Lecture 11: Computational Psycholinguistics

Paula Buttery

Dept of Theoretical & Applied Linguistics, University of Cambridge

What is Psycholinguistics?

- Psycholinguistics is concerned with how we comprehend and produce language
- Psycholinguistics is concerned with understanding how language is stored and processed in the brain.

Example research questions in psycholinguistics

Morphology: What is the representation of words in the brain?

- Full listing: walk, walks, walked, walking
- Minimum redundancy: walk, +ed, +s,+ing

Example research questions in psycholinguistics

Language complexity: What makes a sentence difficult to process?

- The cat the dog licked ran away
- The cat the dog the rat chased licked ran away
- The fact that the employee who the manager hired stole office supplies worried the executive
- The executive who the fact that the employee stole office supplies worried hired the manager

Example research questions in psycholinguistics

Parsing: How does the brain perform parse disambiguation?

- The horse raced past the barn fell.
- The student forgot the solution was in the back of the book.

Example research questions in Psycholinguistics

Semantics: In what manner is meaning stored in the brain?

- Semantic features
- Feature networks

Psycholinguists use both observation and experimental techniques

Observations

- Study of speech errors
- Study of the language of aphasics
- Study of language acquisition

Experimental observation as a response to stimulus

- Measurement of reaction time to a linguistic task
- Measurement of reading times
- Measurement of brain response

Questionnaires

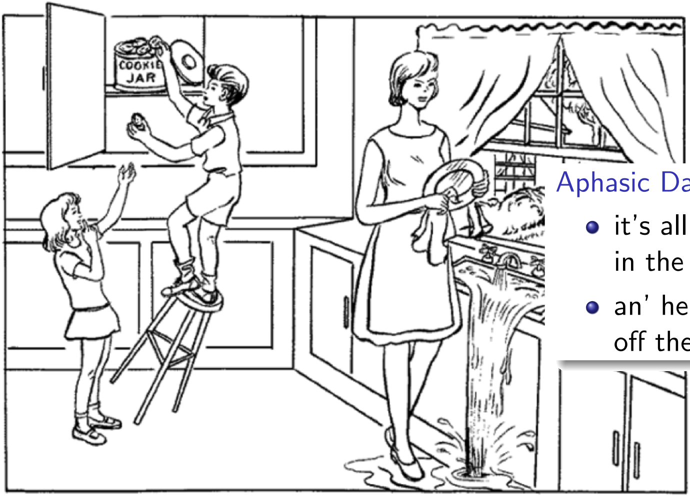
- Rating experiments
- Self evaluations

Evidence may be obtained from observation

Speech Error Data

- It's not only us who have screw looses (screws loose)
- He has already trunked two packs. (packed two trunks)

Evidence may be obtained from observation



Aphasic Data

- it's all happenining in the kitchen.
- an' he's fallenining off the stool

Evidence may be obtained from observation

Language Acquisition Data

- Brown's stages:

Stage 2	(2.0–2.5)	-s plurals
Stage 3	(2.5–3.0)	's possessive
Stage 4	(3.0–3.75)	regular past tense
Stage 5	(3.75–4.5)	irregular 3rd person verbs (dos$\rightarrow$ does, haves $\rightarrow$ has)

- The wug test

There are a variety of experimental techniques

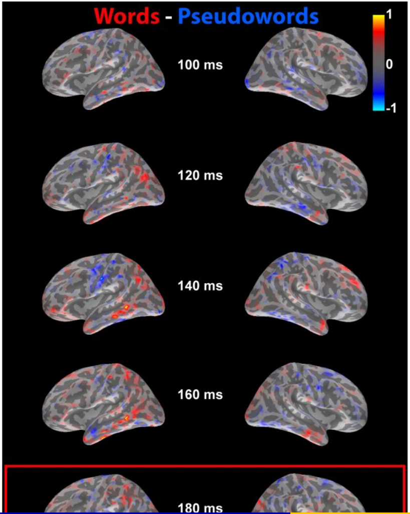
EEG

MEG

- High temporal resolution
- Problematic spatial resolution

There are a variety of experimental techniques

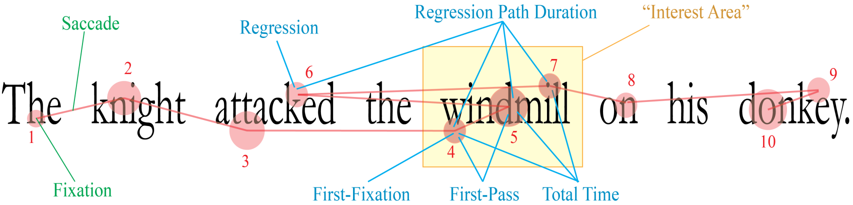
fMRI



- BOLD (Blood-oxygen-level dependent) response—measures the change in magnetization between oxygen-rich and oxygen-poor blood.
- High spatial resolution
- Low temporal resolution

