Many-to-many mappings: circuits not centers

What is special about face processing?
- May be the most developed visual perceptual skill
- Have same local elements
- Convey a large amount of critical information: age, gender, identity, emotion, eye gaze, intention...
- Useful model to study the ventral visual system at its peak.

Faces not objects: Orientation effect
upright > inverted

Whole and configuration:
Faces > other objects

Tanaka and Farah (1993)
Specific N170 waveform for faces not objects

Single neuron recording studies in monkeys: Baylis et al.

Segregated representation: face and building images

Fusiform Face area

Ventral view

Face-selective activation: humans and monkeys
(Tsao et al., 2003; Rajimehr et al. 2009)
Face versus non-face: human with lesions

- Prosopagnosia -
  - Patients more impaired: face than object processing
  - bilateral or right occipitotemporal cortex

- rely on other cues for recognition

Acquired prosopagnosia (AP)
Right inferotemporal - fusiform damage

<table>
<thead>
<tr>
<th>CR</th>
<th>SM</th>
<th>RN</th>
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<tr>
<td>R</td>
<td>R</td>
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<td>L</td>
<td>R</td>
<td>L</td>
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<tr>
<td>Aged</td>
<td>21</td>
<td>29</td>
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<tr>
<td>Metabolic encephalopathy</td>
<td>MVA</td>
<td>Anoxia (MI)</td>
</tr>
</tbody>
</table>

Face recognition

AP: average 17%

(Botteron, Akin et al., JNCL, 2005)
Faces are ‘special’?

A. Psychological investigations

1. Neuropsychological data
   - Impaired at face processing (AP, CP)
   - Impaired at non-face processing too?

2. Why faces disproportionately impaired?

B. Neural investigations

1. Role of fusiform face area

2. Distributed interactivity with other regions

Congenital prosopagnosia (CP)

• Normal neurological status and intelligence

• Right handed

• Full field, normal low-level vision
  - (color, motion, orientation)

• Identify by nonface cues

• These studies: n=7-9 (heterogeneity?)

Anecdotes

A. When I go to pick up my daughter at day care, if the teacher changed her clothing during the day, I can no longer identify which is my daughter and have to wait for her to be brought to me.

B. I suffer from a embarrassing, curiously humbling neurological condition called prosopagnosia, which, translated, means I have a problem in face recognition. I used to think, that it was due to some mental laziness, and I desperately tried to memorize the faces of people I met. Quite by chance, when talking to a friend, I found out that he suffered from the same problem. I could not believe it. Then I discovered that my own sister, Judy, knew similar embarrassment. Perhaps others did also. I wrote to the well-known neurologist Dr. Oliver Sacks. Had he ever heard of such an unusual condition? Not only had he heard from it – he suffered from it himself. And his situation was far more extreme than mine. (Jane Goodall)
Familial component

- Autosomal dominant mode of inheritance
- 2% of population

Face recognition

AP (n=3): average 17%
CP (n=8): average 38%

Face discrimination

Different Gender
Different Individual

Congenital prosopagnosia

- No lesions, nor alterations in vasculature
- Bit more empirical data
  - Alteration in eye movements trajectories on faces
  - Normal discrimination of facial expressions
Expression of emotion?

FEAR

70/30  50/50  30/70

SURPRISE

A. Psychological investigations
   1. Neuropsychological data
      • Impaired at face processing (AP, CP)
      • Impaired at non-face processing too?
   2. Why faces disproportionately impaired?

B. Neural investigations
   1. Role of fusiform face area
   2. Distributed interactivity with other regions

Faces are ‘special’?

Object discrimination

Different trials

Basic  Subordinate  Exemplar

RT (msecs)

Controls  AP  CP

conditions
Novel object discrimination

Faces are ‘special’?
A. Psychological investigations
   1. Neuropsychological data
      • Impaired at face processing (AP, CP)
      • Impaired at non-face processing too
   2. Why faces disproportionately impaired
B. Neural investigations
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Perceptually homogenous exemplars
• Local components insufficient
• Ability to extract configural information
   – Holistic
   – Second order statistics
   – Interrelations between features/parts

Impairment in configural processing?
Composite face paradigm

<table>
<thead>
<tr>
<th>Same Top</th>
<th>Different Top</th>
</tr>
</thead>
<tbody>
<tr>
<td>aligned</td>
<td></td>
</tr>
<tr>
<td>misaligned</td>
<td></td>
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</tbody>
</table>

Deriving configural relations: global from local elements

- hierarchical letters of two types:
  - consistent: global and local have same identity
  - inconsistent: global and local have different identities

- two tasks
  - identify letters at (I) global or at (II) local level
  - use two keys on button box to respond

Normal subjects show global advantage

Accuracy: 96.3%

Global advantage and global-to-local interference
Local advantage and local-global interference

Faces are ‘special’?

