Computational Psycholinguistics

Lecture 2: **Parsing Mechanisms**

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Human Language Parsing

- We understand language incrementally, word-by-word
    - How precisely do people construct interpretations?
- We must resolve local and global ambiguity
    - How do people decide upon a particular parse/interpretation?
- Why are some grammatical sentences so difficult to comprehend
    - Ambiguity: the human parser has been misled, takes time to recover
    - Resources: the human parse has exceeded available memory

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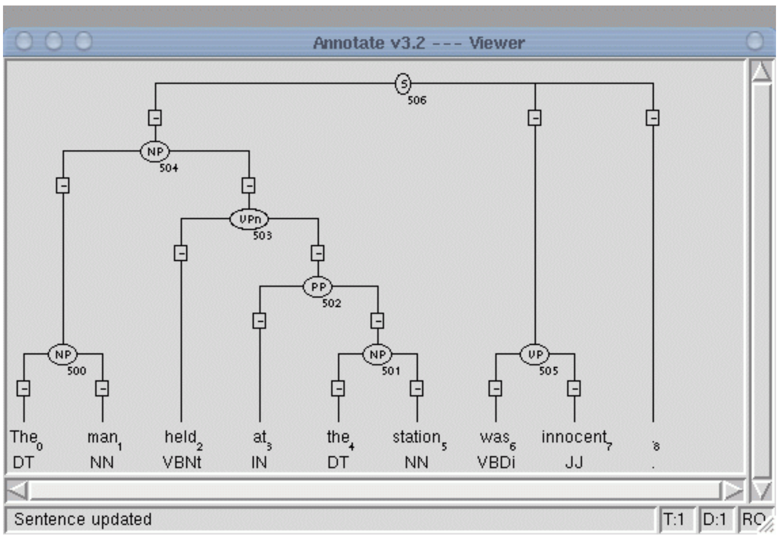
The Problem

- How do people recover the meaning of an utterance in real-time?

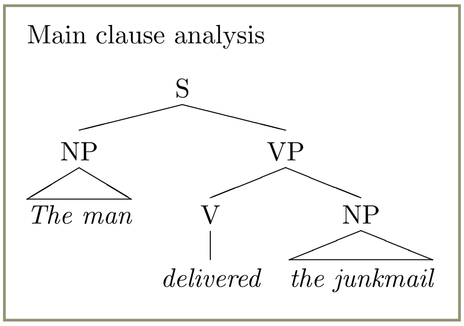


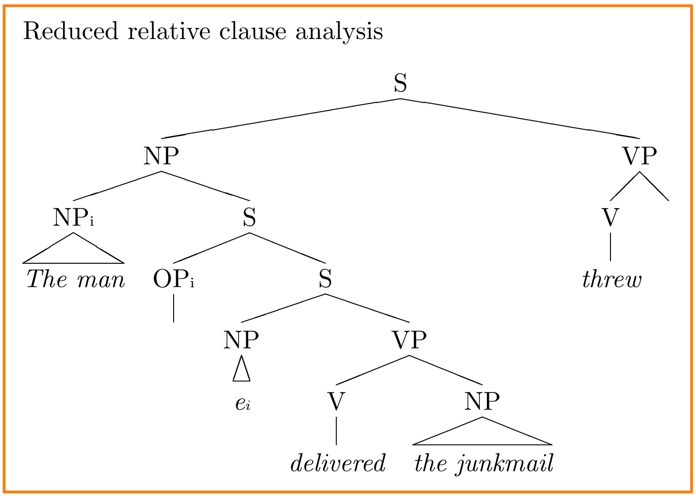
"The man held at the station was innocent"

Crocker & Brants, *Journal of Psycholinguistic Research*, 2000.

(Reduced) Relative Clauses

- One of the most famous (English) syntactic ambiguities!
    - *The man delivered the junkmail ...* threw it away.





Reading time studies

- We can use controlled experiments of reading times to investigate local ambiguity resolution
    - (a) The man held at the station was innocent (LA)
    - (b) The man who was held at the station was innocent (UA)
- Compare the reading times of (b) where there is no ambiguity, with (a) to see if and when the ambiguity causes reading difficulty.
    - Need a “linking hypothesis” from theory to measures
    - Can then manipulate other linguistic factors to determine their influence on on RTs in a controlled manner

Experimental Design

- Decide on the Factor: e.g. Ambiguity
- Decide on the Levels: e.g. ambiguous & non-ambiguous
- One experimental Item includes all conditions (each Level of each Factor)
  - carefully match conditions within an item, minimal differences
  - create multiple items
- Multiple participants, each sees only one condition of each item
- Then average across items and participants, and do inferential statistics!

