Computational Psycholinguistics

Lecture 1: Introduction

Matthew W Crocker

Computerlinguistik
Universität des Saarlandes

Competence and Performance

- **Competence**: our knowledge of language
- **Performance**: how that knowledge is used
  - Understanding/production mechanisms, slips of the tongue, memory limits
- Knowledge of language (KoL): theories of grammar
  - Representations
    - Trees, feature structures, dependency links
  - How they are generated (transformations, unification)
    - PS-rules, move-alpha, unification
  - Constraints on representations and/or generation
    - Case marking, theta-Criterion, empty category principle, Head-Feature Principle
- Use of KoL: the mechanisms which underlie language processing
  - What is the relationship between cognitive systems and linguistic theory?
  - Assume KoL is "used" directly in language processing
  - ➡ the *Competence Hypothesis* [Bresnan & Kaplan]

A Simple Theory of Grammar

The Grammar

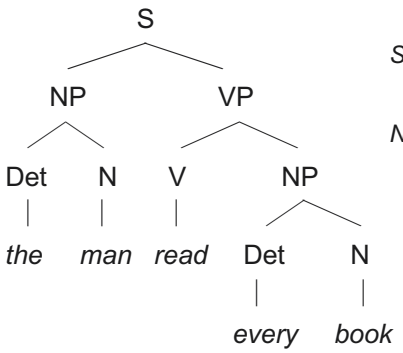
- S → NP VP
- NP → PN
- NP → Det N
- NP → NP PP
- PP → P NP
- VP → V
- VP → V NP
- VP → V NP PP

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



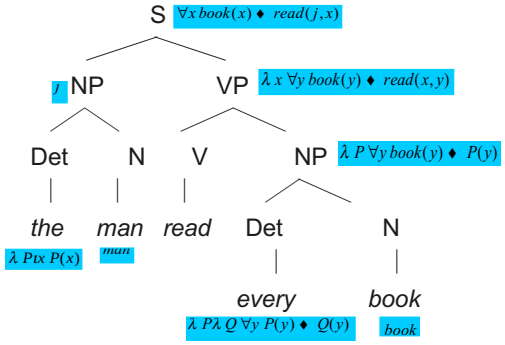
S → *NP VP*

NP → *Det N* *VP* → *V NP*

NP → *Det N*

Semantic Composition

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



Syntactic Ambiguity

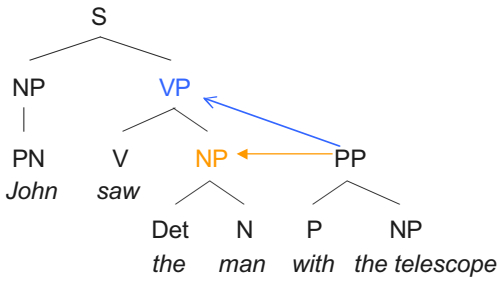
- Lexical ambiguity occurs when a word may be rewritten by more than one category:
  - N → {saw, hammer, book ...}
  - V → {read, saw, witnessed, ...}
- Structural ambiguity occurs when a sentence may be generated in more than one way by the PS rules:

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

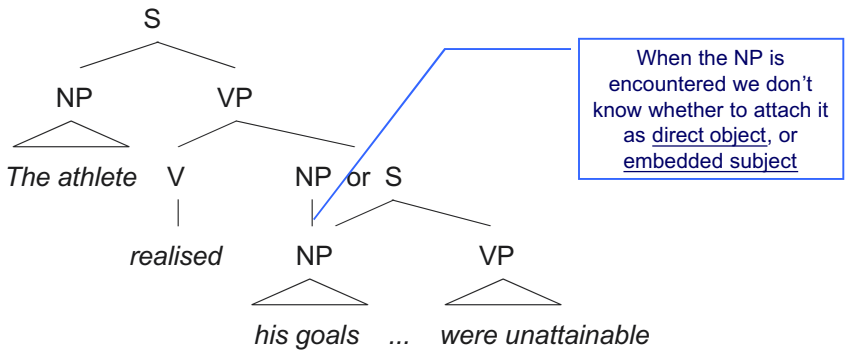
PP Attachment Ambiguity

- 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:



Semantic Ambiguity

- Word sense ambiguity: a word may have more than one SENSE
  - *stock*
- 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 Paris, a man is mugged every 10 minutes"*

Processing and Ambiguity

- What should we do 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?

Overview of syntactic processing

- Syntactic processing requires a solution to the problem of local and global ambiguity

- Serial/backtracking:
  - Initial disambiguation: rule (or structure?) selection strategy
  - Reanalysis: choice point selection
- Parallel:
  - Initial: ranking strategy
  - Limit: what structures to forget
  - Reanalysis: reranking/adjusting
- Parsing/Ranking strategies:
  - Structural, syntactic
  - Interactive: semantics, discourse, ...
  - Probabilistic

Processing Issues

- **Incrementality**: To what extent is language processed incrementally, word-by-word?
- **Ambiguity**: How are ambiguities, local and global dealt with by the language understanding system?
- **Complexity**: How are increases in human processing complexity explained by the processing model:
  - Time: how long it takes to parse
  - Space: how much memory is required
- **Architectures**: Are there distinct components/subsystems?
  - What are the characteristics of these systems/modules?
    - Representations, knowledge/domain, input/output
  - How are modules organised? How do they interact?
  - What is the "time course" of processing?
    - Do different modules, knowledge sources, interact simultaneously

