Computational Psycholinguistics

Lecture 6: **Category Disambiguation**

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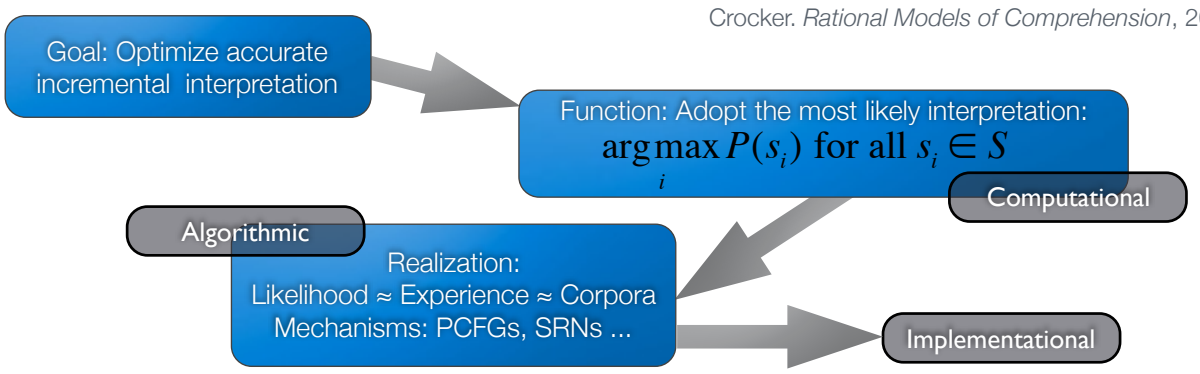
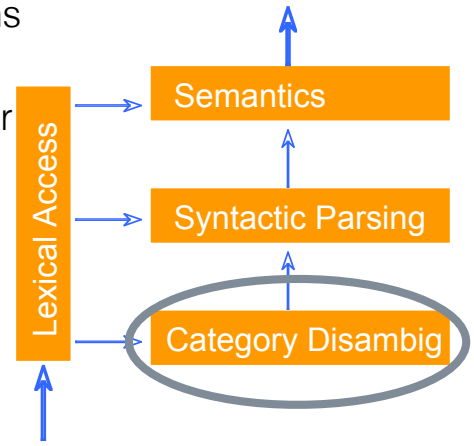


$$\arg\max_i P(s_i) \text{ for all } s_i \in S$$

- Empirical: lexical access, word category/sense, subcategorization
- Rational: accurate, robust, broad coverage
- Rational Models:
  - explain accurate performance in general: i.e. rational behaviour
  - explain specific observed human behavior: e.g. for specific phenomena

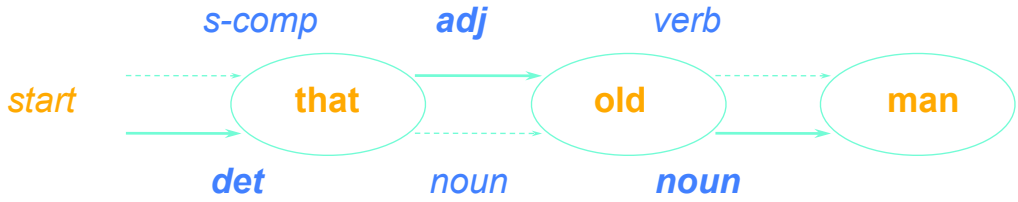
Lexical Category Disambiguation

- Sentence processing involves the resolution of lexical, syntactic, and semantic ambiguity.
  - Solution 1: These are not distinct problems
  - Solution 2: Modularity, divide and conquer
- Category ambiguity:
  - *Time flies like an arrow.*
- Extent of ambiguity:
  - **10.9%** (types) **65.8%** (tokens) (Brown Corpus)



The Model: A Simple POS Tagger

- Find the best category path ($t_1 \ldots t_n$) for an input sequence of words ($w_1 \ldots w_n$): $P(t_0,\ldots t_n, w_0,\ldots w_n)$
- Initially preferred category depends on two parameters:
  - Lexical bias: $P(w_i|t_i)$
  - Category context: $P(t_i|t_{ti-1})$
- Categories are assigned incrementally: Best path may require revision



Viterbi explained!