Reading Methods

Whole sentence reading times:

`The man held at the station was innocent`

Self-paced reading, central presentation:

Self-paced reading, moving window:

`The man held at the station was innocent`

But what do RTs tell us, really?

- Suppose you find an increased reading time for one condition, versus another. What does that mean?
- Various things can result in longer reading times:
  - lexical: longer words, infrequent words, implausible words
  - syntactic: memory load, ungrammaticality, disambiguation, revision
- We need our models to make clear the linking to empirical measures:
  - e.g. high RT when dispreferred structure must be recovered
- And, we need to make sure this is what is causing the RT in our experiment

Summary

- People construct an interpretations, word-by-word
  - People must resolve ambiguity
  - Sometimes we must revise our interpretation of the sentence so far
- Reading time measures can tell us about how/when this occurs
  - Different phenomena are found in different measure
- We can design experiments which exploit these methods (and others!) to investigate the underlying processing architectures and mechanisms

Parsing Mechanisms

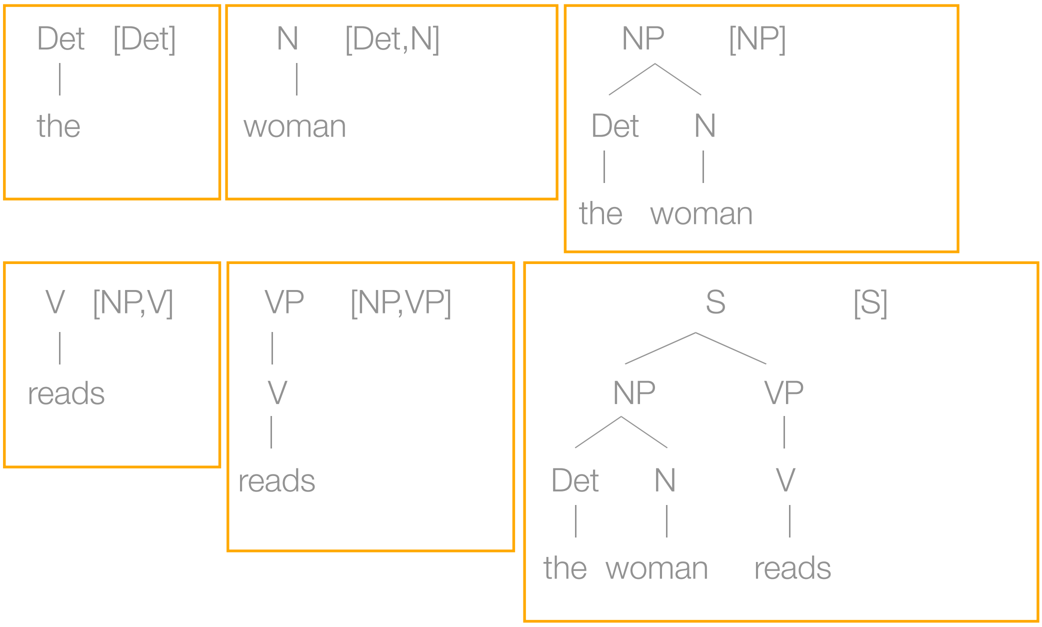
- Syntactic processing requires a solution to the problem of:
  - How structures are **incrementally** constructed
  - How local and global **ambiguity** is resolved
- Incremental Parsing
  - Top-down; Bottom-up; Mixed strategies
- Ambiguity and parsing:
  - Serial (deterministic/non-deterministic)
  - Parallel (bounded/unbounded)

Parsing Algorithms for PSGs

- Algorithms to recover the parse tree for an utterance vary ...
  - left-to-right, head-driven, right to left
  - top-down, bottom-up, mixed
  - deterministic, serial, parallel
- Processing complexity:
  - Time: what time is required to parse a sentence as a function of sentence length, grammar size?
  - Space: how much memory does the parser require?

