Interactivity and competition: Parsing sentences

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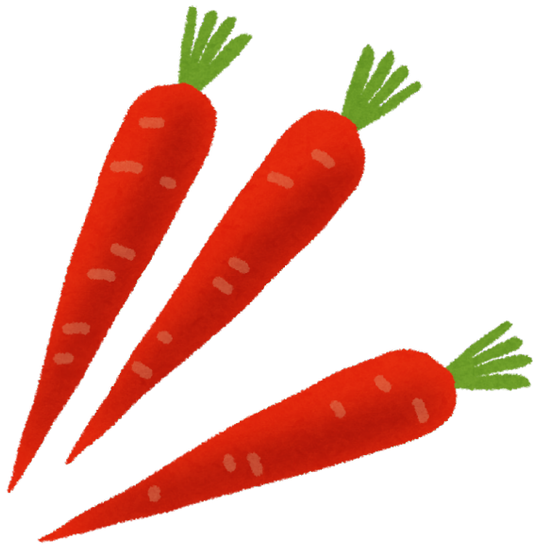
3/8/2021

Recap

Activation / access / generation function:
How are potential word candidates identified, given some sensory input?



CARE

PARROT

CARROT

Kerrianne

Christian

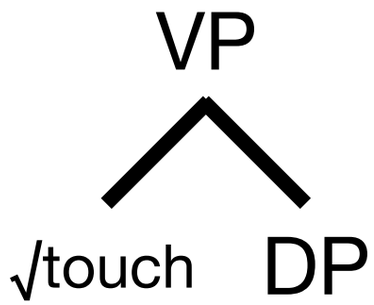
Selection function: How do we make a ‘decision’ about the outcome of the recognition process?

Integration function: How does output of recognition process relate to higher order levels of analysis (e.g. syntactic or semantic analysis)?

Levels of representation

Semantic [[touch]]

Syntactic



Lexical /tʌtʃ/

Phonetic

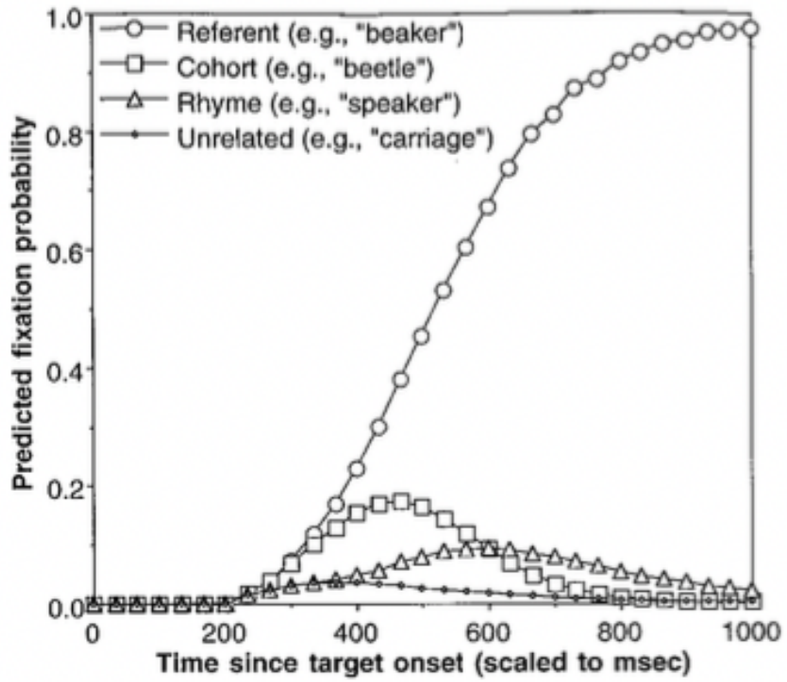


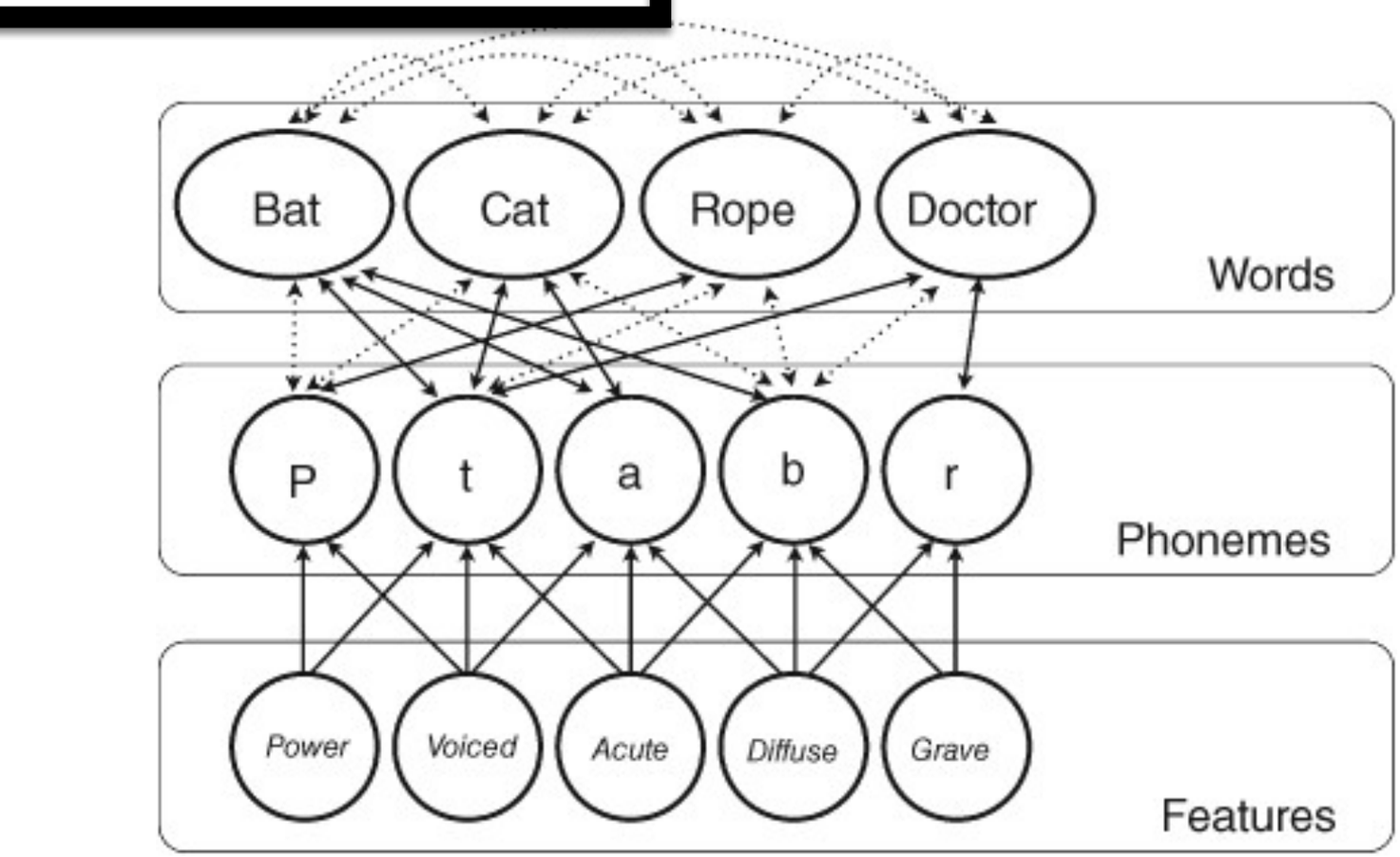
FIG. 2. Predicted response probabilities converted from TRACE using the scaled Luce choice rule.

- Rapid generation of alternatives - **competition**.
- Rapid selection in context.

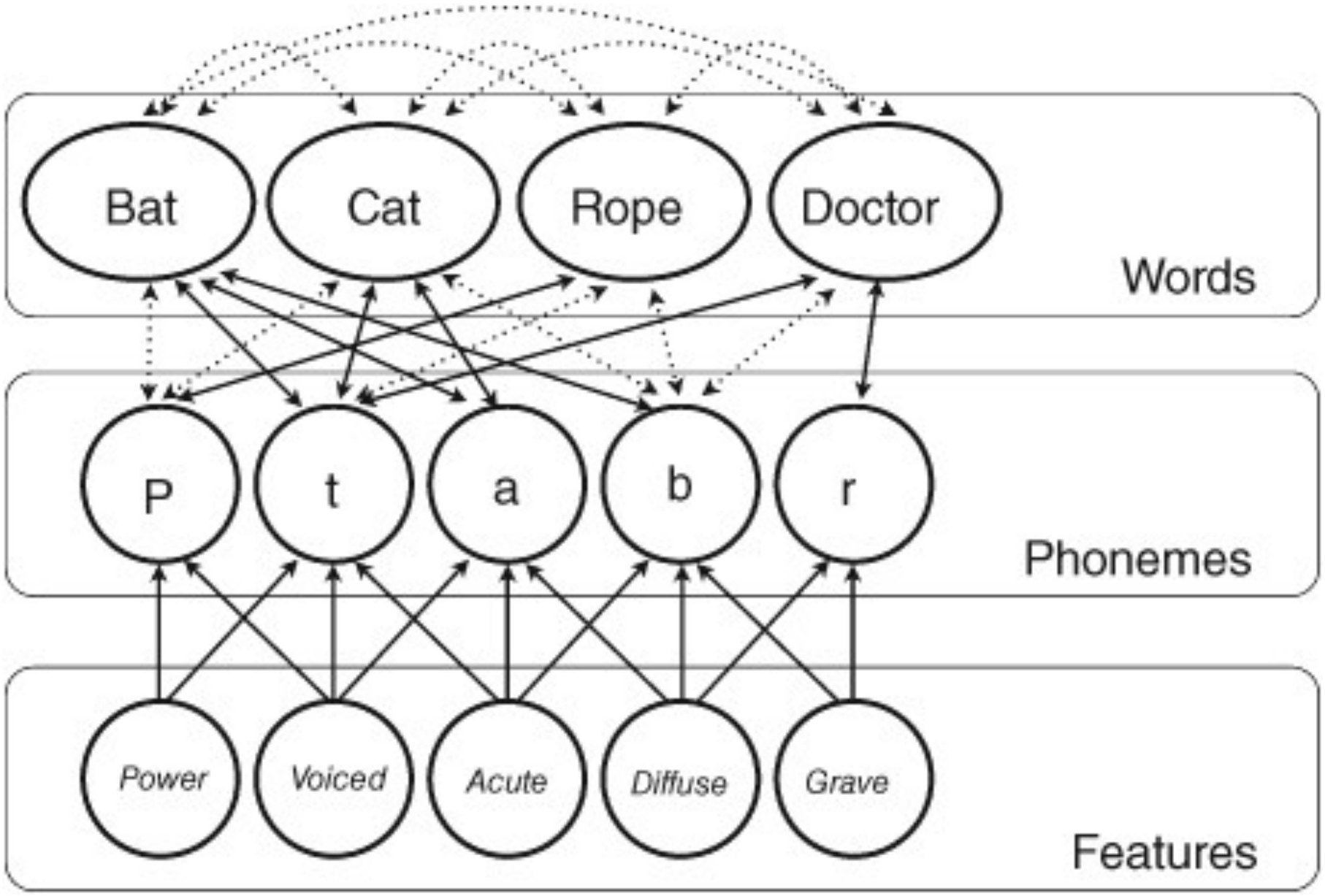
Levels of representation

Lexical /tʌtʃ/

Phonetic



Feedback and top-down perception

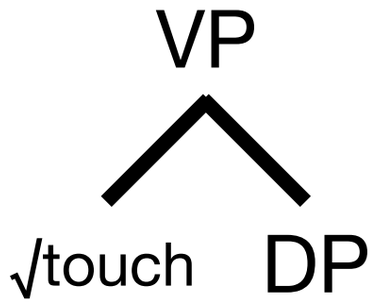


https://www.youtube.com/watch?v=ZyvyGMkzNQc

Today

Semantic [[touch]]