There are a variety of experimental techniques

Eye tracking



Button Pressing

- Self paced reading
- Completion of a task

For all reaction time experiments we assume that the time taken to react to a task reflects the 'difficulty' of the cognitive processes involved.

Experimental Strategies

Priming Effect

- Exposure to a stimulus influences a response to a later stimulus.
- Caused by spreading activation (the priming stimulus activates part(s) of the brain, then when the second stimulus is encountered less additional activation is needed).
- Priming manifests itself as a measurable change in reaction.

e.g. Priming experiments show us that: *lifting* primes *lift*, *burned* primes *burn* but *selective* does not prime *select* (this tells us something about derivational vs. inflectional morphology).

So what is a Computational Psycholinguist?

Computational Psycholinguists generate testable hypotheses by building computational models of language processes and also by drawing on information theory.

Note that Information Theoretic predictions are not always explanatory in terms of processing mechanisms e.g. Uniform Information Density (Jaeger 2007)

What is the representation of words in the brain?

Speed of reaction is predictably affected by:

- Morphological family size. Ratio of lexical item to family size. *Baayen*, *De Jong*
- Lexical isolation point models. *Marslen-Wilson*
- Entropy of the morphological paradigm. *Moscoso del Prado Martin*

$$H(X) = -\sum_{x \in X} p(x) \log_2 p(x)$$

What makes a sentence difficult to process?

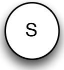
Parsing models as predictors for observed patterns in language–Yngve, 1960

- A sentence is constructed top-down and left-to-right.
- The model consists of a register for the current node being explored and a stack for all the nodes left to explore.
- The size of the stack an approximation to working memory load.
- Yngve predicted that sentences which required many items to be placed on the stack would be difficult to process and also less frequent in the language.
- He also predicted that when multiple parses are possible we should prefer the one with the minimised stack.

What makes a sentence difficult to process?

Parsing models as predictors for observed patterns in language–Yngve, 1960

S→NP VP
NP→Det N
VP→VP NP
Det→the
N→dog
N→cat
V→chased



Register	Stack
S	

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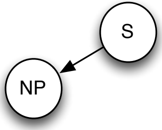

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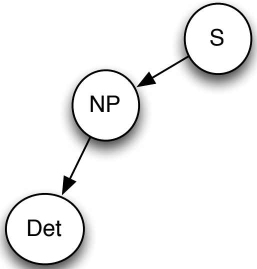

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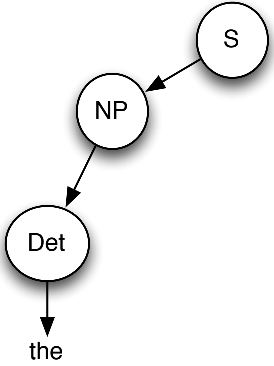

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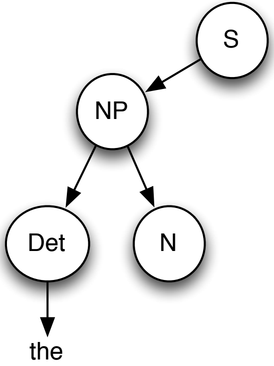

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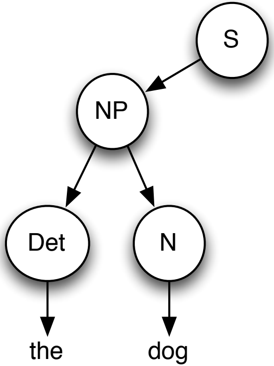

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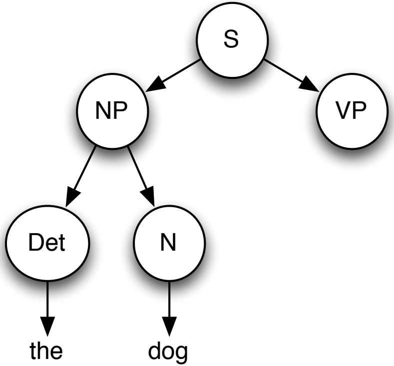