Bottom-up Parsing

- “The woman reads”



Shift-reduce Algorithm

1. Initialise *Stack* = []
2. loop: Either ***shift***:

   2.1. Determine category, *C*, for next word in sentence;

   2.2. Push *C* onto the stack;

3. Or ***reduce***:

   3.1. If categories on the ***Stack*** match the RHS of a rule: LHS → *Stack*

      3.1.1. Remove those categories from the ***Stack***;

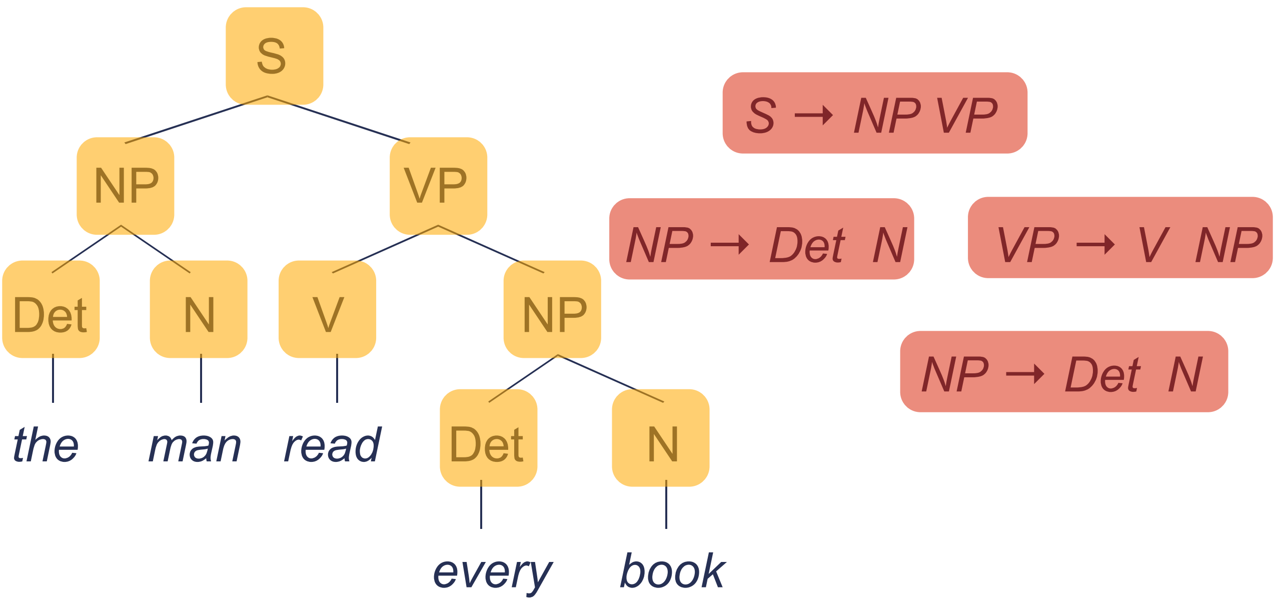
      3.1.2. Push the LHS category onto the ***Stack***;

4. No more words to process?

   4.1. If ***Stack*** = [S], then done;

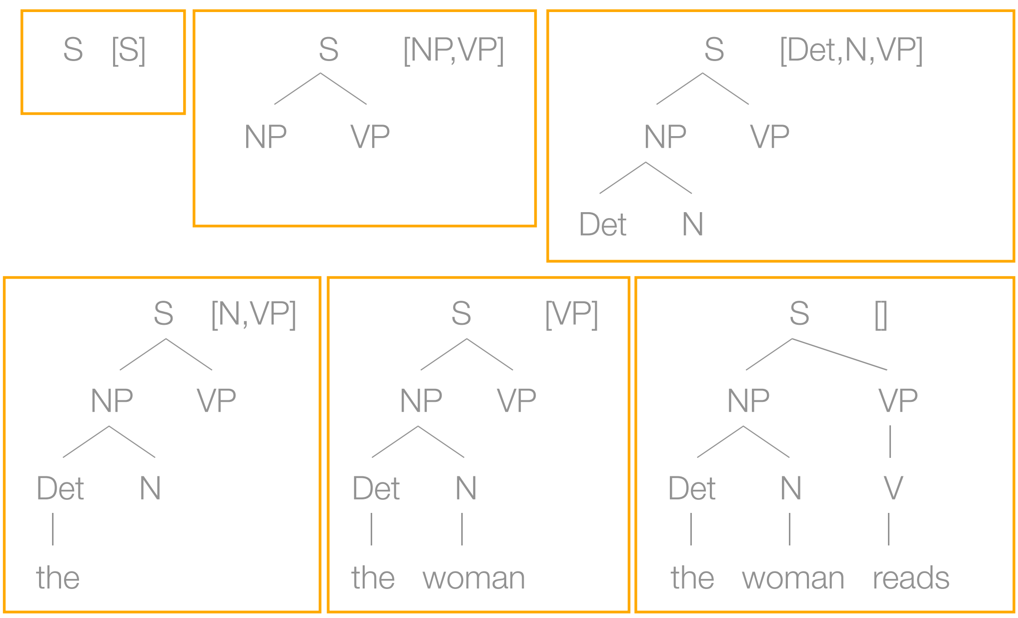
5. Goto loop

Simple example:Bottom-up



Top-down Parsing

"The woman reads"