A. Psychological investigations
   1. Neuropsychological data
      • Impaired at face processing (AP, CP, autism)
      • Impaired at non-face processing too
   2. Why faces disproportionately impaired
      • Failure to derive configural relations necessary to support holistic processing

B. Neural investigations
   1. Role of the fusiform face
   2. Distributed interactivity with other regions

Segregated representation: face and building images

FFA as center for face recognition

- Necessary?
  - Yes, because damage impairs recognition

- Sufficient?
Acquired prosopagnosia (AP)
Right inferotemporal - fusiform damage

CR  SM  RN
Aged  21  29  44
Metabolic encephalopathy  MVA  Anoxia (MI)

FFA as specialized module

• Origin of FFA?
  – Innate?

• Necessary?
  – Yes, because damage impairs recognition

• Sufficient?

Origin of FFA?
• Children 5-8, 11-14 and adults 20-23

Scherf, Reineke et al., 2007
Functional MRI: CP

- Prediction: reduced/no activation in FFA

Congenital Prosopagnosia: Normal category selectivity

(Avidan, Hasson, Behrmann et al., 2005)
Activation maps: individuals

Abnormal behavior in scanner

The motion pictures experiment

Activation maps
Normal magnitude and site of activation

<table>
<thead>
<tr>
<th>Left Hemisphere</th>
<th>Right Hemisphere</th>
</tr>
</thead>
<tbody>
<tr>
<td>x</td>
<td>y</td>
</tr>
<tr>
<td>CP subjects</td>
<td>-81±2</td>
</tr>
<tr>
<td>Control subjects</td>
<td>-37±4</td>
</tr>
</tbody>
</table>

FFA as center for face recognition

- **Necessary?**
  - Yes, because damage impairs recognition

- **Sufficient?**
  - Activation insufficient to support normal face processing

Rapid-event related: familiar versus unfamiliar faces

(Avidan and Behrmann, Curr. Biol. 2009)
Controls and CP: right FFA activation
Multi subject GLM: Familiar > Unfamiliar

Controls (n=10)

CP (n=4)

Faces are ‘special’?

A. Behavioral investigations
   1. Neuropsychological data
      • Impaired at face processing (AP, CP, autism)
      • Impaired at non-face processing too
   2. Why faces disproportionately impaired
      • Failure to derive configural relations

B. Neural investigations
   1. Nature of representation in ventral stream
      • FFA not sufficient for normal face processing
   2. Distributed interactivity with other regions

Rapid-event related:
familiar versus unfamiliar faces

Controls but NOT CP:
L post. cingulate, medial prefrontal cortex

(Avidan and Behrmann, in preparation)
Faces are ‘special’?

A. Psychological investigations
   1. Neuropsychological data
      • Impaired at face processing (AP, CP, autism)
      • Impaired at non-face processing too
   2. Why faces disproportionately impaired
      • Failure to derive configural relations

B. Neural investigations
   1. Role of the fusiform gyrus
      • FFA not sufficient for normal face processing
   2. Distributed interactivity with other regions

Core regions involved in face processing

- Lateral Occipital Complex (LOC): facial features, invariant to orientation.
- Fusiform Face Area (FFA): invariant to size, position and spatial scale of upright faces, sensitive to identity. R-FFA is dominant.

Faces processing recruits more than just the core regions

The functional neuroanatomy of face processing

- Anterior Temporal Cortex (ATC): Biographical information, identity
- Anterior Frontal Cortex (AFC): Resolving perceptual ambiguity
- Amygdala & Limbic areas: Emotion processing
Role of other regions?

(Rajimehr et al., 2009 PNAS)

(Kriegeskorte et al., PNAS, 2007)