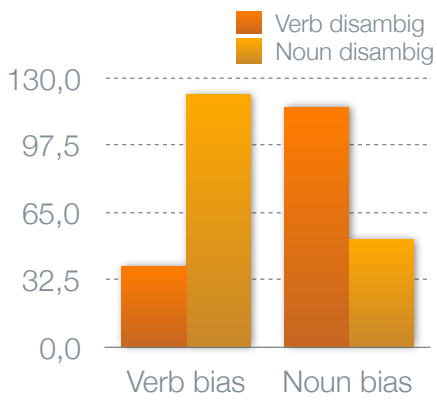
2 Predictions

- The Statistical Hypothesis:
  - Lexical word-category frequencies, $P(w_i|t_i)$, are used for initial category resolution
- The Modularity Hypothesis:
  - Initial category disambiguation is modular, and not determined by (e.g. syntactic) context beyond $P(t_i|_{ti-1})$.
- Two experiments investigate
  - The use word-category statistics
  - Autonomy from syntactic context

Statistical Lexical Category Disambiguation

- Initially preferred category depends on: $P(t_0,...t_n,w_0,...w_n) \approx \prod_{i=1}^{n} P(w_i \mid t_i) P(t_i \mid t_{i-1})$
- Categories are assigned incrementally
  - the warehouse ***prices*** the beer very modestly
  - DET N **N** / V **V!**
  - the warehouse ***prices*** are cheaper than the rest
  - DET N **N** / V **N** ...
  - the warehouse ***makes*** the beer very carefully
  - DET N N / **V** **V**
  - the warehouse ***makes*** are cheaper than the rest
  - DET N N / **V** **N!** ...
- Interaction between bias and disambiguation
- Category frequency determines initial decisions

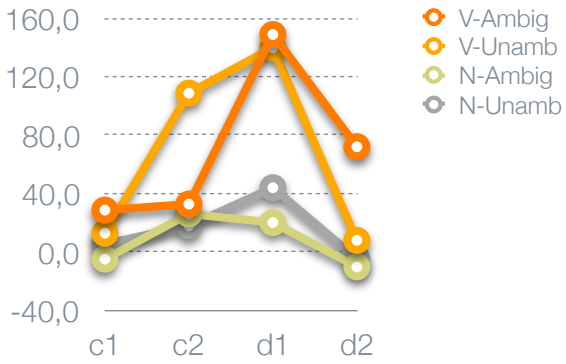
- Lexical bias: $P(w_i|t_i)$
- Category context: $P(t_i|t_{i-1})$ – constant!
- Trained on the Susanne corpus



Modular Disambiguation?

- Do initial decisions reflect integrated use of both lexical and syntactic constraints/biases or just (modular) lexical category biases?
  - N/V bias with immediate/late syntactic disambiguation as noun

- Main effect of bias at disambiguation:
  - Initial decisions ignore syntactic context.
  - Problematic for lexicalist syntactic theories
  - At c2, VA/VU difference is significant
  - Implies lexical category doesn't include number (?!)



a) **[V-bias, N-disamb]** The warehouse **makes are** cheaper than the rest.
b) **[V-bias, N-unamb]** The warehouse **make is** cheaper than the rest.
c) **[N-bias, N-disamb]** The warehouse **prices are** cheaper than the rest.
d) **[N-bias, N-unamb]** The warehouse **price is** cheaper than the rest.

'That' Ambiguity (Juliano & Tanenhaus)

A. ***That experienced*** diplomat(s) would be very helpful ... [DET]

B. The lawyer insisted ***that experienced*** diplomat(s) would be very helpful [Comp]

- Corpus based estimates:
  Initially: det=.35 comp=.11 Post-verbally: comp=.93 det=.06

- Found increased RT when dispreferred POS for "that" (according to context) is forced in the disambiguation region "diplomat(s)"