Top-down Algorithm

1. Initialise *Stack* = [S]
2. If top(*Stack*) is a non-terminal, *N:*

    2.1.Select rule *N* → *RHS*;

    2.2.pop(*N)* off the stack and push(*RHS*) on the stack;
3. If top(*Stack*) is a pre-terminal, *P:*

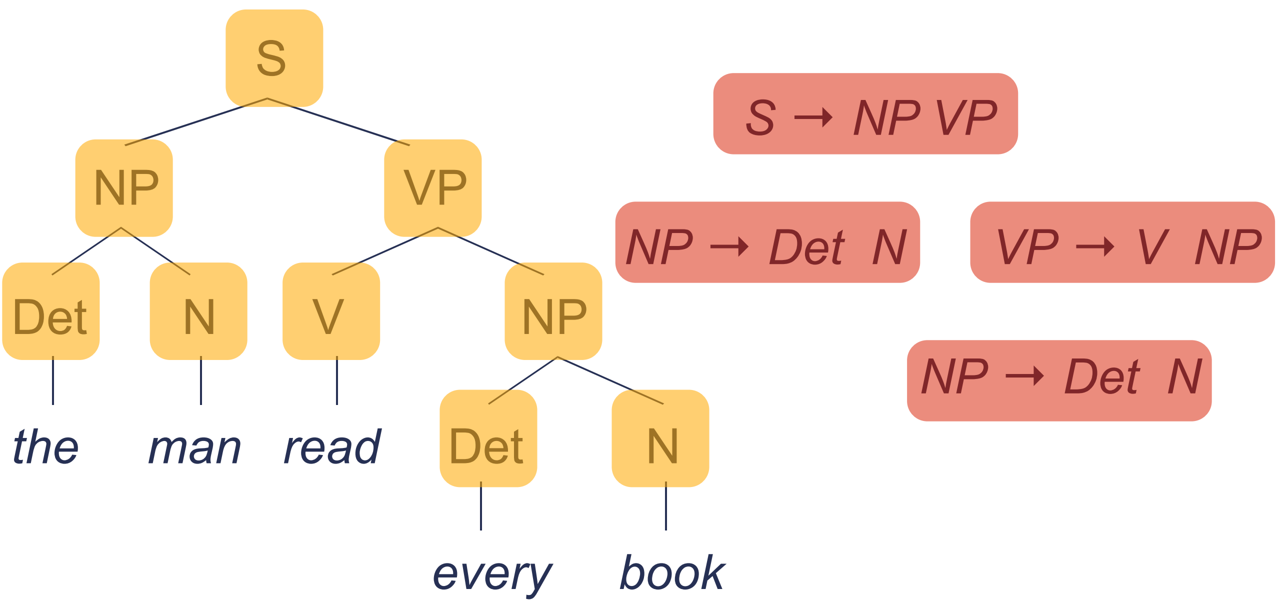
    3.1.Get next word, W, from the input;

    3.2.If *P* *W*, then pop(*P*) from the stack;

    3.3.Else fail;
4. No more words to process?

    4.1.If *Stack* = [], then done;
5. Goto ✒✎

Simple example: Top-down

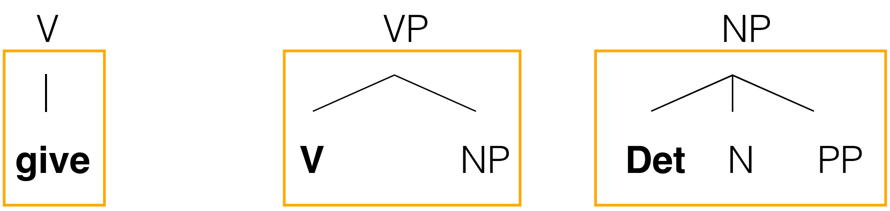


Evaluating top-down & bottom-up

- Are these parsers psychologically plausible?
- Incrementality:
  - Bottom-up: no
  - Top-down: yes
- Input-driven:
  - Bottom-up: yes
  - Top-down: no + problems with left-recursion

