Introduction to Psycholinguistics

Lecture 3: Sentence Processing

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What makes up Psycholinguistics?

- Computational models of the representations, architectures and mechanisms that underlie human language processing.
  - Linguistics:
    - Wow people represent linguistic knowledge
  - Psycholinguistics:
    - How people use this knowledge to produce and understand language
  - Computational Models:
    - Implementations of psycholinguistic theory, using linguistic representations.
    - More complete theory: models and predicts human behaviour
  - Experiments & Data:
    - Descriptive studies of human language processing
      - Off-line: grammaticality judgement, completions, global reading time (?)
      - On-line: "word-by-word", self-paced reading, eye-tracking, ERP
    - Test prediction of theories and computer models
    - Corpus data: word-frequency, category and sense bias, subcategorization

Sentence Processing

- *Sentence processing is the means by which the words of an utterance are combined to yield and interpretation*
  - All people do it well
  - It is a difficult task: complexity and ambiguity
  - Not simple 'retrieval', like lexical access
  - Compositional: interpretation must be built, rapidly, even for novel word/structure input
- What are the architectures, mechanisms and representations underlying this process?
  - Architectures: modularity vs. interaction
  - Mechanisms: how is input mapped to interpretations using knowledge
  - Representations: How is knowledge encoded

A Simple Theory of Grammar

The Grammar

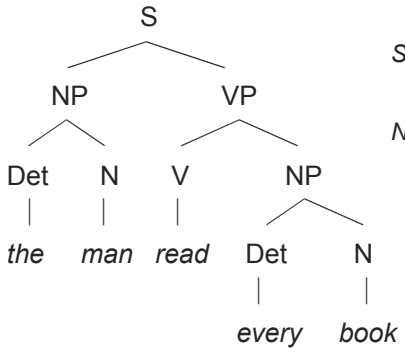
- S → NP VP
- NP → PN
- NP → Det N
- NP → NP PP
- PP → P NP
- VP → V
- VP → V NP
- VP → V NP PP

The Lexicon

- Det = {*the, a, every*}
- N = {*man, woman, book, hill, telescope*}
- PN = {*John, Mary*}
- P = {*on, with*}
- V = {*saw, put, open, read, reads*}

A Generated Sentence

- the man read every book



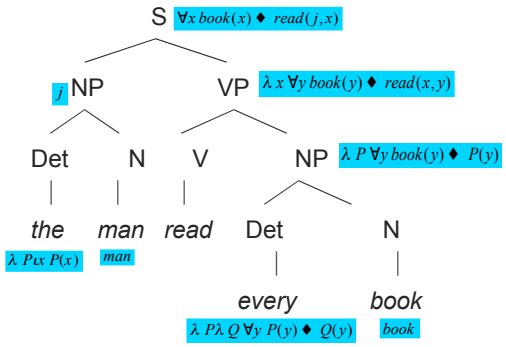
$S \rightarrow NP\ VP$

$NP \rightarrow Det\ N$ $VP \rightarrow V\ NP$

$NP \rightarrow Det\ N$

Semantic Composition

- Theories of meaning and knowledge representation
- Semantic composition:
  - lexical competence + semantic operations
- "the man read every book"



Semantic Ambiguity

- Word sense ambiguity: a word may have more than one SENSE
  - Stock *(soup vs investments),* bank *(money repository vs side of river),*
- Anaphoric underspecification: anaphoric expressions derive their meaning from context:
  - *She, it, the book, every man*
- Scope ambiguity: the interpretation of sentence constituents may be controlled by the interpretation of other constituents
  - *"In New York, a man is mugged every 10 minutes"*

Syntactic Ambiguity

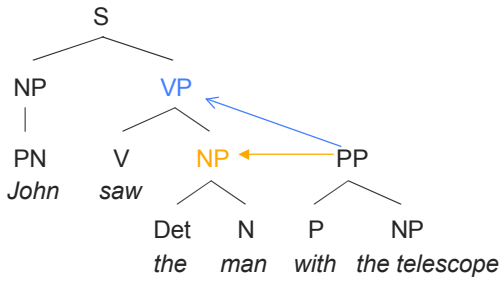
- Lexical ambiguity occurs when a word may be rewritten by more than one category:
  - N → {saw, hammer, book ...}
  - V → {read, saw, witnessed, ...}
- Structural ambiguity occurs when a sentence may be generated in more than one way by the PS rules:

The spy saw the cop with the gun/binoculars

  - The gun is usually interpreted as a modifier of the cop
  - The binoculars is usually interpreted as an instrument of saw

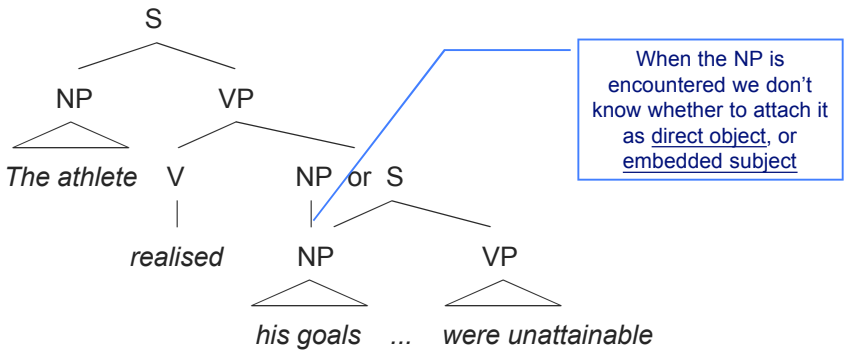
PP Attachment Ambiguity

- PPs may attached to NPs, and VPs:
  - *John saw the man with the telescope*



Local Ambiguity: NP/S complements

- Local ambiguity occurs during incremental parsing, when there is insufficient local information to determine the correct structure:



Processing and Ambiguity

- What if an utterance may be interpreted in more than one way:
  "I saw the man on the bench in the park with a telescope"
  - choose a singe parse/interpretation
  - determine all possible interpretations
- Incrementality
  - Local ambiguity:
    "I knew the solution to the problem was incorrect"
  - How much is interpreted incrementally?
  - What are the implications for parsing and understanding?
- Most evidence suggest people …
  - … are consciously aware of only one interpretation at any time, and
  - … construct interpretations on a word-by-word basis (at least!)

Mechanisms for syntactic processing

- Human syntactic processing requires a solution to the problem of *local and global ambiguity*
- Serial/backtracking:
  - Initial disambiguation: rule (or structure?) selection strategy
  - Reanalysis: reparsing? parse repair? …
- Parallel:
  - Preferences: ranking strategy
  - Limitations: what structures to forget
  - Reanalysis: reranking/adjusting
- Parsing/Ranking strategies:
  - Structural, syntactic
  - Interactive: semantics, discourse, ...
  - Probabilistic

From Theory to Data

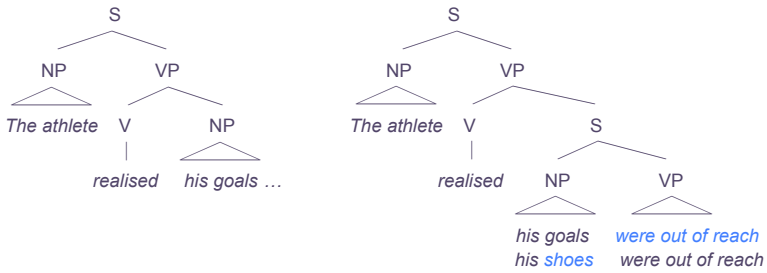
- We want to understand, and ideally model, sentence comprehension
  - Organisations, mechanisms, representations, acquisition, interaction …
- What methods can we use to get at these issues:
  - Introspection is notoriously unreliable
  - Direct: Neuroscientific methods are not (yet!) that revealing …
  - Behaviour: Rather we focus on observed behaviour
    - Judgements on meaning or grammaticality
    - Unconscious measure, e.g. reading times, priming …
- Why do we focus on ambiguous or "pathological" sentences?
  - Ambiguity is more common than you think, yet usually not problematic
  - Understanding how people cope with ambiguity can reveal a lot about the underlying architectures and mechanisms
  - Easier to investigate *minimal pairs*: similar sentences, with one difference