Syntactic

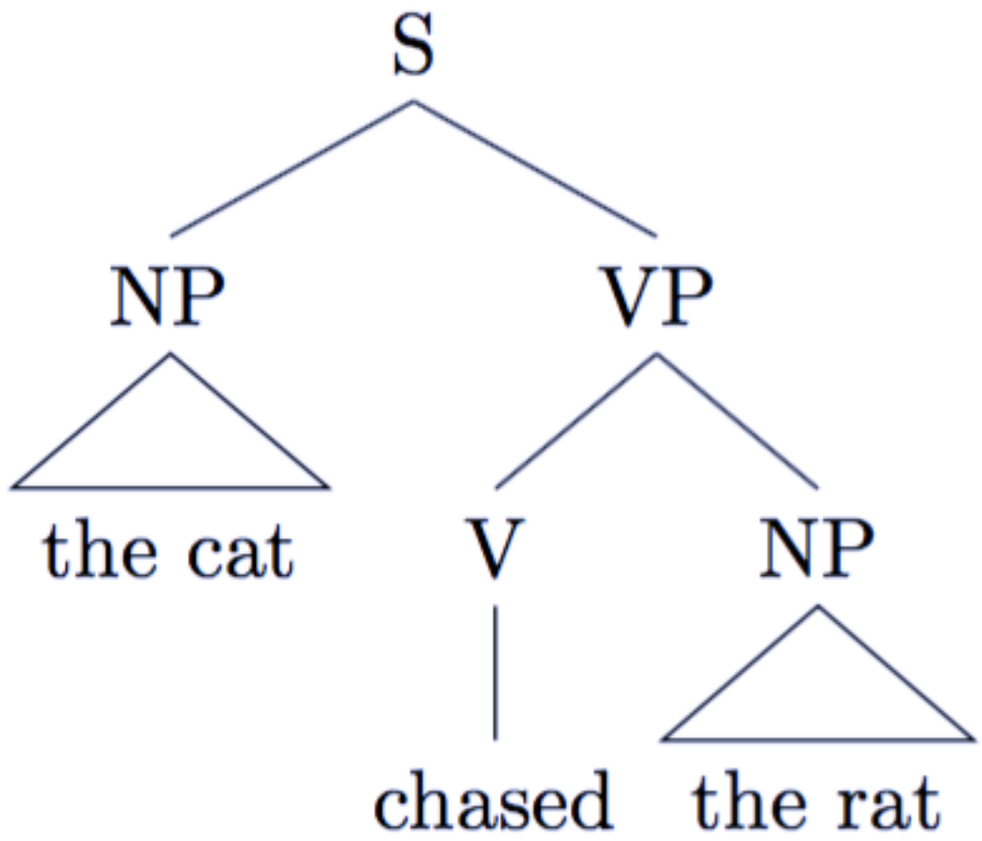


Lexical /tʌtʃ/

Phonetic

Parsing sentences

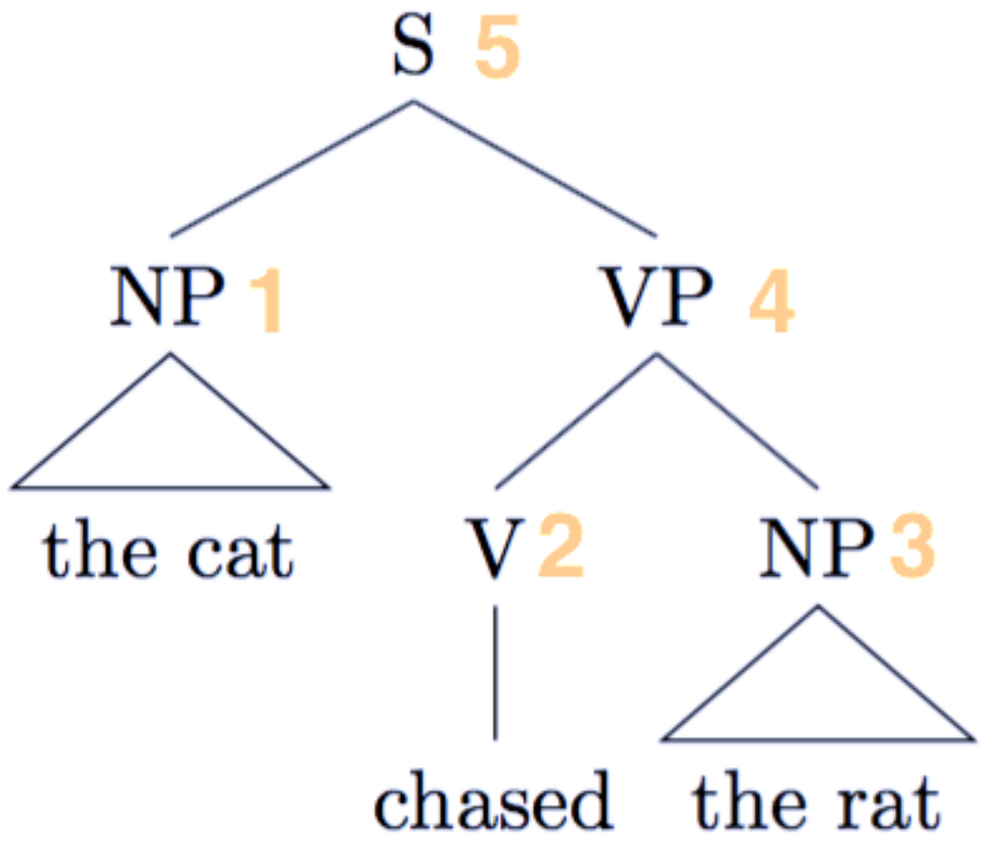
String → **Syntactic parse**



the cat chased the rat

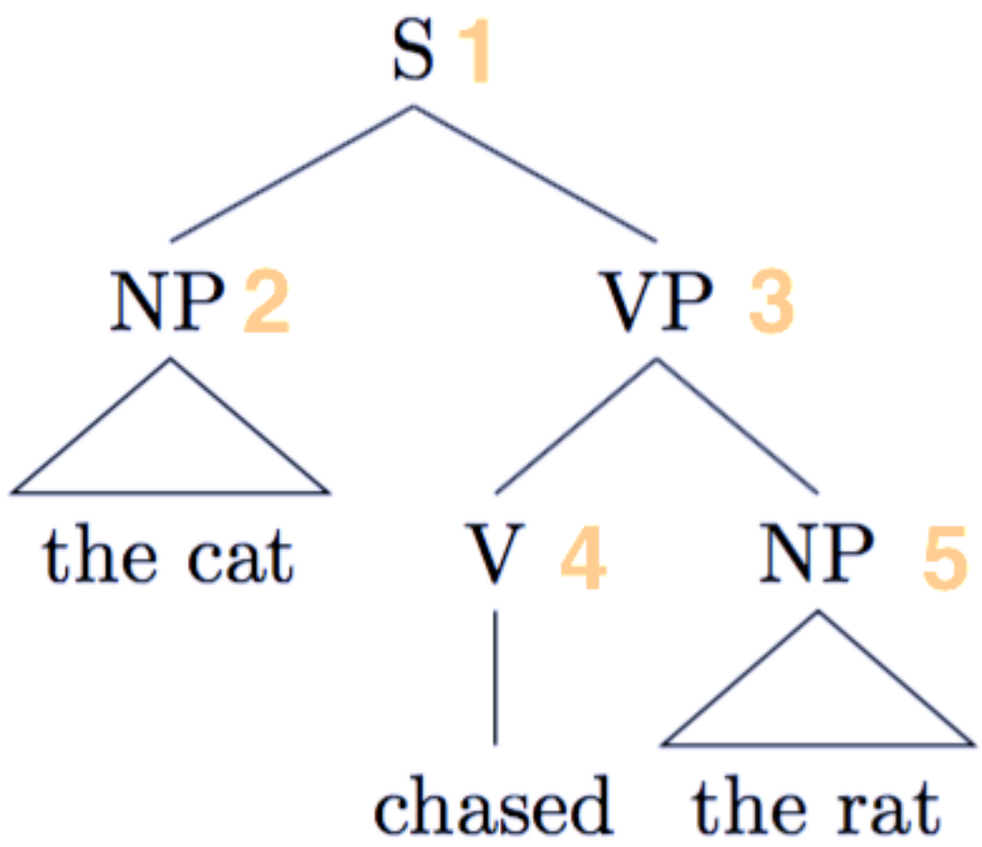
General strategies: Bottom-up

String → Syntactic parse



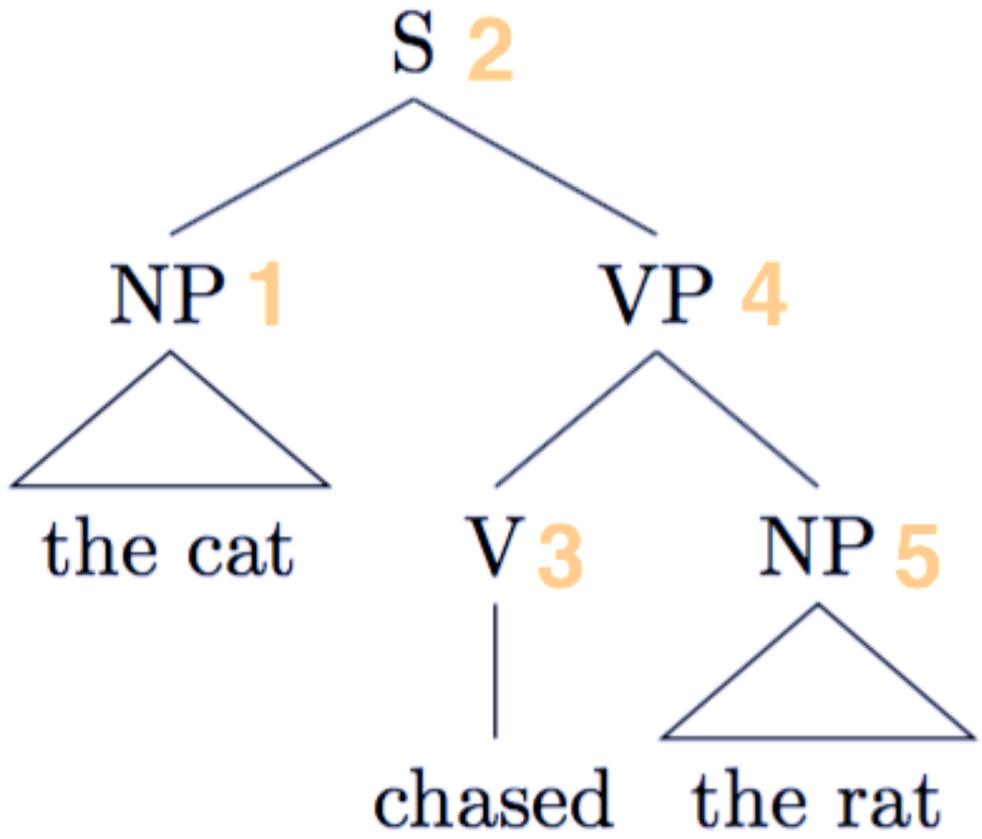
General strategies: Top-down

String → Syntactic parse



General strategies: Left-corner

String → Syntactic parse



Garden path sentences

the horse raced past the barn fell

Garden path sentences

→ **Garden path sentences** are sentences where a listener commits to an incorrect syntactic analysis at an early point in the sentence, which is later disconfirmed at a later point in the sentence. This leads to processing difficulty: a **garden path effect**.

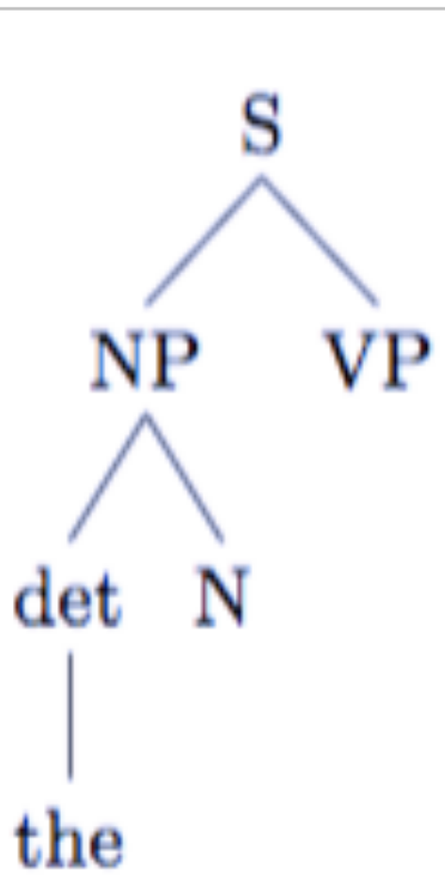
`the horse raced past the barn fell`

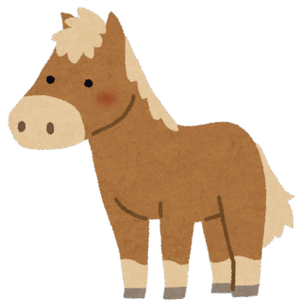
Ambiguous verb

Disambiguation point

Incremental parse

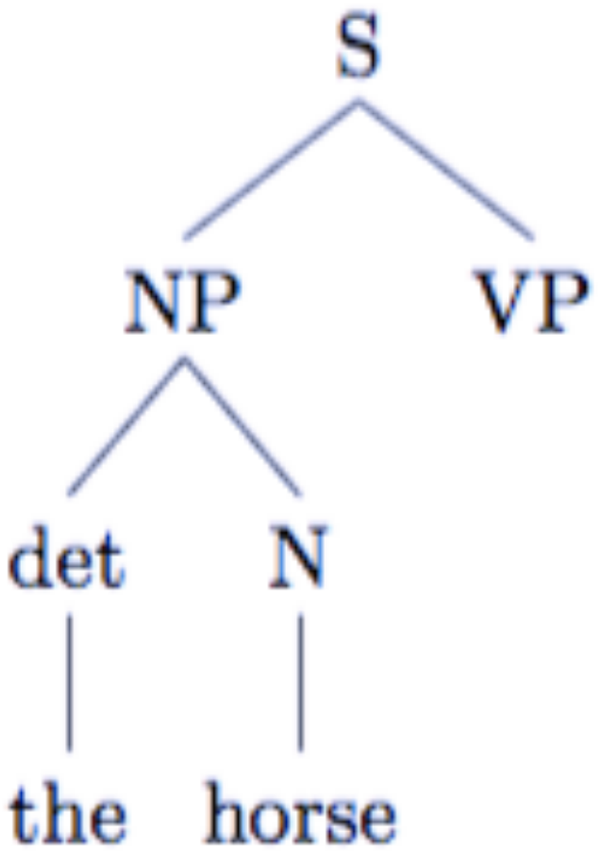
```
the
```

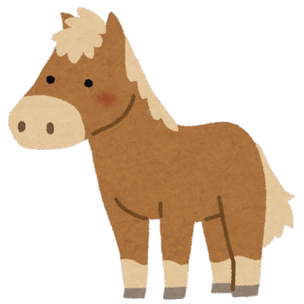




Incremental parse

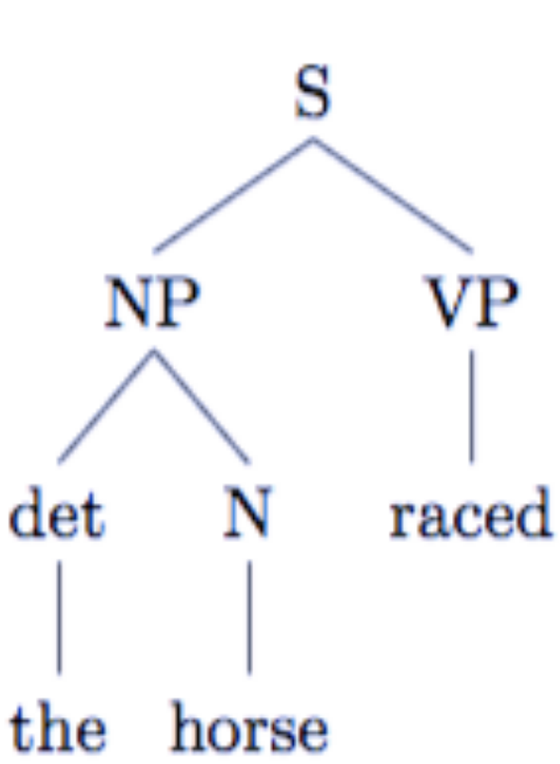
the horse

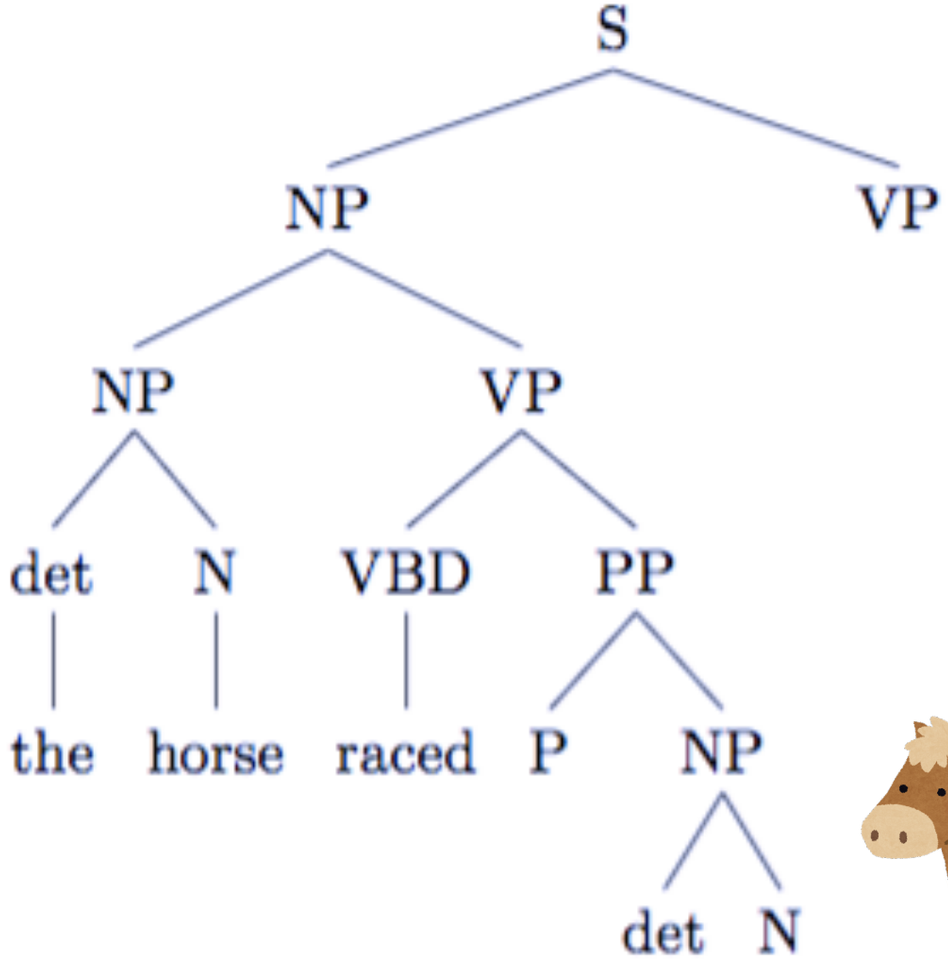


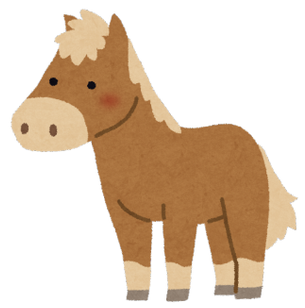


Incremental parse

```
the horse raced
```

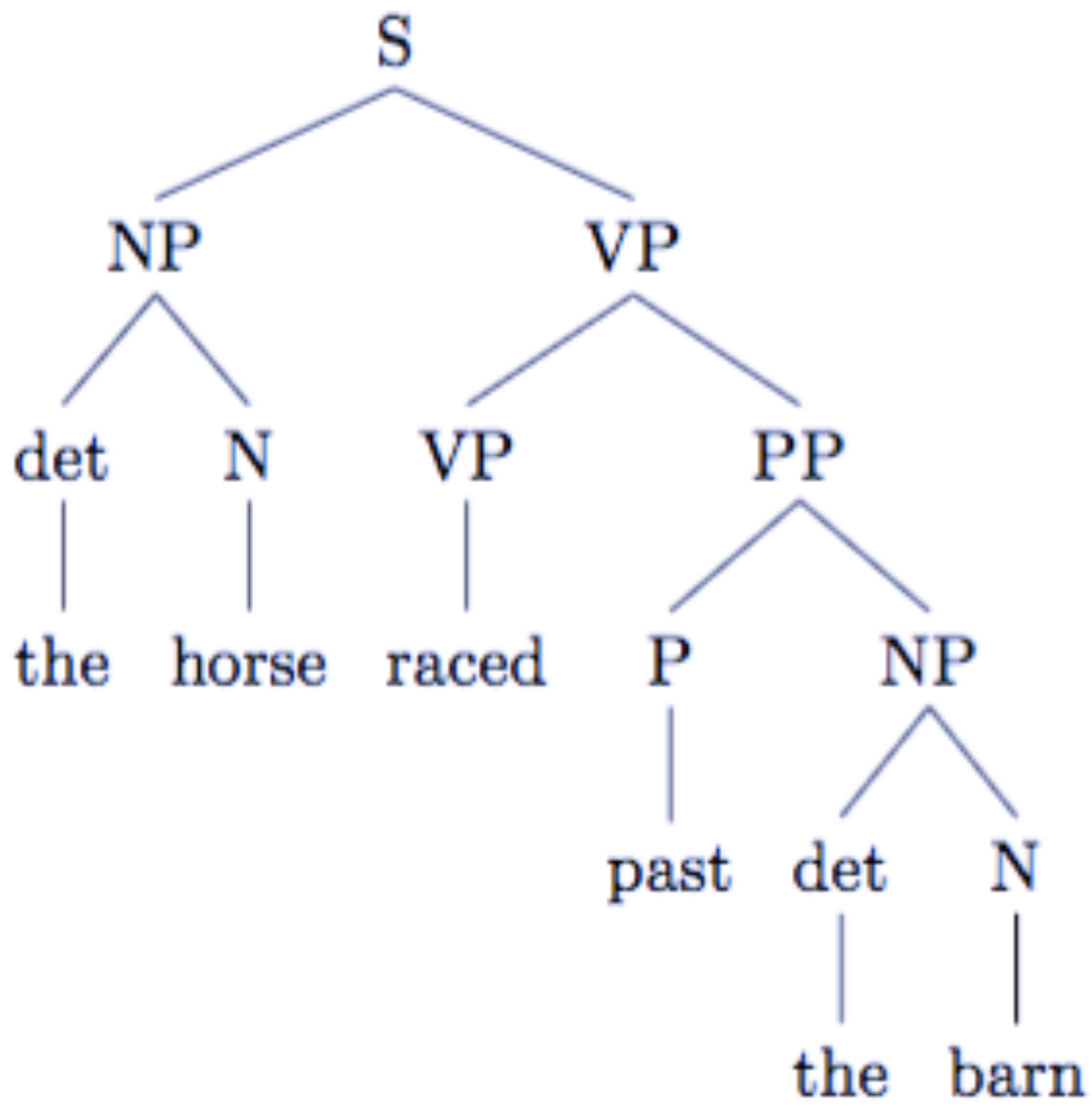


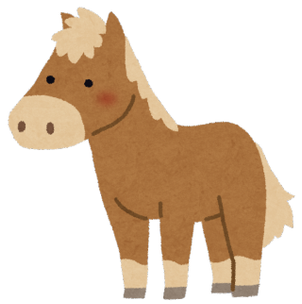




Incremental parse

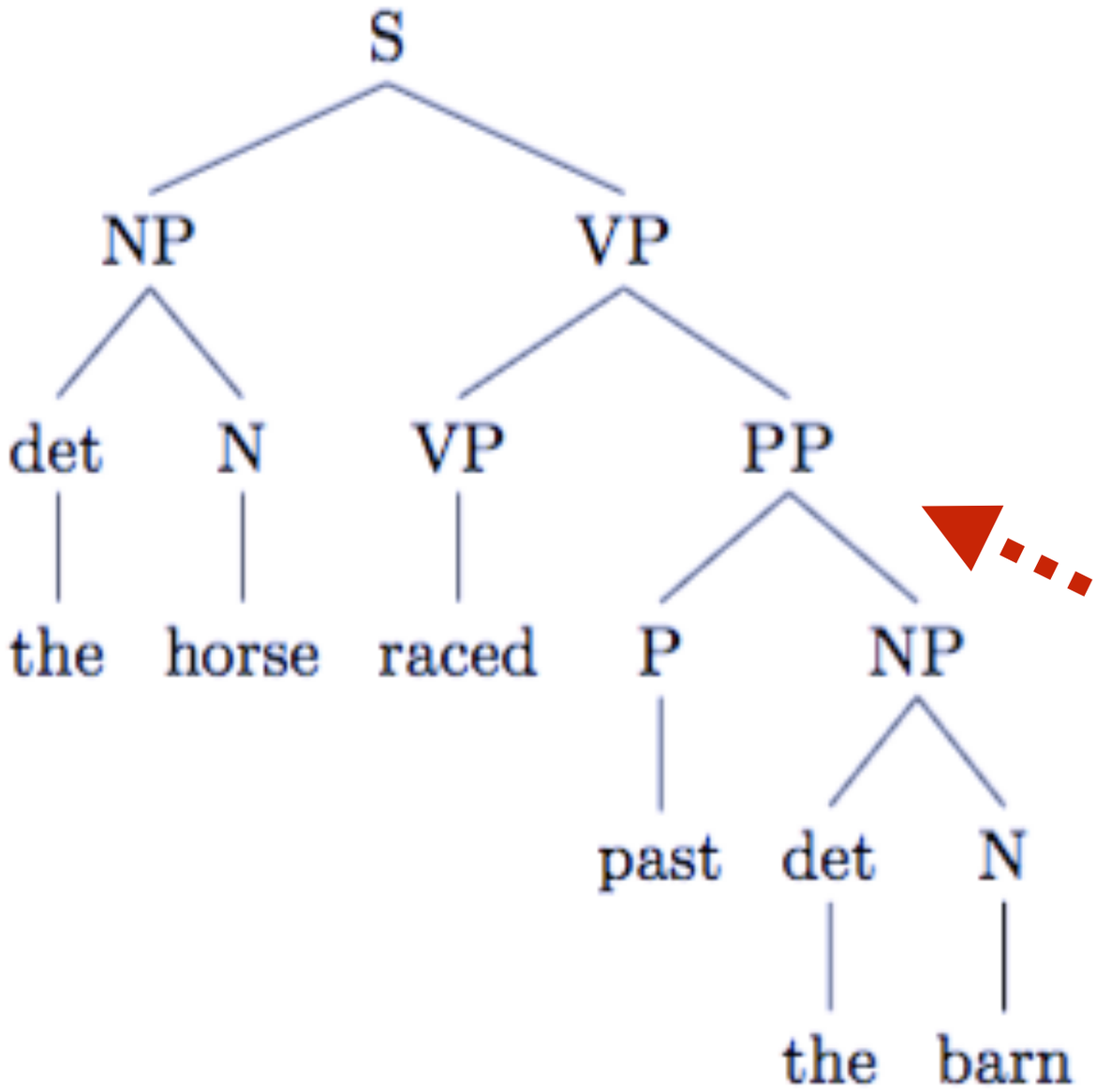