Multiple constraints in ambiguity resolution

- The doctor told the woman that
  - *story*
  - *diet was unhealthy*
  - *he was having trouble with her husband*
  - *he was having trouble to leave*
  - *story was was about to leave*
- Prosody: intonation can assist disambiguation
- Lexical category ambiguity:
  - *that* = {Comp, Det, RelPro}
- Subcategorization ambiguity:
  - *told* = { [_ NP NP] [_ NP S] [_ NP S'] [_ NP Inf] }
- Semantics: Referential context, plausibility
  - Reference may determine "argument attach" over "modifier attach"
  - Plausibility of *story* versus *diet* as indirect object

Behaviour and Data

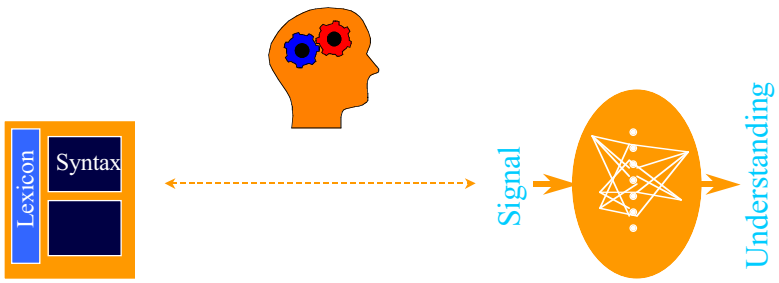
- People *can* interpret all "initial substrings"
  - When there is useful information in the input, people use it:
    - There may still be isolated cases of "delayed" processing
  - A connected interpretation must therefore be built incrementally
    - And therefore incremental parsing, assuming semantics builds on syntax
- People are aware of a single interpretation
  - *The woman sent the flowers was pleased*
  - *The first thing that hits someone in New York is a yellow cab*
  - Must perform incremental local ambiguity resolution
- Empirical data:
  - Offline judgements (questionaires) about "final" preferences
  - Online measures (self-paced, eye-tracking) about immediate preferences
    - I.e. initial preferences are based on partial input, and selected information
  - Corpus-based measure: various frequencies
    - Reflect production (edited/spontaneous), but also "experience"

Architectures and Mechanisms

- Are there distinct modules or levels of processing in the human language processor?
- What does "distinct" mean:
  - Representational autonomy: e.g. trees *versus* logics
  - Procedural autonomy: e.g. parser *versus* interpreter
- If so, how are any such "distinct subsystems" for language processing organised? How do they interact?
- What are the possible parsing mechanisms?
  - Serial (backtracking), parallel (bounded?), underspecified …
  - What are the implications for semantic processing?
- What are the theoretical, computational and empirical arguments for and against 'modularity'?

The Modularity Issue

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



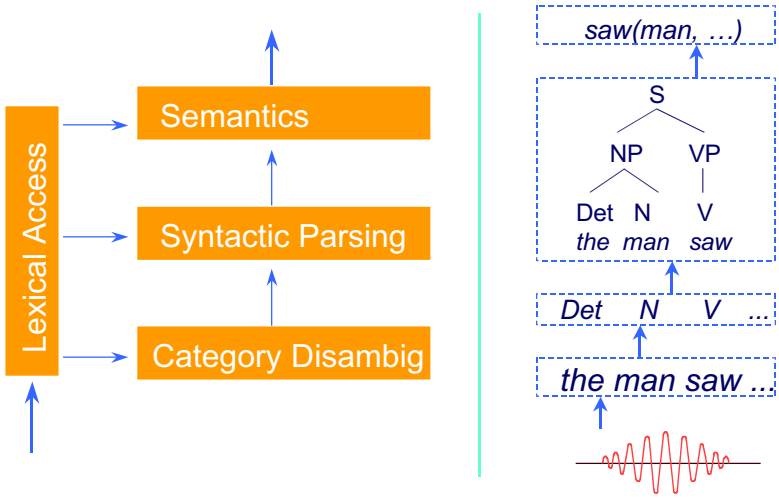
Modularity and Computation

- The brain is the natural computer, *par excellence*:
  - Fast: perception is real-time
  - Strategic: uses relevant knowledge in making inferences
  - Robust: handles novel situations; speed versus accuracy; recovers from error
- Cognitivist: *inferential, unencapsulated*
  - cognitive penetration of perceptual processes
- Behaviourist: *non-inferential, encapsulated*
  - perception reduces to conditioned reflexes
- Fodor: inferential *but* encapsulated
  - perception is performed by modules: "*informationally encapsulated systems which may carry out complex computations*"

Characteristics of Modules

- Domain specific: distinct stimulus domains
- Mandatory: can't avoid perception
- Fast: real-time processing of stimulus
- Encapsulated: stimulus specific knowledge
- Shallow output: no introspection of modules
- Specific breakdown: e.g. aphasias vs. dementia
- Modular lexical access *versus* syntax: Forster
  - all possibilities temporarily available
  - not influence by syntactic context
- Modular syntax *versus* semantics: Frazier
  - initial attachment ambiguities resolved by purely structure strategies/preferences
  - no *first-pass* effect of semantics

A Modular Model



Summary

- Syntax mediates the mapping sound to meaning
  - If syntax exists, then 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.
- Ambiguity and Incrementality entail making decision 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?
- Little evidence of "conscious parallelism"