Linking Hypotheses

- Linking Hypothesis:
  - Need to relate the theory to some observed measure
  - Typically impossible to predict measures completely
- Common view: Theories of parsing typically determine …
  - **which information** sources are used when
  - **which representation is preferred**/constructed when ambiguity arises
  - If the sentence is consistent with that representation, **processing should be easier** than if it is not
    - ➪ Preferred sentences should have **faster reading times** in the disambiguating region than dispreferred
- Don't overfit the data: remember,our theories are *about* sentence comprehension, not reading times …
  - Must explain **competence**, and possible **other behavioural measures**

Evidence from reading times

- Language comprehension entails the incremental recovery of an interpretation for an utterance/sentence:
  - Grammar, lexicon, parser, semantics, world knowledge, situation

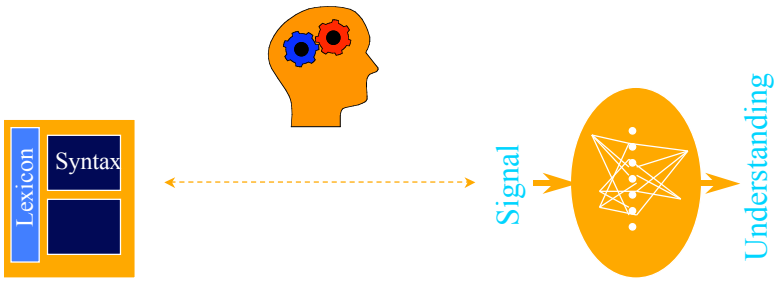


- Ambiguity: two possible structures
  - How do we know which one people build first?
  - Reading times increase when disambiguated towards the dispreferred interpretation.

Pickering, Traxler & Crocker, 2000

The Modularity Issue

- What is the architecture of the mind and brain?
  - How is computation achieved/organised?



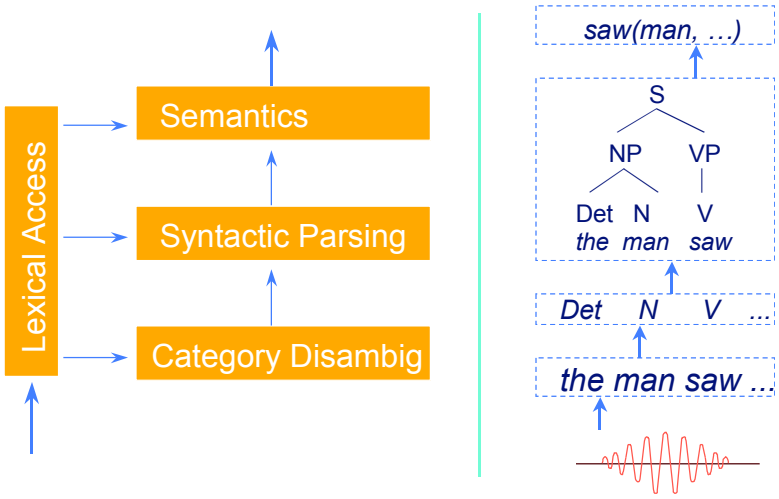
Architectures and Mechanisms

- Are there distinct modules within the human language processor?
  - What does "distinct" mean?
  - Representational autonomy: e.g. parse trees *vs* conceptual representations
    - *Possibly shared procedures*
  - Procedural autonomy: e.g. parser *versus* interpreter
    - *Possibly shared representations*
- If so…
  - How are any such "distinct subsystems" for language processing organised?
  - How do they interact?
- How does the *architecture* affect possible *mechanisms*?
  - Serial (backtracking), parallel (bounded?), underspecified …
  - Kinds of ambiguity resolution strategies?
  - What are the implications for semantic processing?
- What are the arguments for and against 'modularity'?
  - theoretical, computational and empirical

Towards a theory of parsing

- Syntax mediates the mapping sound to meaning
  - If syntax exists, the construction of syntactic representations must precede semantics or be part of the same system.
- The construction of syntactic dependencies and semantic interpretations occurs incrementally, word-by-word.
- Little evidence of "conscious parallelism"
- Ambiguity and incrementality entail making decisions and building interpretations in the face of "uncertainty":
  - What kinds of mechanisms are used to deal with ambiguity?
  - What kinds of linguistic knowledge inform the decision making process?
  - What does this tell us about the architecture of the sentence processor?