- Advocates bigram over unigram: $P(t_i|t_{i-1})$

P(*that*|comp)= 1, P(*that*|det)=.171

P(comp|verb)=.0234, P(det|verb)=.0296

P(comp|start)=.0003, P(det|start)=.0652

t_i	Comp	Det
t_{i-1} = verb	.0234	.0051
t_{i-1} = start	.0003	.0111

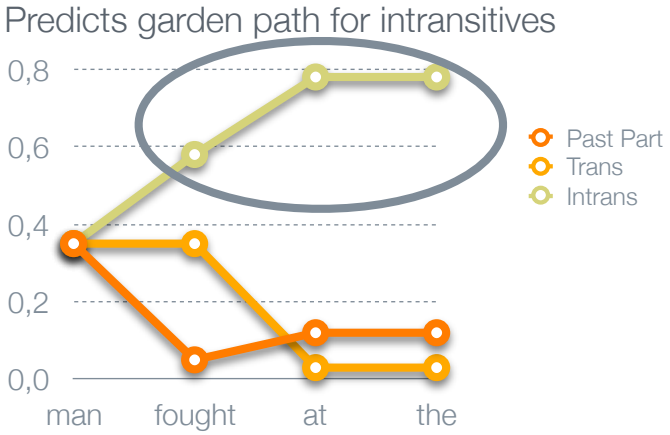
Internal Reanalysis

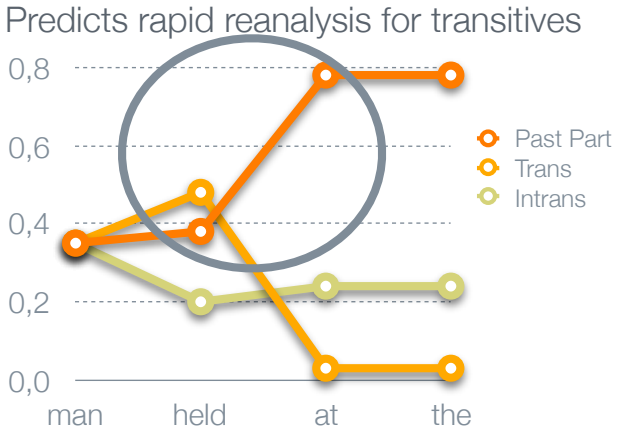
- The tagger model predicts internal reanalysis for some sequences.
- Viterbi: revise most likely category sequence based on next transition
- Right context in RR/MV ambiguities: [MacDonald 1994]
  - The sleek greyhound ***raced*** ***at the track*** won the event
  - The sleek greyhound ***admired*** ***at the track*** won the event
- ***raced*** = intrans bias, ***admired*** = trans bias
- Increased RT (blue) indicate transitivity bias is used

An SLCM Account

- Assume transitive/intransitive POS categories, extract frequencies from the Susanne corpus:

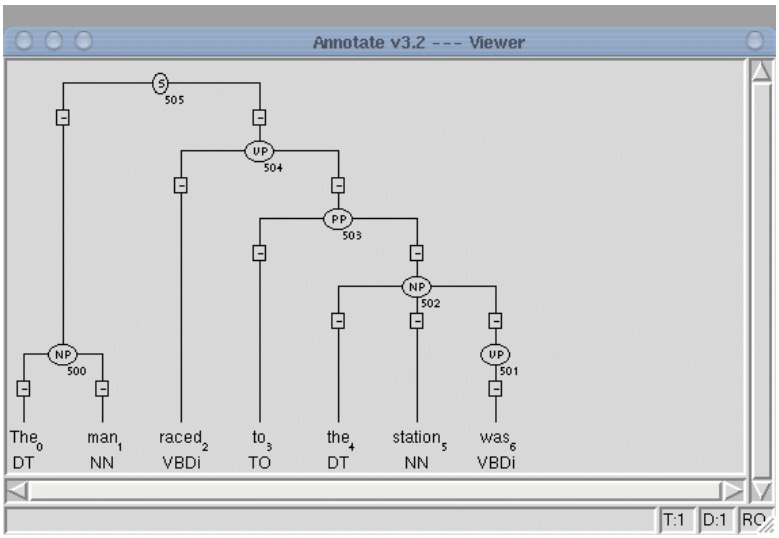
The man fought at the police station fainted [intransitive]
The man held at the police station fainted [transitive]





Reduced Relative Clause

- Parsers can make wrong decisions that lead them up the garden path

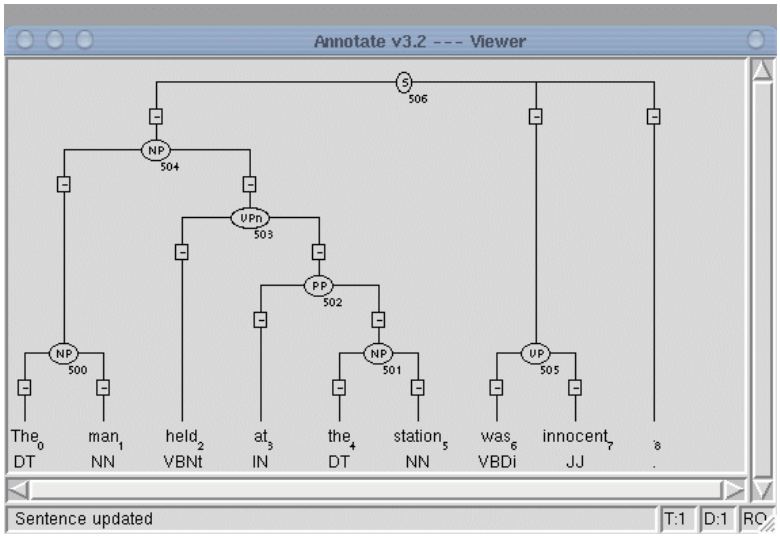


"The man raced to the station was innocent"

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

The Problem

- In some cases is may be possible to recover from the error earlier



"The man held at the station was innocent"

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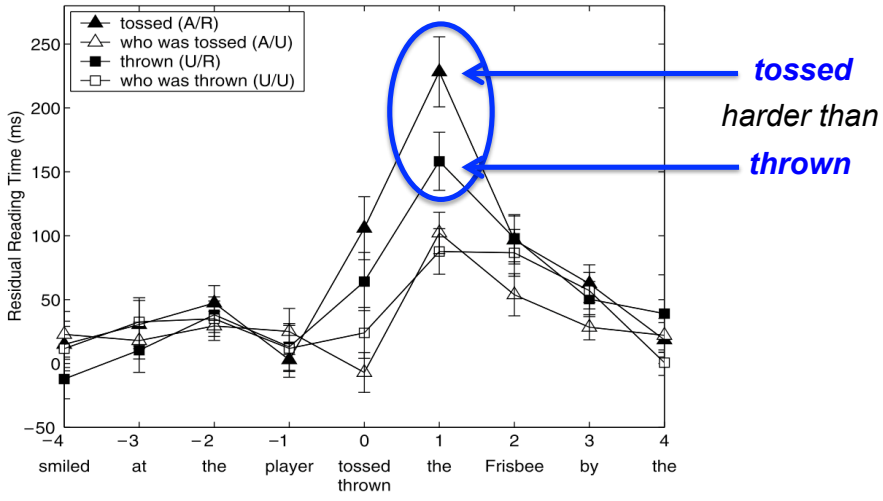
A Puzzle

- Sometimes local dependencies appears to violate the global parse:
  - **[A/R]** The coach smiled at the player tossed a frisbee by the ...
  - **[U/R]** The coach smiled at the player thrown a frisbee by the ...
  - **[A/U]** The coach smiled at the player who was tossed a frisbee by the ...
  - **[U/U]** The coach smiled at the player who was thrown a frisbee by the ...
- Syntactically, “tossed” is must a past-participle in this context, but what do people do?
- We might expect to see:
  - *Main effect of verb ambiguity*: if ambiguous verbs are difficult
  - *Main effect of structure ambiguity*: if ambiguous RRCs are difficult

Results:



- These results are problematic for theories requiring global syntactic wellformedness (e.g. Frazier, 1987; Gibson, 1991, 1998)

An SLCM Account

Note: explains the difficulty, but doesn't construct the local active clause interpretation! Is this right?

- Initially preferred category depends on two parameters:
  - Lexical bias: $P(w_i|t_i)$ Category context: $P(t_i|_{ti-1})$
- **[AS-AV]** The coach smiled at the player **tossed** a frisbee … [*slowest*]
  - *P(tossed|Vpast) * P(Vpast|noun)* **>** *P(tossed|Vpart) * P(Vpart|noun)*
  - So: assign *tossed=Vpast*, but can't integrate into parse, so reanalyse
- **[US-AV]** *The coach smiled at the player who was **tossed** a frisbee …* [*fast*]
  - *P(tossed|Vpast) * P(Vpast|Aux)* **<** *P(tossed|Vpart) * P(Vpart|Aux)*
  - So: assign *tossed=Vpart*, integrate into parse, no difficulty

SLCM Summary

- Psychologically plausible: lower statistical complexity than other models
- High accuracy in general: explains why people perform well overall
- Explains where people have difficulty
  - Statistical: category frequency **drives** initial category decisions
  - Modular: syntax structure **doesn't determine** initial category decisions
  - Bigram evidence: "that" ambiguity [Juliano and Tanenhaus]
  - Reanalysis of verb transitivity for 'reduced relatives' [MacDonald]

Comments on the SLCM

- Evidence category preference appears truly frequency-based
- Indication of which features are exploited [e.g. transitivity, not number]
  - But this is subject to further empirical investigation & verification
- Combines optimality of probabilities with advantages of modularity
  - psychological plausibility due to tractable parameter space
- Implications for the **Grain Problem**?
  - Bigrams used, but not tri-grams, or syntactic structure ?
  - Transitivity but not number ? More/less syntactically-rich POS tags ?

Probabilistic Syntax

- The SLCM is only a model of lexical category assignment
  - But note: these category decisions underlie many “syntactic” ambiguities
- Some ambiguities are purely syntactic, however:
  - Relative clause attachment, or other modifier attachment
  - NP/S complement ambiguity (unless subcat is encoded in the POS tags)
- Also evidence that compositional interpretation influences parsing
  - Can’t be modeled in the SLCM alone
- Apply probabilistic approaches to modeling human syntactic parsing