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Functional imaging of neuroplasticity in aphasia

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August 8, 2017

Learner outcomes

As a result of this course, participants will be able to:

1. Describe the neural substrates of language processing in the healthy brain.
2. Describe ways in which language processing is altered after brain damage.
3. Identify methodological challenges to research in neuroplasticity in aphasia.
In many patients with aphasia, language function improves over time.

![Graph showing improvement over time for different types of aphasia](image)

Early improvements may reflect return to function of compromised brain areas.

![Brain scan images](image)

Figure 1: An fMRI scan with hyperactivity in Broca's area, which reflects improved language function.

Hillis et al., 2006
But most improvements after 24 hours probably reflect functional reorganization.

Normal brain organization of language is quite well understood.

Adaptive semantic vs perceptual matching

Healthy Controls ($n = 14$)

Wilson, unpublished data; Hickok and Poeppel, 2007; Price, 2012
Studies in children show that other brain regions can process language in principle.

Verb generation, 5 children with pre- or peri-natal lesions and R hemipareses

Staudt et al., 2002

Acquired aphasia is much harder to study, for many reasons.

- How do you study language processing when it is impaired?
- Confounds of difficulty, success, failure, etc., changing over time
- Group studies difficult to due individual differences in lesion location
- Test-retest reliability questionable for longitudinal studies
- Possible hemodynamic abnormalities, esp. in stroke
- Practical challenges, e.g. recruitment, other medical problems, MRI compatibility, mobility
Four papers


Turkeltaub et al. (2011)

- An ALE meta-analysis of language activations in 105 patients with chronic post-stroke aphasia compared to 129 controls, derived from 12 fMRI or PET studies.
- Provides insight into nature of language reorganization, incorporating results from many studies that may individually have lacked power.
- Tasks included picture naming, lexical decision, word reading, word stem completion, speech discrimination, listening to stories, propositional speech production, verb and noun generation, semantic and phonemic fluency.
- Mostly low level baselines.
Patients and controls

Turkeltaub et al., 2011

Patients with and without left inferior frontal damage (“Broca’s area”)

Turkeltaub et al., 2011
Interpretation of findings

Turkeltaub et al., 2011

Review

- Strengths:
  - large number of patients
  - basic evidence for reorganization
  - sophisticated interpretation

- Weaknesses:
  - no statistical comparisons between groups
  - diverse tasks of questionable validity

Turkeltaub et al., 2011
Four papers


Robson et al. (2014)

- Language reorganization in Wernicke’s aphasia (poor comprehension and repetition, fluent paraphasic speech)
- How does the semantic system reorganize when one of its crucial components is damaged?
Three tasks were used in a block design fMRI study.

- Task 1: judge if written words are animate or inanimate.
- Task 2: judge if pictures are animate or inanimate.
- Task 3: judgment if scrambled pictures are high or low on the screen.
- Each task was performed in a separate run, alternating with rest blocks.
- Tasks 1 and 2 were compared to task 3 as well as rest (?!)

<table>
<thead>
<tr>
<th></th>
<th>Pictures</th>
<th></th>
<th>Words</th>
<th></th>
<th>Scrambled pictures</th>
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<td>RT (SD)</td>
<td>d' (SD)</td>
<td>RT (SD)</td>
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<td>Wernicke's aphasia</td>
<td>4.9 (5.5)</td>
<td>1460 (422)</td>
<td>4.3 (5.6)</td>
<td>1181 (156)</td>
<td>6.5 (5.0)</td>
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<tr>
<td>Control</td>
<td>9.8 (4.8)</td>
<td>929 (187)</td>
<td>11.0 (5.3)</td>
<td>1123 (422)</td>
<td>11.7 (4.2)</td>
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<td>4</td>
<td>3</td>
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<td>0.001</td>
<td>0.006</td>
<td>0.018</td>
<td>0.02</td>
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</tbody>
</table>

Robson et al., 2014

Activation appeared to be shifted ventrally for patients, esp. in the left hemisphere.

Figure 2: Whole-brain results for semantic condition versus dual baseline. (A) significant activation in the Wernicke’s aphasia group for picture (red) and word (green) semantic judgment, overlapping regions in yellow. (B) Main effect of group. Regions significantly more active in Wernicke’s aphasia than control group are shown in blue. No temporal lobe regions were more active in the control than Wernicke’s aphasia group. Displayed activations significant at P < 0.005, uncorrected.

Robson et al., 2014
Review

• Strengths:
  – homogenous patient group
  – tasks should tap damaged network

• Weaknesses:
  – patients found task more difficult, may explain more extensive activation
  – normal neural correlates of task not clear
  – results not corrected for multiple comparisons

Four papers

“Consideration is rarely given ... to the influence of intact domain-general networks on recovery, or the possibility that some of the ‘abnormal’ activity recorded in post-stroke aphasia is the result of the upregulation of normal activity within domain-general networks” (p. 2639)
For example, early right hemisphere recruitment in Saur et al. (2006)...

Implications

- It is important to match language conditions with control conditions.
- It is also important to match difficulty between individuals with aphasia and healthy controls.
- The role of domain-general cognitive control systems in recovery is not just a confound; these functions may also be targets for rehabilitation.
Four papers


Griffis et al. (2017)

• 43 patients with chronic aphasia and 43 matched controls.
• “[T]ested the prediction that longterm language outcomes depend on the preservation/restoration of language task-driven activation in canonical language networks.” (p. 1638)
• Does right hemisphere activity depend on left hemisphere damage?
Study design

- Semantic decision vs tone decision fMRI study (a well validated task that activates the semantic network)
- Language measures: BNT, semantic and phonemic fluency

Results

A. Lesion frequencies

B. Language test scores

C. Canonical semantic network (Controls) vs Residual semantic network (Stroke)

D. Partial behavioral correlations (Stroke)

Griffis et al., 2017
Preserved language function in aphasia reflects function of the normal network.

The canonical network identified in controls is shown in green, regions within the CSN identified in healthy controls where SD activation was positively related to performance on any language measure in patients are shown in red.

Right hemisphere recruitment depends on lesion size.
Review

- **Strengths**
  - very large sample size
  - fMRI task well characterized (in controls)
  - clear demonstration that normal language network critical for language function in aphasia
  - some evidence for right hemisphere recruitment
- **Weaknesses**
  - poor task performance in individuals with aphasia
  - limited language measures
  - addressed lesion size but not lesion location

Griffis et al., 2017

Conclusions

- Normal language regions comprise the most important neural substrate for preserved or recovered language function in aphasia.
- There is more limited evidence for recruitment of new regions in the left and right hemispheres.
- Domain-general cognitive control systems may explain many activations that have been attributed to reorganization.
- Recovery from aphasia may involve more neuroplasticity *within* the normal language network than outside it.