A Modular Model

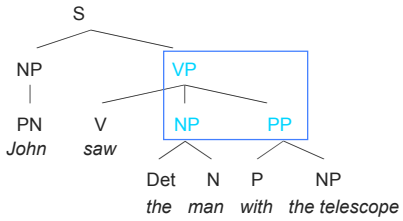


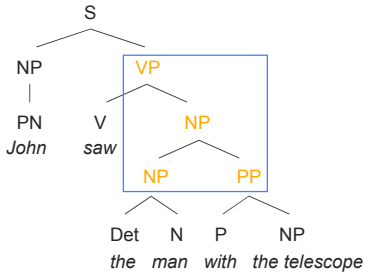
The Garden Path Theory

- Parser operates incrementally:
  - Each word it attached into the *Current Partial Phrase Marker*
- The parser operates serially:
  - A "race" to find an analysis: first wins
  - Reanalyse if the analysis is thematically impossible
- Ambiguity resolution strategies:
  - Minimal Attachment: *Adopt the analysis which requires postulating the fewest nodes*
  - Late Closure: *Attach material into the most recently constructed phrase marker*
  - Active Filler Strategy: *Associate fillers with possible gaps (traces) as early as possible.*

Minimal Attachment: VP Attachment

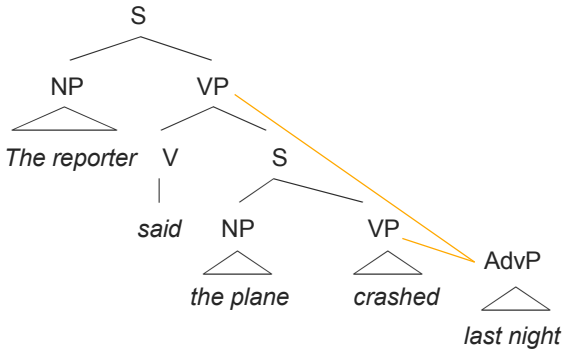
- *John saw the man with the telescope*





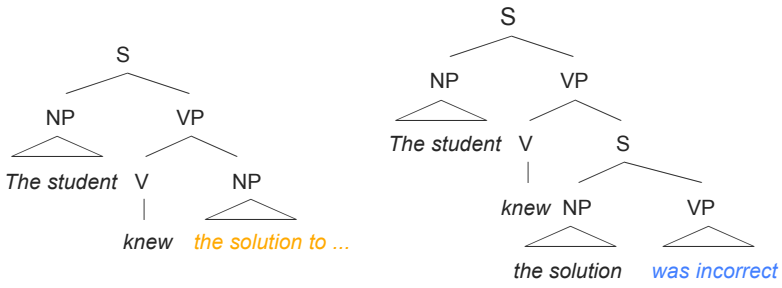
Late Closure

- Prefer 'low attachment'



NP/S Complement Ambiguity

- The student knew the solution to the problem.
- The student knew the solution was incorrect.



Ambiguities revisited: [preferred/dis-preferred]

- NP/VP Attachment Ambiguity:
  - "The cop [saw [the burglar] [with the binoculars]]"
  - "The cop saw [the burglar [with the gun]]"
- NP/S Complement Attachment Ambiguity:
  - "The athlete [realised [his goal]] last week"
  - "The athlete realised [[his shoes] were across the room]"
- Clause-boundary Ambiguity:
  - "Since Jay always [jogs [a mile]] the race doesn't seem very long"
  - "Since Jay always jogs [[a mile] doesn't seem very long]"
- Red. Relative-Main Clause Ambiguity:
  - "[The woman [delivered the junkmail on Thursdays]]"
  - "[[The woman [delivered the junkmail]] threw it away]"
- Relative/Complement Clause Ambiguity:
  - "The doctor [told [the woman [that he was in love with]] [to leave]]"
  - "The doctor [told [the woman] [that he was in love with her]]"