Connectionist models of language deficits

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...remember Dell et al. (1997)

- 2-step theory of lexical retrieval
- Interactive activation model

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Model performance and patient data

- 'lesioning' the model
- Matching model performance to data

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Modelling...what's the point?

- Parameterise, develop, and test theories
- Try to explain 'why'?
- Generate predictions

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Overview...

- **Part 1, the principles**
  Dissociations, modularity and functional specialisation

- **Part 2, in practice**
  The connectionist models

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Part 1: Dissociations and modularity

- Shallice (1988, p248):
  "If modules exist then...double dissociations are a relatively reliable way of uncovering them. Double dissociations exist, therefore modules exist"

  but...
Delusions about dissociations...

Shallice describes a number of non-modular systems that could produce DDs.

"the idea that the existence of a double dissociation necessarily implies that the overall system has separate subcomponents can no longer be taken for granted"

“functional specialisation”

Shallice (1988): “functional specialisation” is a more appropriate inference from dissociations in patients

But the dimensions on which behavioural dissociations are based may not be a direct reflection of the function responsible for specialisation

If so, the degree of specialisation may not be a useful guide to system architecture and functional organisation

Dissociations and modules

Sartori (1988): Components in a fully serial architecture can only produce single dissociations. Some contribution of parallel organisation is required for double dissociations.

Parallel Distributed Processing

Double dissociations without specialisation?

Suppose the existence of three elements x, y, and z (which may be, for example, groups of neurons)

Task A performed with levels of activation

\[ x = 80\% \quad y = 20\% \quad z = 80\% \]

Task B performed with levels of activation

\[ x = 20\% \quad y = 80\% \quad z = 20\% \]

Dissociations in a distributed memory (Wood, 1977)

Input Vectors

\[
\begin{array}{c|c}
A & B \\
\hline
1 & 0 \\
1 & 1 \\
0 & 1 \\
1 & 0 \\
\end{array}
\]

Matrix

\[
\begin{array}{cccc}
1 & 5 & 2 & 6 \\
9 & 6 & 5 & 4 \\
8 & 13 & 2 & 6 \\
6 & 2 & 8 & 10 \\
\end{array}
\]

Threshold

\[
\begin{array}{c}
24 & 14 & 16 & 20 \\
\end{array}
\]

Output vectors

\[
\begin{array}{c}
A' \\
B' \\
\end{array}
\]

\[
\begin{array}{c|c|c|c|c}
A' & B' & A & B & \text{Row} \\
\hline
1 & 0 & 0 & 1 & 1 \\
0 & 1 & 0 & 1 & 2 \\
\end{array}
\]
Part 2: Connectionist modelling

- **Abstract model**
  - Expand range of candidate inferences from behaviour to structure
  - This kind of behaviour can be produced by these kinds of system
- **Specific models**
  - Theoretically motivated – test hypotheses
  - Use empirically driven constraints

Model topics

- Past tense debate
- Acquired deficits
- Developmental deficits
- Emergent modularity
- Double dissociations with modularity
- Connectionism and modularity

English past tense formation

- **A “quasi-regular” domain**
  - Regular: TALK - TALKED
  - Irregular: THINK - THOUGHT, HIT - HIT
  - Rule: WUG - WUGGED

The past tense debate

The past tense debate

- Output past tense
- Blocking
- Listing of exceptions / associationist network
- Regular route
- Dual Mechanism model of past tense formation (Pinker, 1991, 1994)

Dissociations

<table>
<thead>
<tr>
<th>Regular/Developmental</th>
<th>Acquired</th>
<th>Irregular/Developmental</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frontal lesions</td>
<td>SLI</td>
<td></td>
</tr>
<tr>
<td>Parkinson's D.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Posterior lesions</td>
<td>WS</td>
<td></td>
</tr>
<tr>
<td>Alzheimer's D.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

...but why?

Modified models

- Multiple phonological rules
- Distinction between phonology and word-specific information
- Multiple inflection all paradigms (nouns, verbs)
Acquired past tense deficits
Joanisse and Seidenberg (1999)

- speaking
- hearing
- repeating
- transformation

Phonological deficits
- all word types affected
- poorest performance on nonwords

Semantic lesions
- all word types affected
- poorest performance on irregulars

Modelling developmental language deficits
- Beware of models where developmental disorders are being used in a directly analogous fashion to acquired deficits
  - Is this really appropriate?
  - Developing systems are dynamic
  - A developing model is a training model
  - Stages as well as end performance may differ

Specific Language Impairment
- Deficit in regular inflection in SLI and frequency effects for regular verbs
  - Ullman and Pierpoint (in press): developmental deficit to a system specialised for grammar (procedural memory system)
  - Thomas (in press): same data can arise from a deficit to a processing resource common to regulars and irregulars

The model

Alter initial level of processing unit discriminability

Thomas (in press)
Transfer functions and category boundaries

Cliffs – sharp category boundary, good for rule-like distinctions

Slopes – broad category boundary, good for fine-grained distinctions

Another cause of SLI

- Perception theory: impaired speech perception which affects the use of phonological information in working memory, which in turn leads to poor syntactic comprehension

The results

Thomas (in press)

The data

Emergent modularity

- Functional specialisation may be an outcome of a developmental process rather than a precursor – i.e., no innate modularity
- Brain activity in early infancy – less localised, less specialised for particular stimuli

Emergent modularity and the past tense

- i.e. for past tense, regulars and irregulars can (partially) specialise to different parts of the system across training due to structure-function correspondences

Thomas & Karmiloff-Smith (2002)
"Double dissociation without modularity" in a reading model: Plaut and Shallice (1993)

- There is a double dissociation between concrete and abstract word reading
  - Most researchers believe that skilled readers rely almost exclusively on the phonological route
  - Only in cases where this route is inoperative as as in deep and phonological dyslexia, are strong semantic effects such as concreteness observed
- Patient CAV exhibited better performance on abstract words (partial reliance on semantic route)

Deep dyslexia

- The hallmark: semantic errors
  - i.e. reading CAT as "dog"
- Also...
  - Visual errors: CAT -> cot
  - Mixed errors: CAT -> rat
  - Morphological: GOES -> go

The Plaut and Shallice reading model (1993)

- An "attractor" network
- Lesioned normal model by randomly removing connections
  - Locations
  - Severity

Lesion location and behaviour

Lesion severity and behaviour

Functional specialisation

- Different parts of the network have a different function: pointers and valleys
- Abstract words are assumed to have fewer semantic features (sparser semantic neighbourhood)
- Concrete relies more on valleys, abstract more on pointers
Attractor space: pointers and valleys

Implications: Plaut (1995)

- "...Both pathways are involved in processing both types of words. However, they make different contributions the course of this processing...
- The direct pathway generates an initial approximation of the semantics
- Those are refined by the clean-up pathway
- Functional specialisation: this exists in the network "but does not directly correspond to the observed behavioural effects under damage (abstract vs. concrete words)"
- "[Regarding Averaged vs. Rare lesions]... the occasional lesion of each type may produce effects that are exactly opposite to those produced by most quantitatively equivalent lesions"
- The observation of a double dissociation does not even indicate functional specialisation, as Shallice (1988) suggests, for how can the same portion of a mechanism be "specialised" in two different ways?

Note

- Concrete-Abstract double dissociation appears to violate Sartori’s (1988) argument that double dissociations cannot arise from serial stages
- Clean-up pathway appears to follow Direct pathway in a serial fashion
- Either parallel processing permits this, or the two parts of network do not conform to independent stages (see McClelland, 1979)

Connectionism and modularity

- Connectionist approaches to cognitive processing are current highly modular, indeed consistent with innate modularity
  - the “past tense network”
- Yet connectionism typically associated with equipotentiality - whole brain is a homogeneous distributed network

But...

- Even single networks aren’t equipotential - the way you damage the processing resource affects the single dissociations produced

And...

- "A mixture of experts": specialised systems can emerge from slight computational differences in processing components + initial biases of connectivity + experience-driven competition
- Different tasks may recruit different sub-sets of experts, some only one
- Many processing principles may be domain-general
- This research is at an early stage in developmental cognitive neuroscience
Conclusions (1): modelling

- Models can be used to explore "how" and "why" behavioural dissociations emerge
- Theory development tool

Conclusions (2): behaviour and modularity

- Double dissociations do not necessarily imply a modular system
- Dissociations imply functional specialisation
- Distributed systems may show chance unusual dissociations – not clear whether this is an artefact of model simplifications
- Specialisation of function may be emergent

Questions?