```
the horse raced past the barn
```





Incremental parse

the horse raced past the barn fell

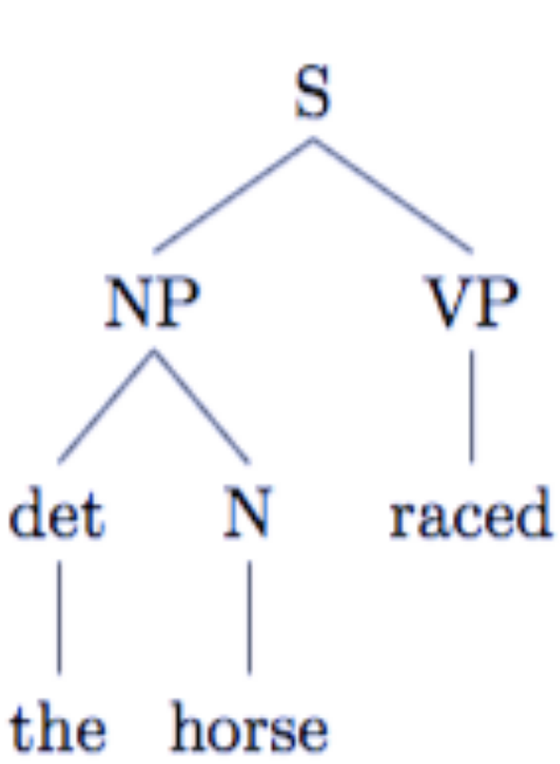


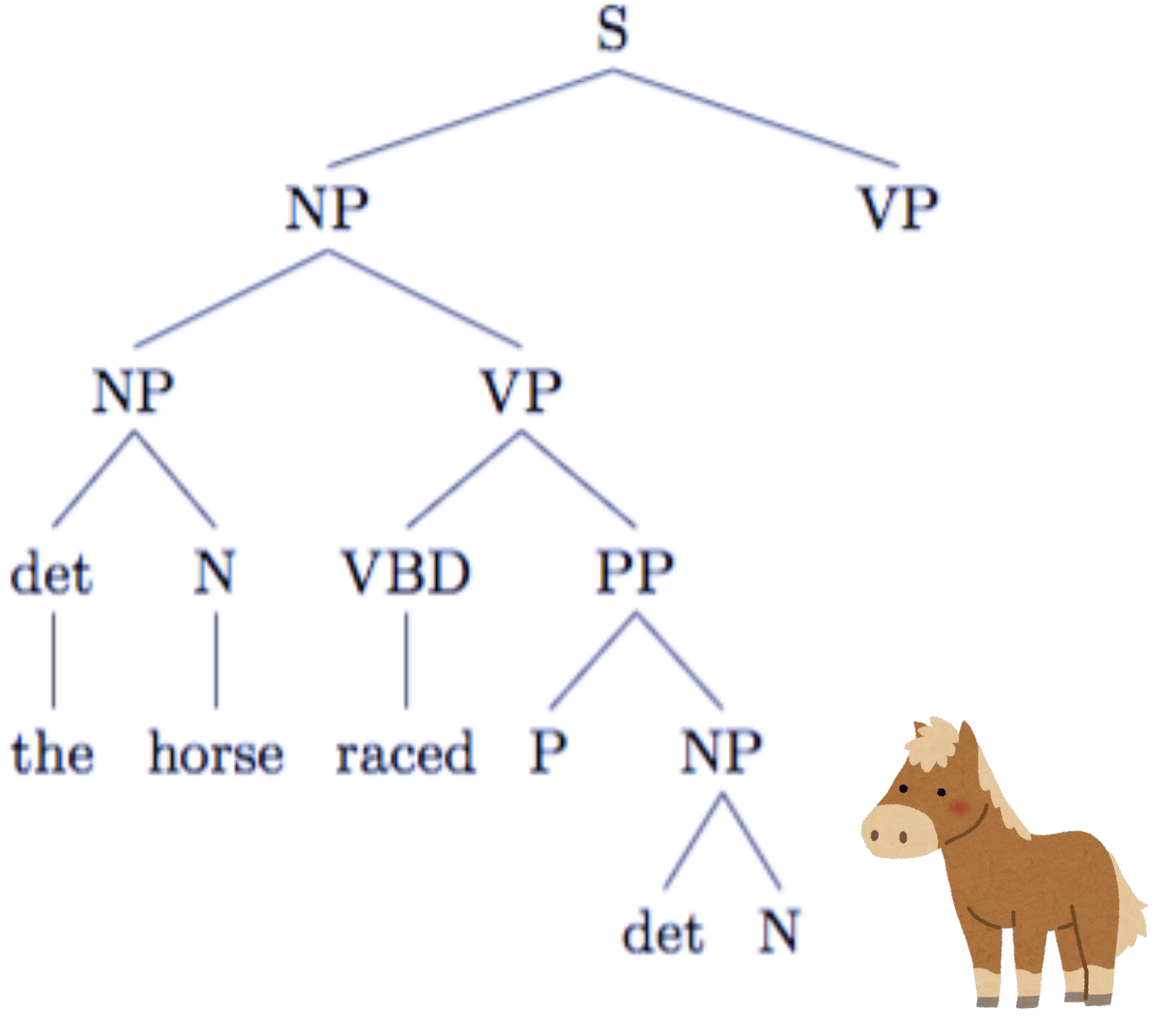
fell

??!!

Incremental parse

```
the horse raced
```





One idea: Garden Path Theory

→ **Garden Path Theory claims**

1) It is difficult to maintain unstructured (i.e. unparsed) words in memory. To conserve memory resources, we must assemble them into a syntactic structure as soon as possible. As an analogy, consider how easy it is to remember a structured phone number compared to a list of 10 random digits. Structure helps!

