Methods for a complex system:
The neuroscience of visual object recognition

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The brain

- Wrinkly, fatty organ inside skull
- Network of neurons
- Produces all of human behaviour
- How?
  - Answer constrained by our knowledge of psychology
Psychology

- Reverse-engineering the mapping of sensation to action
- Scientific description of behaviour
- Informs our neuroscientific hypotheses about mechanisms
Experimental methods

1) Anatomical
   - Lobes, wrinkles, neural connectivity

2) Live recording
   - Functional imaging (fMRI..)
   - Single cells (electrodes)

3) Interference
   - Natural lesions (stroke etc)
   - Experimental lesions
   - TMS
   - Pharmacology
Organisational questions

- Is the brain modular, or equipotential?
- If modular, is there a hierarchy of processing?
- What is the role of connections between regions?
- How is information represented by neurons?
- Is sensory information topographic?
- Are more abstract representations distributed, or localised?
### Case study: visual agnosia

<table>
<thead>
<tr>
<th>Neurologist:</th>
<th>“What is this?”</th>
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<tbody>
<tr>
<td>Dr P (patient):</td>
<td>“A continuous surface, infolded on itself. It appears to have five outpouchings, if this is the word.”</td>
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<tr>
<td>Neurologist:</td>
<td>“Yes, you have given me a description. Now tell me what it is.”</td>
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<tr>
<td>Dr P:</td>
<td>“A container of some sort.”</td>
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<tr>
<td>Neurologist:</td>
<td>“Yes, and what would it contain?”</td>
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<td>Dr P:</td>
<td>“It would contain its contents! There are many possibilities. It could be a change purse, for example, for coins of five sizes.”</td>
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<tr>
<td>Neurologist:</td>
<td>“Does it not look familiar? Do you think it might contain, might fit, a part of your body?”</td>
</tr>
<tr>
<td>Dr P:</td>
<td>(no sign of recognition)</td>
</tr>
<tr>
<td>(later, by accident, gets it on and exclaims:)</td>
<td>“My God, it's a glove!”</td>
</tr>
</tbody>
</table>

Sacks (1985)
Basic anatomy of visual processing

- Sensory neurons have “receptive fields”
- Retina projects to occipital lobe, and then information projects forward
- Increasing abstraction with later processing
- Dorsal and ventral pathways
  - “Where” vs “what”
  - “Action” vs “perception”
More specific lesion deficit: *prosopagnosia*

- Impaired face recognition
- (Bilateral) medial occipital-temporal damage
- Have humans evolved a 'face module'?
  - The “fusiform face area”?
- Or is prosopagnosia just a particularly obvious symptom of a more general discrimination deficit?
Non-human primate lesion studies

• Somewhat controversial:
  • train monkeys on a task,
  • carefully remove some cortex,
  • see how performance is affected.

• More precise and controlled than natural lesions
  • less destructive, too!

• But how well do animal models translate?
  • Humans have more complex brains!
  • Fewer techniques are available for human application
Monkey lesion study: agnosia or amnesia?

- Couldn't an object recognition deficit be a memory problem?
- Reversal learning vs discrimination learning
- IT lesions did not impair reversals, but did impair discrimination
- Suggests IT involved in object discrimination; not just perceptual memory

Gaffan et al (1986)
Non-human primate cell recording

- IT neurons have spatially large receptive fields
  - Not retinotopic
- Respond to complicated features
- Often invariant for size / contrast / colour / position
- Some seem specialised for faces or hands

Gross (2008)
Do human lesions produce deficits like those seen in monkeys?

Slightly different “oddity” discrimination task.

Nonetheless, seemingly so:

Lee et al (2005)
Human neuroimaging: faces or 'expertise'?  

Task: sequential presentation of images. Subjects respond to one of two questions – Different individuals? Or different families?  

Result: perhaps FFA is “expertise” area?  

Gauthier (1999)
Human single-cell recording

- Patients with intractable epilepsy undergo surgery to stop seizures
  - beforehand, electrodes are implanted to measure where the focus of the epilepsy lies

- Provides opportunity to measure directly human neural activity
  - imaging studies cannot achieve fine resolution

- Assumes epileptic brains are sufficiently normal
'Jennifer Aniston' neurons?

Quiroga *et al* (2005)  

**NB:** This is in anterior medial temporal lobe
'Halle Berry' neurons?

Quiroga et al (2005)

NB: Responses to text, too!
But also... 'Sydney Opera House' neurons?

Quiroga et al (2005)

NB: Responses to text, too!
Prosopagnosia and the bigger picture
Conclusions

- What about processing at the cell network level?
  - Much progress has been made in early visual processing, and in the hippocampus (for memory)
- How much wiser are we?
  - Perhaps more new questions than answers
- Caveats
  - Just because cells respond to some stimuli sometimes, doesn't mean that they only or always do this
  - NB: Attention, feedback, emotions
- Regions are interconnected
  - Hard to unpick, so we need clever experimental design, alongside suggestive theoretical models
- Can the approach here be applied to more abstract human processing?
Thanks!

Bibliography:


