Functional neuroimaging and the architecture of the language system

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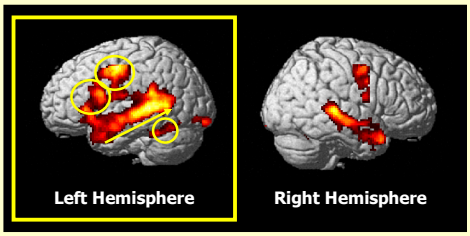
Today's lecture

Functional anatomy of the language system

- **Classic lesion studies**
  - How *damage* can reveal function
- **Functional imaging**
  - Methods
  - Tasks
- **The default language network**
  - Typical system

First, a preview …

Typical functional activation in a language task



Activation during reading sentences

Classic lesion studies

What studies of acquired damage tell us about functional anatomy

Neuropsychological studies of brain and language

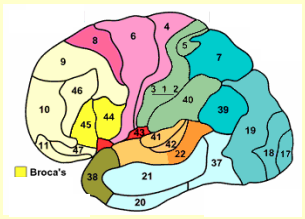
Clinical syndromes *(behaviour)*

Topography of brain damage *(structure)*

Identify brain areas necessary for language

- Relate profile of language performance in brain injured patients to impaired and intact brain regions
  - Processes spared/impaired motivated by cognitive theory

Broca's area



- Broca's area: consists of the pars triangularis (BA 45) and the pars opercularis (BA 44)
  - *Located in close proximity to motor-speech area*

- Classically, damage to Broca's area results in expressive language difficulties *(Broca's aphasia)*
- Case studies:
  - Patient *Leborgne:*

> He could no longer produce but a single syllable, which he usually repeated twice in succession; regardless of the question asked him, he always responded: *tan*, *tan*, combined with varied expressive gestures. This is why, throughout the hospital, he is known only by the name *Tan* (Broca, 1861*c*).

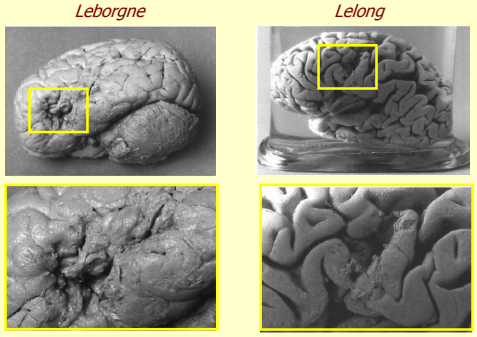
  - Patient *Lelong:*

> A few months later, Broca encountered a second patient, Lelong, who also exhibited reduced productive speech as the result of a stroke 1 year before. This 84-year-old patient could say only five words, 'oui' ('yes'), 'non' ('no'), 'tois' (a mispronunciation of 'trois' ('three') which he used to represent any number), 'toujours' ('always') and 'Lelo' (a mispronunciation of his own name)

Dronkers *et al.*, (2007) Brain

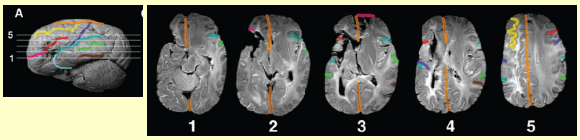
Broca's area: a modern perspective

Leborgne *Lelong*

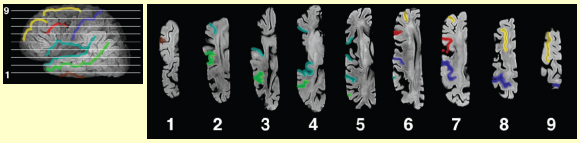


Dronkers *et al.*, (2007) Brain

Leborgne



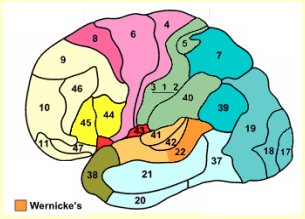
Lelong



Broca's area: a quick summary

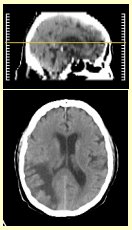
- Broca's cases were pivotal in identifying a relationship between speech and the inferior frontal gyrus in the left hemisphere
  - Region viewed by Broca is not exactly the same area as we term Broca's area today
  - Patients also had damage in multiple regions
  - Although this area is not as critical as once thought, Broca's area is certainly involved in the execution of articulatory movements

Wernicke's area



- Wernicke's area: posterior portion of the superior temporal gyrus (BA 22)