2) *Therefore, to conserve memory, we are under pressure to parse the incoming words as soon as possible. In doing so, we maintain only a single syntactic analysis of a sentence at a time (**serial or depth-first syntactic analysis**).*

3) *The analysis chosen is the one that is the fastest to compute (**a race model**).*

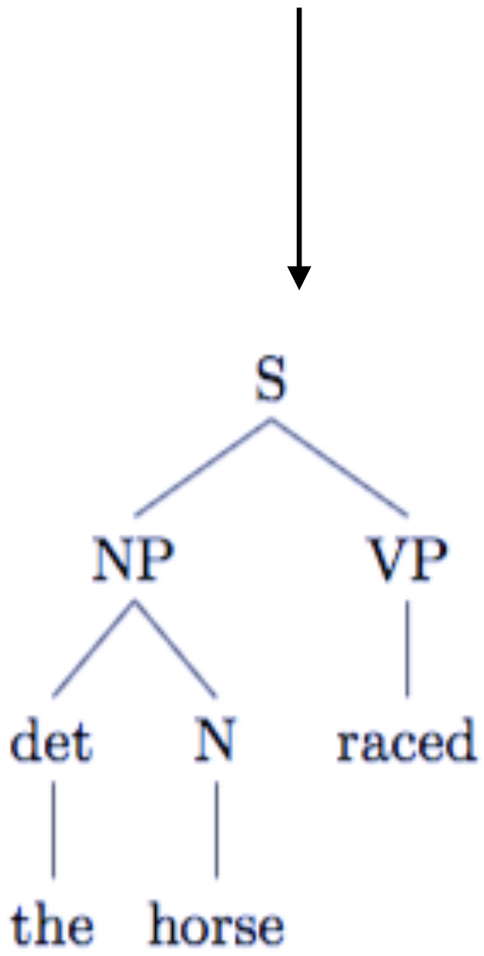
Garden Path Theory derives two principles of syntactic processing from these assumptions:

***Minimal Attachment**: When more than one structure is consistent with the input, build the structure with the fewest nodes.*

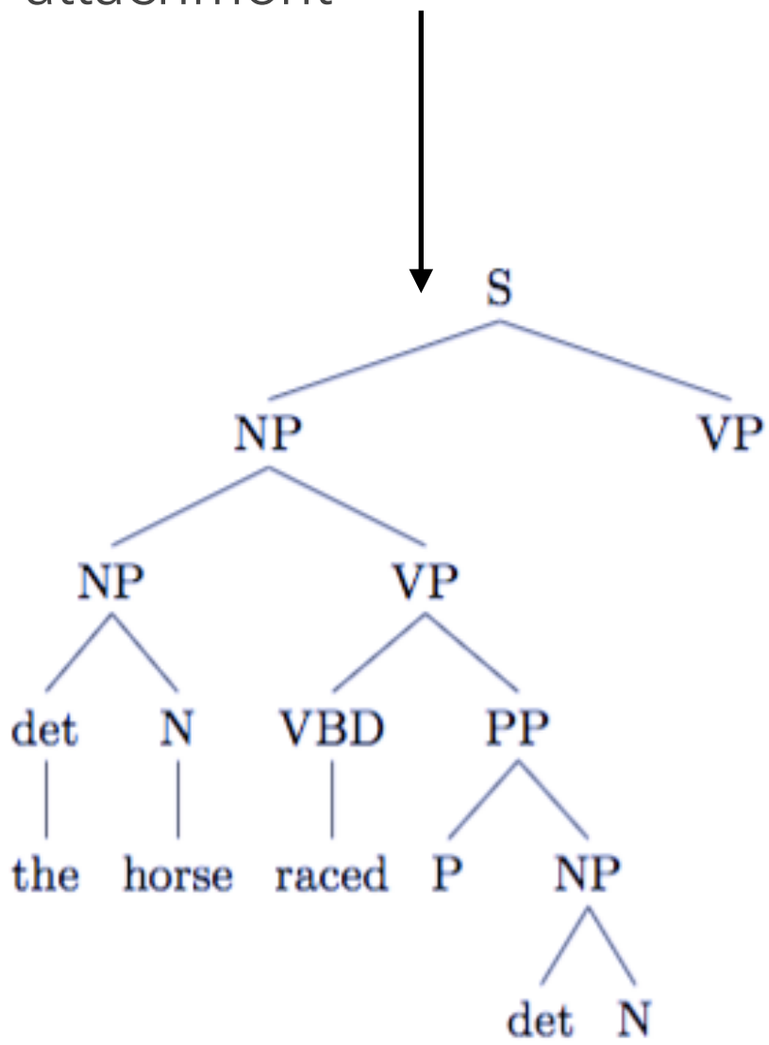
***Late Closure:** If possible, continue to work on the same phrase or clause as long as possible. In other words, do not close off a phrase prematurely.*

Minimal attachment

Fewer nodes; minimal attachment says choose this one

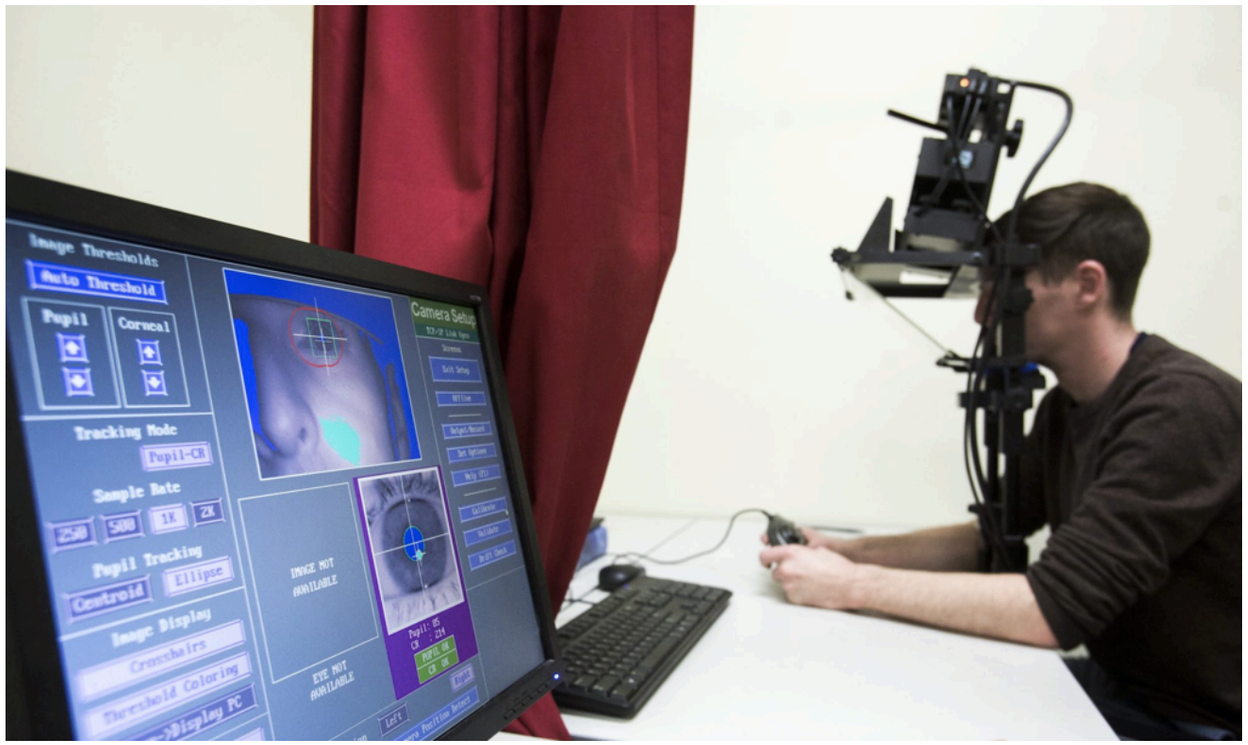


More nodes; not a good choice according to minimal attachment



the horse raced

How to test?



→ **Eyetracking-while-reading** is an experimental paradigm where readers eye movements are monitored as they read text.

Frazier & Rayner (1982)

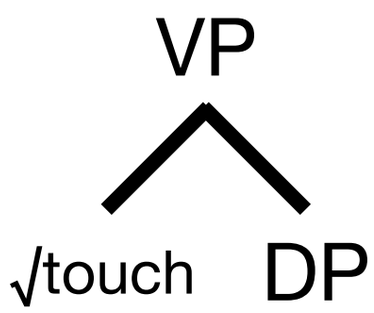
Since Jay always jogs a mile and a half **seems like** a short distance to him.

Since Jay always jogs a mile and a half this **seems like** a short distance to him.

Garden Path Theory in context

Semantic [[touch]]

Syntactic



Lexical /tʌtʃ/

Phonetic

- Generation of parses is feedforward: Grammatical rules have logical priority in the selection of potential syntactic analyses of the input.

- Only one parse at a time is selected, in according with parsing “principles”

- If the parse selected is no longer compatible with input or context - then reanalysis is required.

-> **“Two stage” parsing model.**

Constraint-based parsing

In the 1990's, a major competitor to the Garden Path theory was developed: **constraint-based models** of parsing. Constraint-based models rejected the modular, syntax-first approach of Garden Path theory. Constraint-based models of parsing proposed that sentence comprehension...

... was **interactive**, not modular, involving multiple levels of representation that could freely interact during the course of sentence comprehension.

... used many different sources of information to inform syntactic analysis, such as frequency, plausibility, contextual fit, prosody, and so on.

... proposed that multiple syntactic alternatives could be activated in parallel, and would compete for selection (just as in TRACE).

... were inspired by neural network models (just like TRACE).

Constraint-based parsing

In a constraint-based parser, multiple levels of syntactic and semantic representation are activated when a word is processed, including:

... lexical category

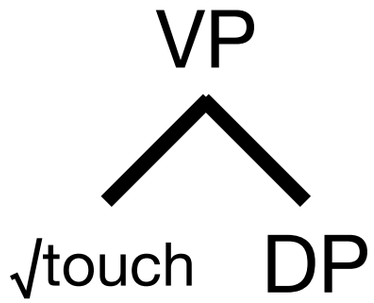
... syntactic structure in the form of 'templates' associated with the word

... thematic roles associated with the word / structure ... semantic features associated with the word

Constraint-based parsing

Semantic [[touch]]

Syntactic



Lexical /tʌtʃ/

Phonetic

- Generation of parses is interactive: Grammatical rules **do not** have logical priority in the selection of potential syntactic analyses of the input. They provide one constraint out of many on interpretation.

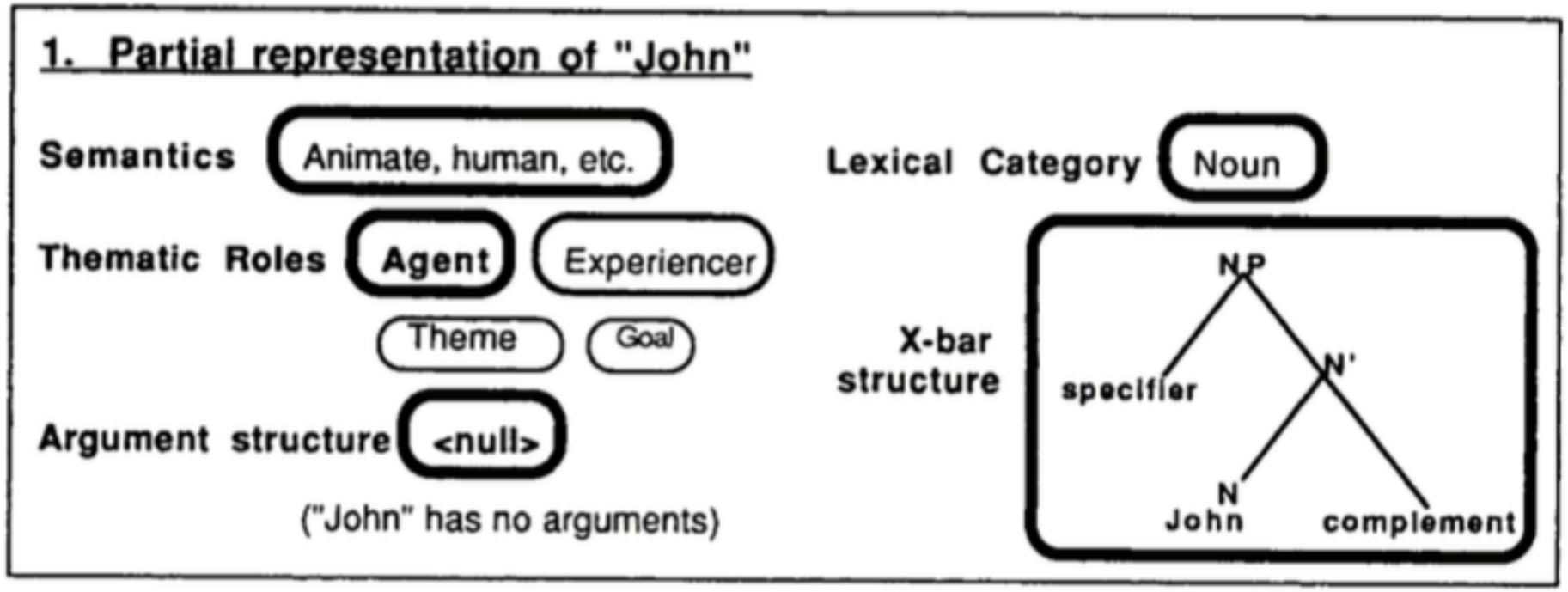
- Multiple alternative parses may be co-activated and evaluated w.r.t. constraints

- If the parse selected is no longer compatible with input or context - then reranking of candidate parse activations occurs.

-> **“Single stage” parsing model.**

MacDonald et al (1994)

John cooked.



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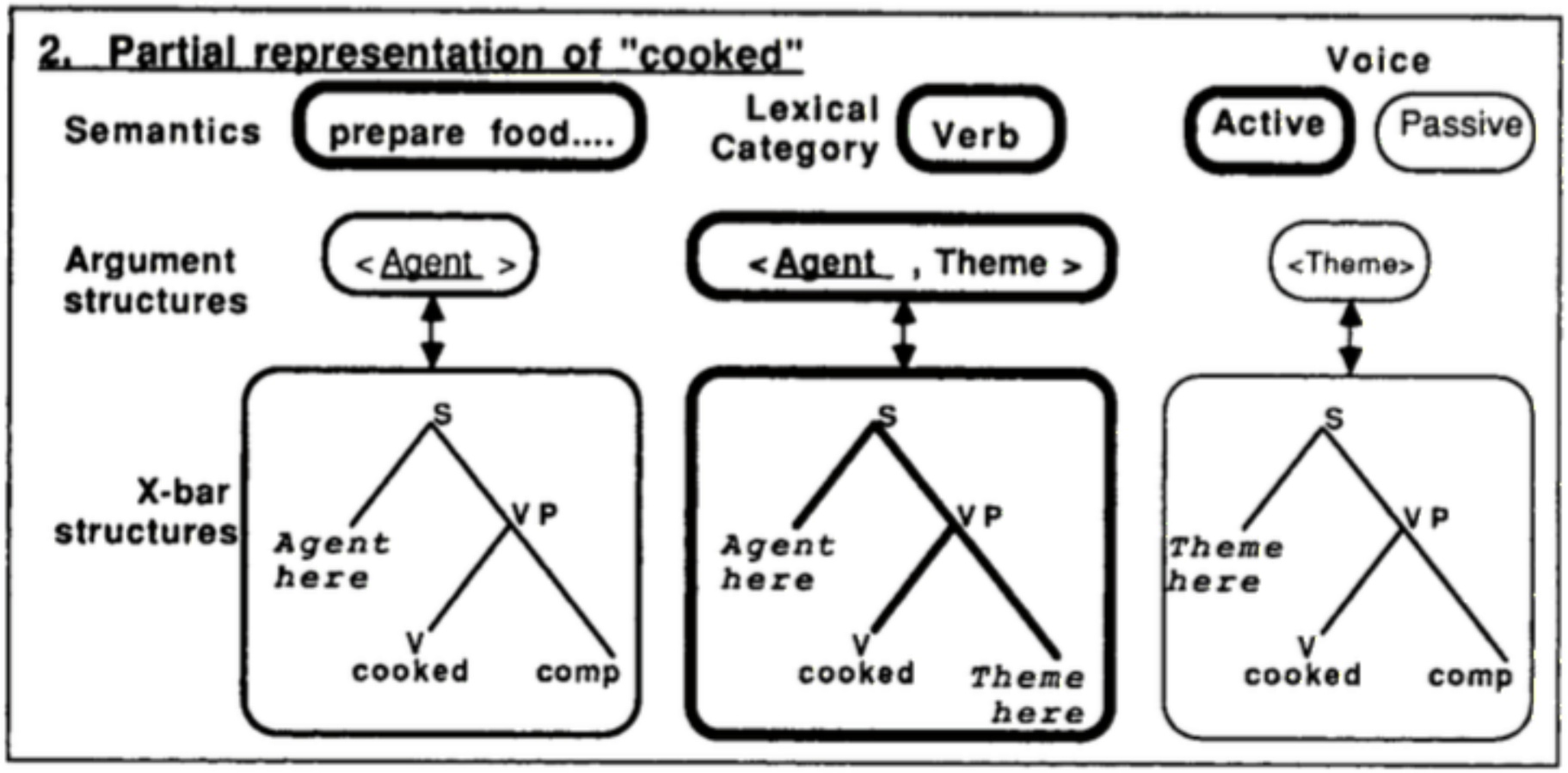

MacDonald et al (1994)

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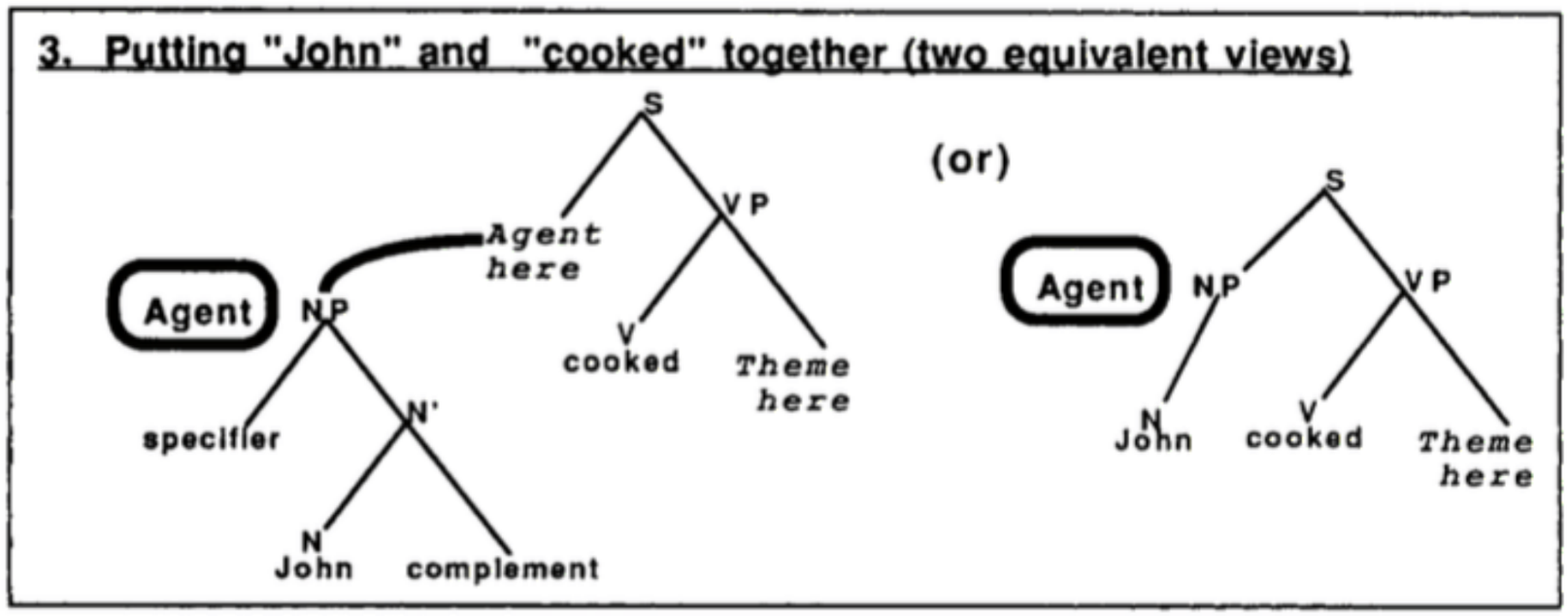
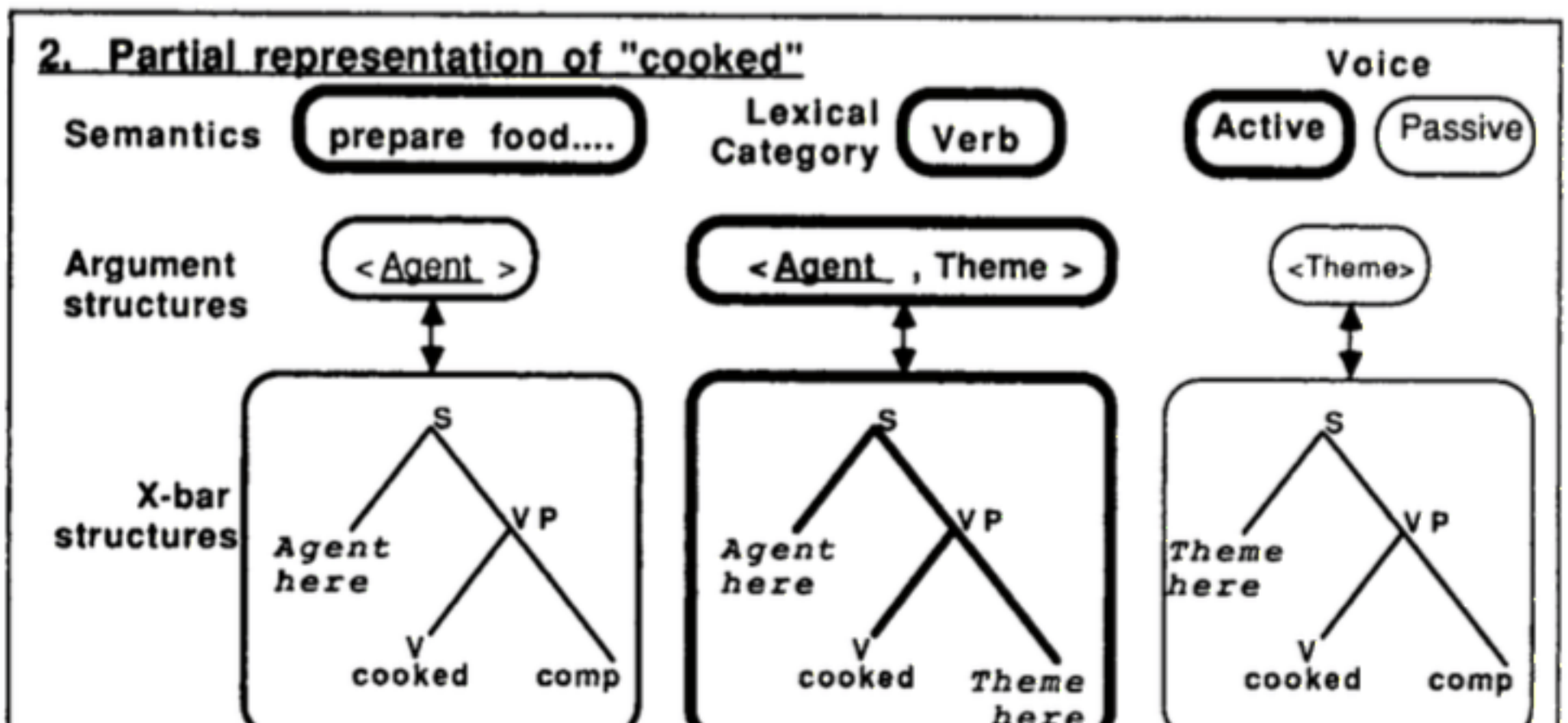


