Hemispheric contributions to spoken language comprehension in patients with left hemisphere stroke

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Introduction & Motivation

- Controversy surrounds the role of the left and right hemispheres in spoken language comprehension
- Patients with left hemisphere stroke may have impaired comprehension of syntactically complex sentences, but preserved semantics and pragmatics
- Studying performance and brain activity in the context of damage gives unique insights into the neural systems essential for function
- HYPOTHESIS: syntax depends upon a left hemisphere frontotemporal system whereas semantics may be supported bilaterally
- RESEARCH QUESTION: are syntactic and semantic performance in patients with left hemisphere lesion associated with distinct patterns of damage and functional activation?

Imaging experiment

- Participants: 21 stroke survivors with left hemisphere (LH) lesions, minimum 1.4 years post-injury
- Imaging:
  - Structural MRI: T1-weighted MPAGE
  - Functional MRI: BOLD-sensitive sparse EPI, 2 sec, TA, 11 sec TR; audio stimuli delivered during 9 sec silence between scans
  - Word monitoring task presented in two 165 sec blocks each of normal (NP) and anomalous prose (AP)
  - Preprocessing (SPM5): motion correction, normalisation and smoothing
  - Structural images skull-stripped and smoothed, using T1 intensity to index tissue integrity
  - Functional activation to NP and AP estimated using GLM
- Joint independent components analysis (JICA)
  - Allows identification of distinct but overlapping patterns of variance in tissue integrity and neural activity by their relationship with task performance. Unlike univariate analysis, may tease apart interacting networks supporting syntax and semantics.

Behavioural tasks

- Word monitoring (fMRI task)
  - Normal prose (NP: syntax and semantics)
    - “She was trying to find the name of the TREE she planted last year”
    - Participants respond on hearing target word, presented as a visual cue
- Sentence-picture matching
  - Post-test, outside the scanner
    - “The boy chases the horse”

Sentence-picture matching

- “She boys chases the horse”
- Participants hear a sentence and select the matching picture
- 34 semantically reversible sentences, 17 in passive voice
- Correct role assignment relies upon syntactic structure
- Reverse role = lexical errors = syntactic deficit

Syntactic valid sentences:

- A: surface view and B: sagittal sections showing tissue integrity (TI) and activity for NP and AP in the colours in the central legenda: A: surface view of LH and RH Lesion frequency in left hemisphere

Results

- Behavioral tasks:
  - Patients showed a range of impairment on syntactic, with semantics mostly spared.
  - Word monitoring: patients & controls both showed normal advantage for NP > AP.
  - Patients performance on AP tended to be lower than controls (n.s.).
  - Sentence-picture matching: patients’ range of IR errors much wider than controls, but neither group made many lexical errors.

- Syntax component:
  - Syntax depends upon a left fronto-temporal network, consistent with previous studies.
  - Performance: significant correlations with WPE for NP and with IR, but not with NP or lexical errors.
  - FMRI activity: AP in left inferior frontal gyrus and posterior superior & middle temporal gyrus, NP in temporal gyrus only.
  - Tissue integrity: single, long cluster extending from the grey matter of LIFG, through the white matter of the superior longitudinal and arcuate fasciculi, to the white matter underlying the planum temporale

- Semantics component:
  - Semantics does not correlate with tissue integrity, but only with right hemisphere (RH) activation.
  - Performance: significant correlations with WPE for NP but not AP.
  - FMRI activity: NP in right posterior superior & middle temporal gyrus, AP to a lesser extent.
  - Tissue integrity: no significant voxels for semantics

Conclusions

- Syntax depends critically upon spared activity and tissue in LIFG and posterior LpSTG/MTG and the white matter connecting them.
- In contrast, semantics may be supported by activity in RpSTG/MTG, regardless of LH damage.
- Semantics is preserved after LH stroke by activity in the intact RH as a result of bilateral, degenerate representation of semantic processes in the intact brain.
- In a degenerate system, multiple components can perform the same function, allowing preserved function after partial damage.
- These results support a neurocognitive framework for language with two distinct systems:
  - core linguistic processes in left-lateralised fronto-temporal system
  - general communicative processes in bilateral superior & middle temporal gyri
- Linguistic specificity is critical in imaging investigations of language recovery in patients.