14
numRegionsSpec = 408
numRegionsSpec = 17
numRegionsSpec = 34
numRegionsSpec = 10
numRegionsSpec = 11
Human coding ➔ Algorithmic Implementations

Texture versus a collection of objects?

Low in clutter versus high in clutter?

How do these classifications differ for younger and older babies?