Figure 3. The process of comprehending *John cooked.* Parts 1 and 2 are partial lexical representations of these words. For simplicity, most excitatory and inhibitory connections between components of lexical representations have been omitted from Parts 1 and 2, and some intermediate nodes have been omitted from the verb (V) X-bar structures (e.g., V'). Part 3 shows the linking of X-bar structures and thematic role assignment. A simplified X-bar structure, omitting some nodes, is shown at the right of Part 3. NP = noun phrase; N = noun; VP = verb phrase; comp = complement; S = sentence.

Plausibility vs. the Garden Path

The witness examined by the lawyer was useless.

The evidence examined by the lawyer was useless.



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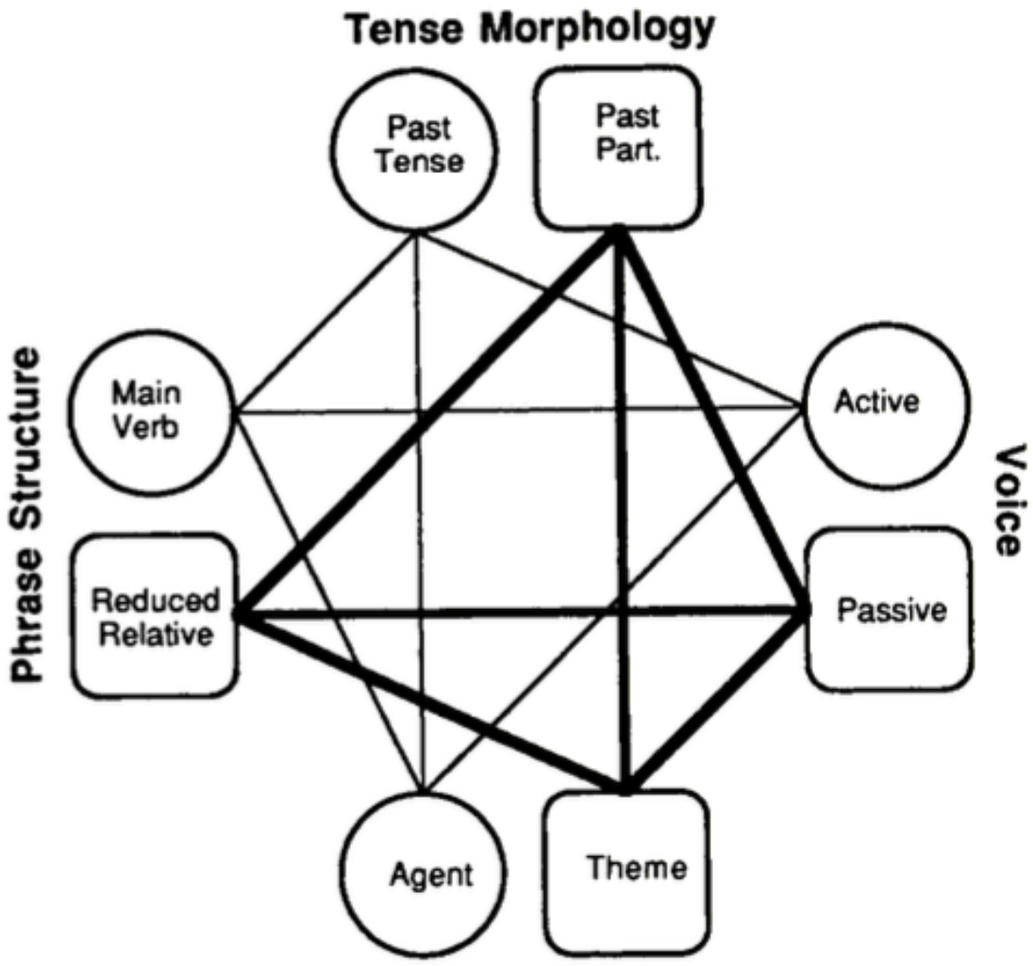


Figure 4. Input properties allowed to co-occur by grammatical constraints. The lines indicate permitted co-occurrences. Thin lines and round nodes correspond to the main verb interpretation; thick lines and square nodes represent the reduced relative interpretation. NP = noun phrase; part = participle.

Trueswell et al. (1994)

Ambiguous items:

The witness examined by the lawyer was useless.

The evidence examined by the lawyer was useless.

Unambiguous control items:

The witness who was examined by the lawyer was useless.

The evidence who was examined by the lawyer was useless.

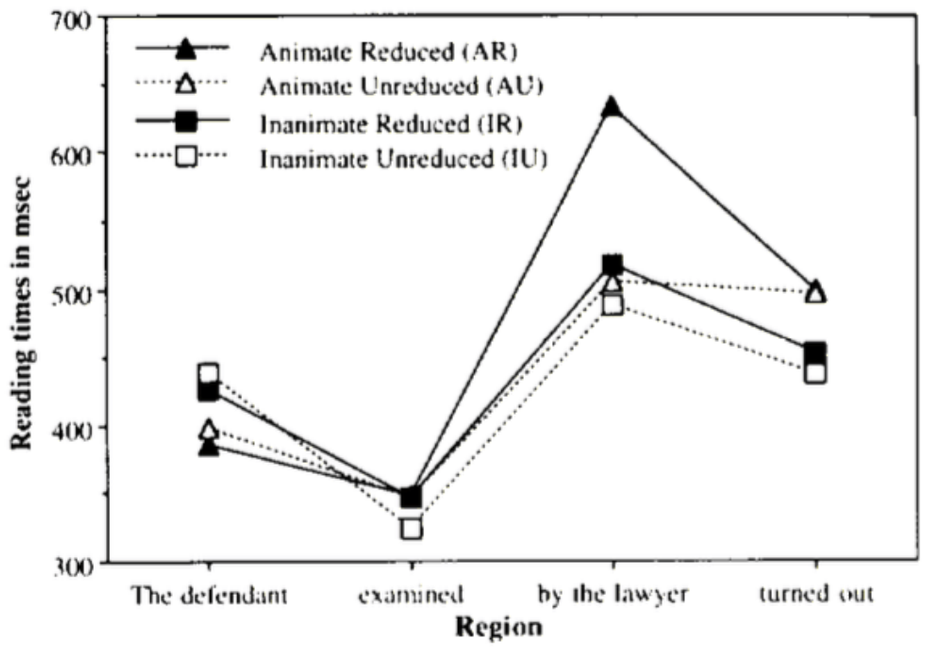


FIG. 3. Mean first pass reading times in ms (Experiment 2).

Clifton et al (2003)

Ambiguous items:

The witness examined by the lawyer was useless.

The evidence examined by the lawyer was useless.

Unambiguous control items:

The witness who was examined by the lawyer was useless.

The evidence who was examined by the lawyer was useless.

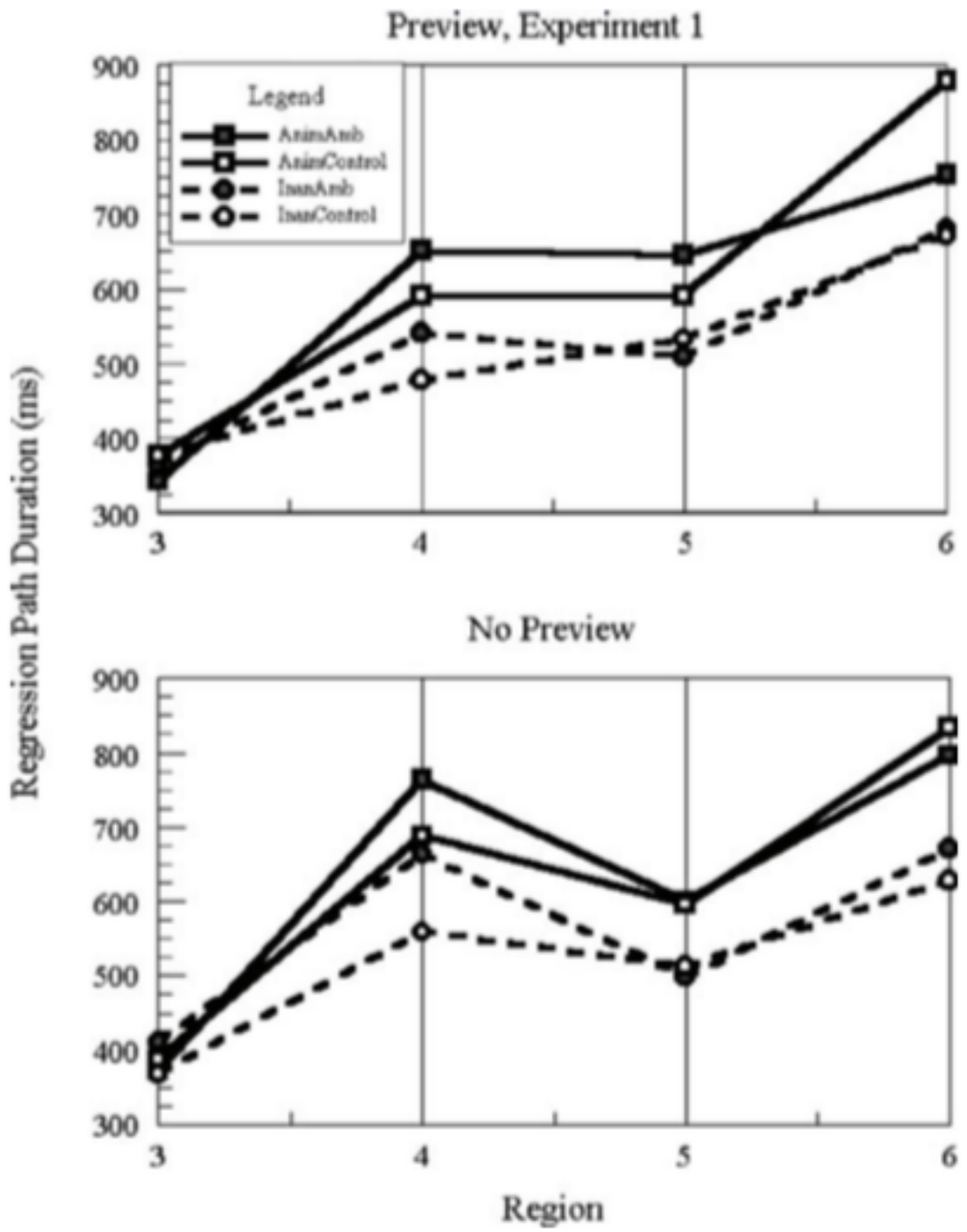
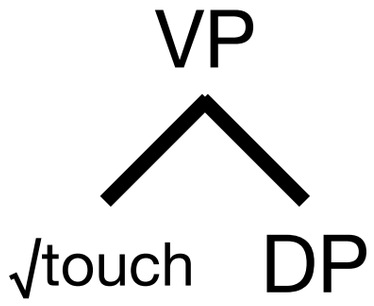


Fig. 1. Regression path durations, Experiment 1.