Wernicke's aphasia

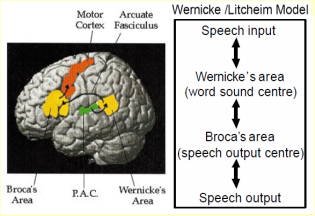


- Also known as fluent aphasia
- Reasonably good speech (sentences and syntax)
- Very poor language comprehension
- Wernicke's Patient died soon afterwards: brain showed selective damage in rear parietal/temporal region of the left hemisphere

For full CT scan go to the whole brain atlas
http://www.med.harvard.edu/AANLIB/cases/case13/ct3/017.html

Conduction aphasia

Damage to Arcuate Fasciculus: a tract of fibres connecting BA and WA

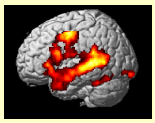


Patients show:
- Good comprehension
- Good production
- Poor repetition

Current neuropsychological position

- Aphasia is not just a question of fluent/non-fluent speech
- Patients rarely present with isolated speech production/comprehension damage
- Although there are regions of the brain that are prone to damage lesions vary in their positions and extent
- Multiple interconnected cognitive levels of language processing
- Detailed patient assessment provides a valuable insight into the nature of the underlying linguistic damage

The typical language network



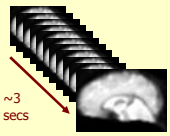
Patterns of speech and language processing in fMRI

Left hemisphere

Functional imaging

First a little bit about how it's done ...

Functional Imaging



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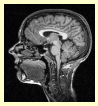


Functional scans: record task related activity

- Participants carry out a series of simple tasks
  - This may be over a number of sessions (i.e., 4 x 8 minute sessions)
  - Each task has an **activation** and a **baseline** condition

i.e. Reading: The large cup is in the box

Generating Contrasts: *Cognitive Subtraction*

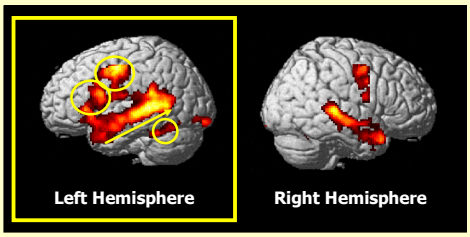
The difference between two tasks can be formulated as a separable cognitive or sensorimotor component

- Relies on the assumption of **Pure Insertion**
  - A new cognitive (A) component can be purely inserted without affecting the expression of the previous ones (e.g., B).

The experimental task and baseline task must be identical in every way except for the process of interest

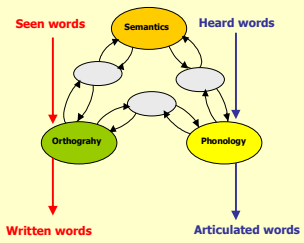
Activation task involving process of interest	—	**Baseline task** identical to A except for process of interest	=	Region(s) involved in the cognitive/ sensorimotor process of interest
The large cup is in the box	—	٥٧٤٦٥٩٢١٥٨٤٣	=	Reading

Just to recap …

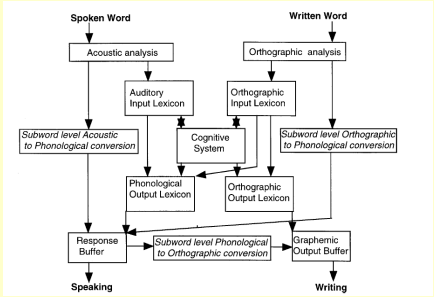


Activation during reading sentences

Thinking about language …

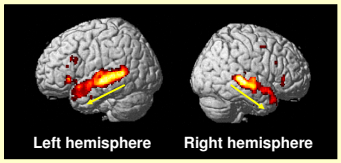


Model: Seidenberg & McClelland (1989)

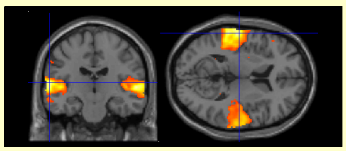


See: Price (2000) Journal of Anatomy

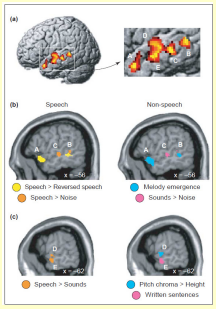
Processing speech



activation whilst listening to sentences



Speech perception: input

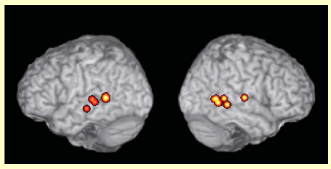


- No speech-specific processing at the *macro-anatomical* level
- Hypothesis:
  speech and linguistic processing stem from changes in the functional integration among acoustic and conceptual regions that are also engaged by nonverbal stimuli

From Price *et al.*, (2005) TICS

Phonological processing

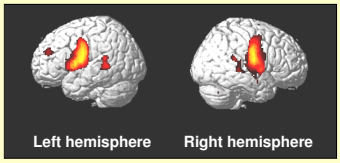
- Study comparing high-density words (many phonologically similar neighbours) with low density words (few phonologically similar neighbours



- High-density words produce more activation in the posterior portion of the superior temporal sulcus

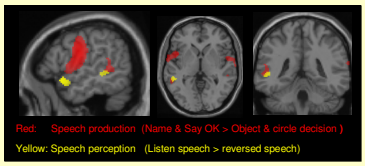
Okada & Hickok (2006) NeuroReport

Speech production: output

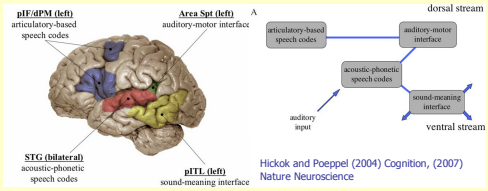


- Activation of inferior frontal and motor cortical areas corresponding to articulatory processes

Speech perception vs. production



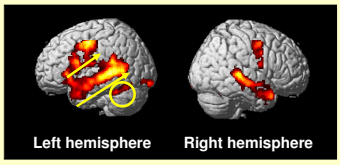
- Speech production: inferior frontal and motor cortical areas
- Speech perception: anterior temporal activation
- Perception and production: posterior temporal activation



Hickok and Poeppel (2004) Cognition, (2007) Nature Neuroscience

- From the superior temporal gyrus (STG) processing diverges into two streams:
  - a ventral stream: which is involved in mapping sound onto meaning, and a
  - dorsal stream, which is involved in mapping sound onto articulatory-based representations.

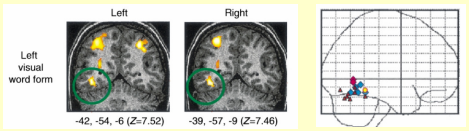
Reading



activation whilst reading sentences

- Activation of temporal areas
- Inferior frontal and motor cortical areas
- Fusiform gyrus

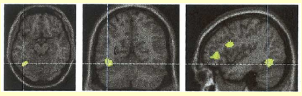
The Fusiform Gyrus (aka. The Visual Word Form Area)



Reliably active for word reading across multiple studies

From Cohen *et al.*, (2000) Brain

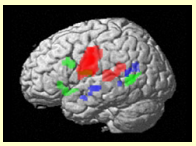
May not necessarily be storage of visual word forms but an interface between visual form information and higher order stimulus properties such as its associated sound and meaning. More importantly, this function is not specific to reading but is also engaged when processing any meaningful visual stimulus.



Manipulate to pictures of objects

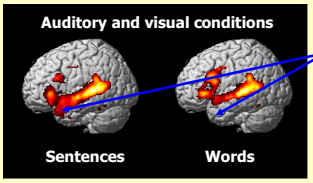
From Price and Devlin (2003) Neuroimage

Semantic and syntactic processing in language



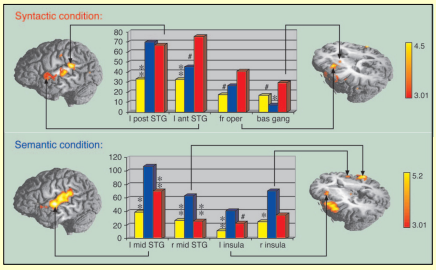
- Syntactic and semantic sentence processing
- Articulation
- Amodal semantic processing

Sentence level and word level processing



- Anterior temporal lobes

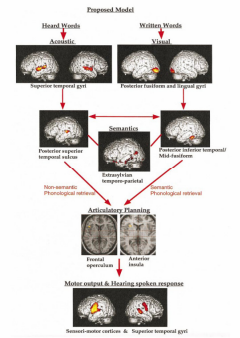
Sentence processing study designed to examine differential syntactic and semantic aspects of sentence processing



(yellow = correct sentences, blue = semantic violations, red = syntactic violations

Friederici *et al.,* (2003) Cerebral Cortex

The bigger picture...



- Language processing is carried out over a distributed network of brain regions
- Language function is usually left-lateralised (but right hemisphere is also active)
- Key regions engaged in language processing include:
  - inferior frontal,
  - temporal,

  and
  - occipito-temporal areas

Price (2000) Journal of Anatomy

The End

Useful References:

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