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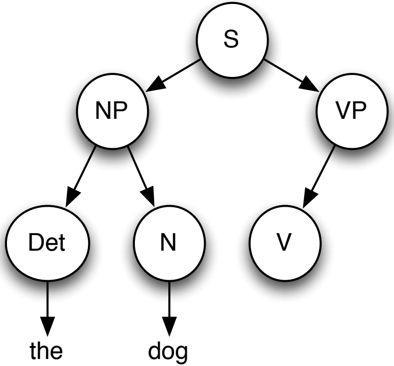

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NP	VP
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the	N VP
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VP	
V	NP

What makes a sentence difficult to process?

Yngve's make correct predictions about centre embedding

Consider:

> *This is the malt that the rat that the cat that the dog worried killed ate.*

as opposed to:

> *This is the malt that was eaten by the rat that was killed by the cat that was worried by the dog.*

What makes a sentence difficult to process?

Yngve's make correct predictions about centre embedding

Consider: STACK: N VP VP VP

> *This is the malt that the rat that the cat that the dog worried killed ate.*

as opposed to:

> *This is the malt that was eaten by the rat that was killed by the cat that was worried by the dog.*

Yngve evaluated his predictions by looking at frequencies of constructions in corpus data.

What makes a sentence difficult to process?

Dependency Locality Theory—Gibson 1998

- Processing cost of integrating a new word is proportional to the distance between the word and the item with which the word is integrating.
- Distance is measured in words plus new phrases and discourse referents.

DLT predicts that object relative clauses are harder to process because they have two nouns that appear before any verb.

The girl who likes me, went to the party.
The girl who Peter likes, went to the party.

How does the brain perform parse disambiguation?

Surprisal as a measure of complexity

$$S(w_i) = \log 1/P(w_i) \tag{1}$$

- The horse raced past the barn fell.
- The student forgot the solution was in the back of the book.

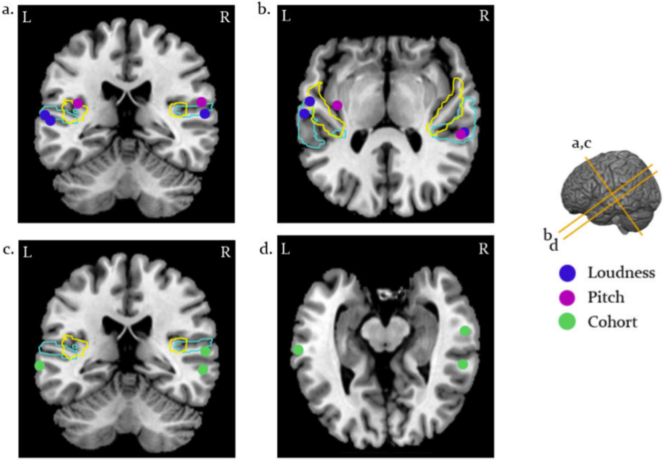
What makes a sentence difficult to process?

50 years later:

> *We used functional Magnetic Resonance Imaging (fMRI) to monitor brain activation while subjects passively listen to short narratives. The texts were written so as to introduce various syntactic complexities (relative clauses, embedded questions, etc.) not usually found (in such density) in actual corpora. With the use of a computationally implemented probabilistic parser (taken to represent an ideal listener) we have calculated a number of temporally dense (one per word) parametric measures reflecting different aspects of the incremental processing of each sentence. We used the resulting measures to model the observed brain activity (BOLD). We were able to identify different brain networks that support incremental linguistic processing and characterize their particular function.*

Asaf Bachrach 2008

What makes a sentence difficult to process?



'Identifying computable functions and their spatiotemporal distribution in the human brain'. Andrew Thwaites et al.

How is meaning represented in the brain?

- Vector space models (VSMs) and semantic priming *Pado and Lapata*
  - take word pairs from the psychological literature
  - compute vector representations for target words and related and unrelated prime words
  - distributional distance between related prime and target should be smaller than distance between unrelated prime and target.
- Towards Unrestricted, Large-Scale Acquisition of Feature-Based Conceptual Representations from Corpus Data *Tyler et al.*

- Psycholinguistics is concerned with understanding how language is stored and processed in the brain
- Computational Psycholinguistics contributes to the field by making predictions using information theory or by computational modelling.
- Many methods are employed to test the predictions.