A Psychologically Plausible Parser

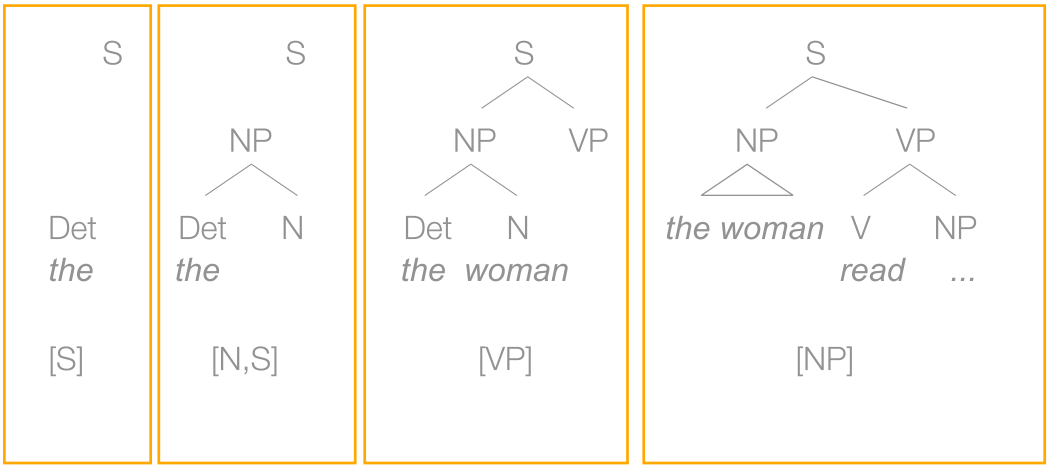
- Left-Corner Parsing
- Rules are 'activated' by their 'left-corner'



- Combines input-driven with top-down
- There is a 'class' of LC parsers

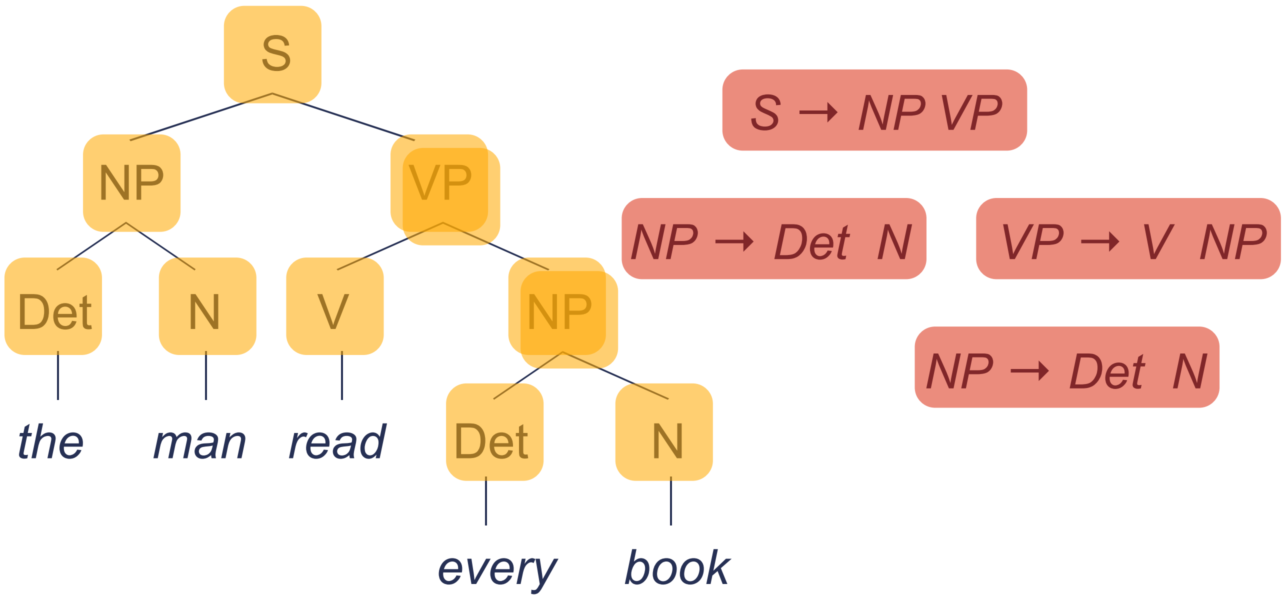
An example LC parse

"The woman read the book"



Is this incremental?

Simple example:Left-Corner



Evaluating the LC Parser

- Variations: **arc-standard** *versus* **arc-eager**

- Affect on ambiguity resolution for arc-eager:
  - Commitment to attachments is early, before daughters are completely built