Interactivity in parsing

Semantic [[touch]]

Syntactic



Lexical /tʌtʃ/

Phonetic

More on constraints and generation

Let's consider the **NP/S ambiguity.**

Verbs subcategorize for different types of complements. This can create other temporary ambiguities: **see** could take a direct object NP, or it could take a full sentential complement:

NP complement: `The student saw [the answer].`

S complement: `The student saw [the answer was in the back of the book].`

More on constraints and generation

There are lots of verbs that allow NP and S complements in English.

NP complement: *`The student wrote [the answer].`*
S complement: `The student wrote [the answer was in the back of the book].`

NP complement: *`The student regretted [the answer].`*
S complement: `The student regretted [the answer was in the back of the book].`

NP complement: *`The student confessed [the answer].`*
S complement: `The student confessed [the answer was in the back of the book].`

Garnsey et al 1997

Individual verbs vary in the frequency with which they take NP and S complement types.

NP BIAS: *wrote* is very strongly biased towards a direct object. Given a sentence fragment like *the student wrote*, participants continued it with an NP continuation 75% of the time, and when they continued it with an S continuation, it almost always had *that* (89%).

NP complement: *`The student wrote [the answer].`*

S complement: *`The student wrote [the answer was in the back of the book].`*

S BIAS: *confessed* is very biased towards a sentential complement. Given a sentence fragment like *the student confessed*, participants continued it with an S continuation 59% of the time, and when they continued it with an S continuation, it less often had *that* (67%).

NP complement: *`The student confessed [the answer].`*

S complement: *`The student confessed [the answer was in the back of the book].`*

Garnsey et al (1997)

Do readers use this statistical information to resolve syntactic ambiguity?

Constraint-based theories say we should *because processing a verb involves activating multiple compatible syntactic structures in parallel, weighted by their frequency.*

Garden Path theory says we should not *because the NP complement structure is always simpler and so should be categorically chosen on every parse.*

Garnsey et al asked if readers slowed down at the disambiguating region in examples like the following:

NP BIAS: *`The student wrote (that) the interview had been interesting.`*

EQ BIAS: *`The student regretted (that) the decision had ever been made.`*

SC BIAS: *`The student confessed (that) the robbery had been planned in advance.`*

Garnsey et al (1997)

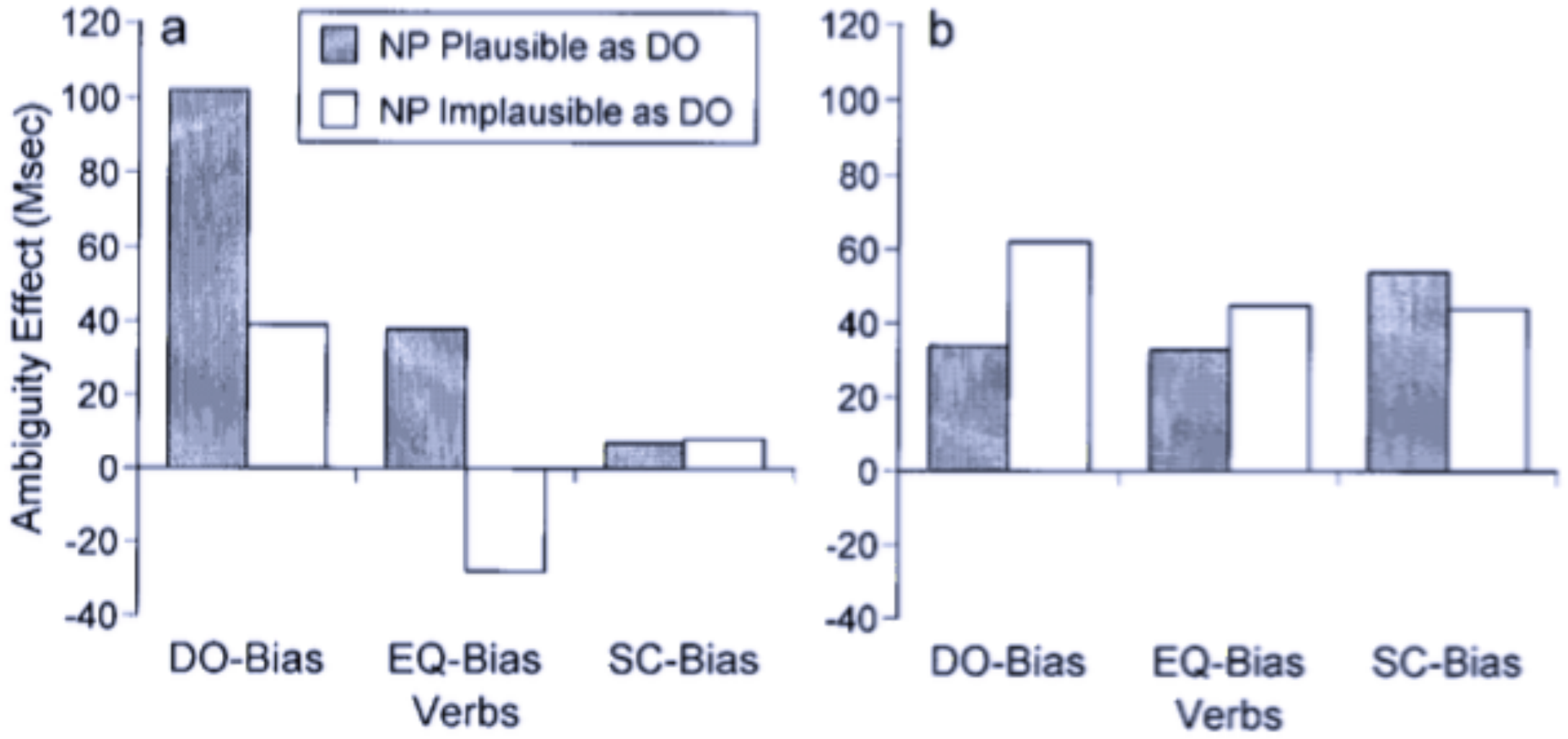


FIG. 2. Ambiguity effects (ambiguous minus unambiguous) at the the disambiguating region (a) and at temporarily ambiguous NP (b) in total reading times in Experiment 1.

Garnsey et al (1997)

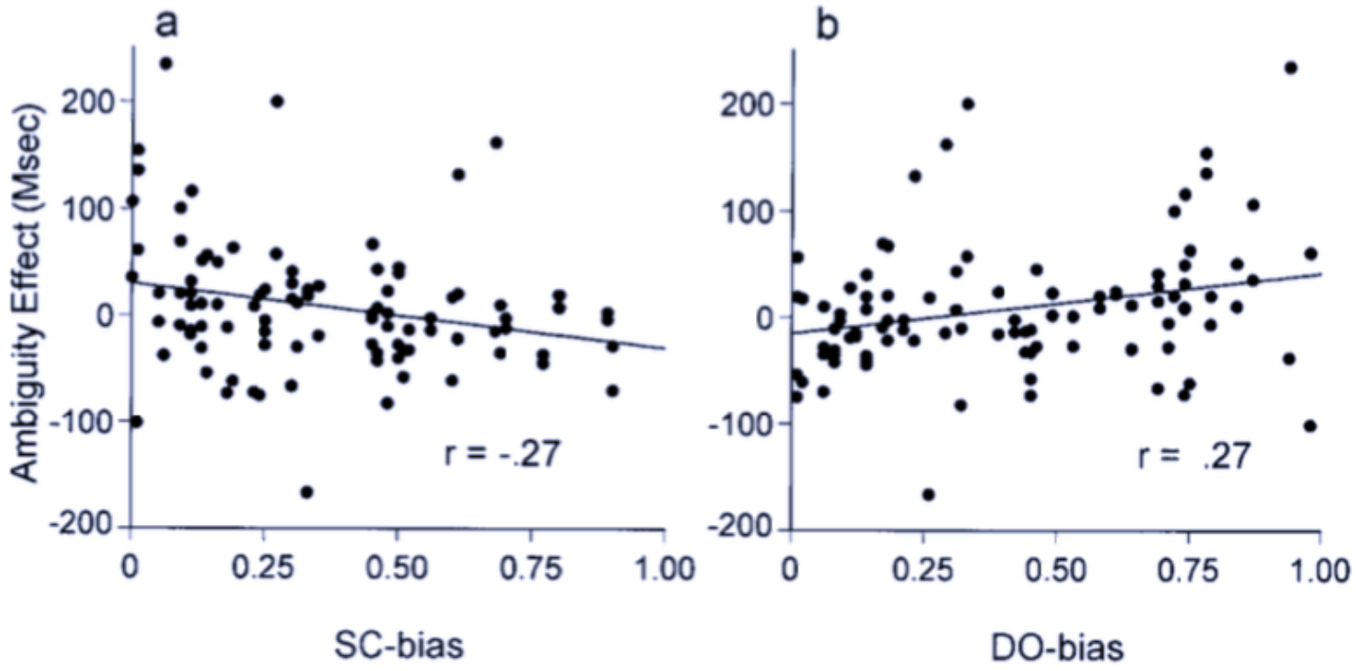


FIG. 3. SC-bias (a) and DO-bias (b) strengths plotted against the ambiguity effect at the disambiguating region in first-pass reading times in Experiment 1 across all items.

Duffy et al. 1988

Slower reading compared to control word (whiskey)

Of course the **pitcher** was forgotten because it was kept on the shelf

Last night the **port** was a great success when she served it

Not slower reading compared to control word (soup)

Duffy et al. 1988

Slowdown reflects competition in meaning

Of course the **pitcher** was forgotten because it was kept on the shelf

Last night the **port** was a great success when she served it

Less of a competition here; not much slowdown.

Duffy et al. 1988

Not slower reading compared to control word (whiskey)

Because it was kept on the back of a high shelf, the **pitcher** was …

When she finally served it to her guests, the **port** was …

Slower reading compared to control word (soup)

Duffy et al. 1988

Context reinforces already dominant meaning. Competition is less acute now.

Because it was kept on the back of a high shelf, the **pitcher** was …

When she finally served it to her guests, the **port** was …

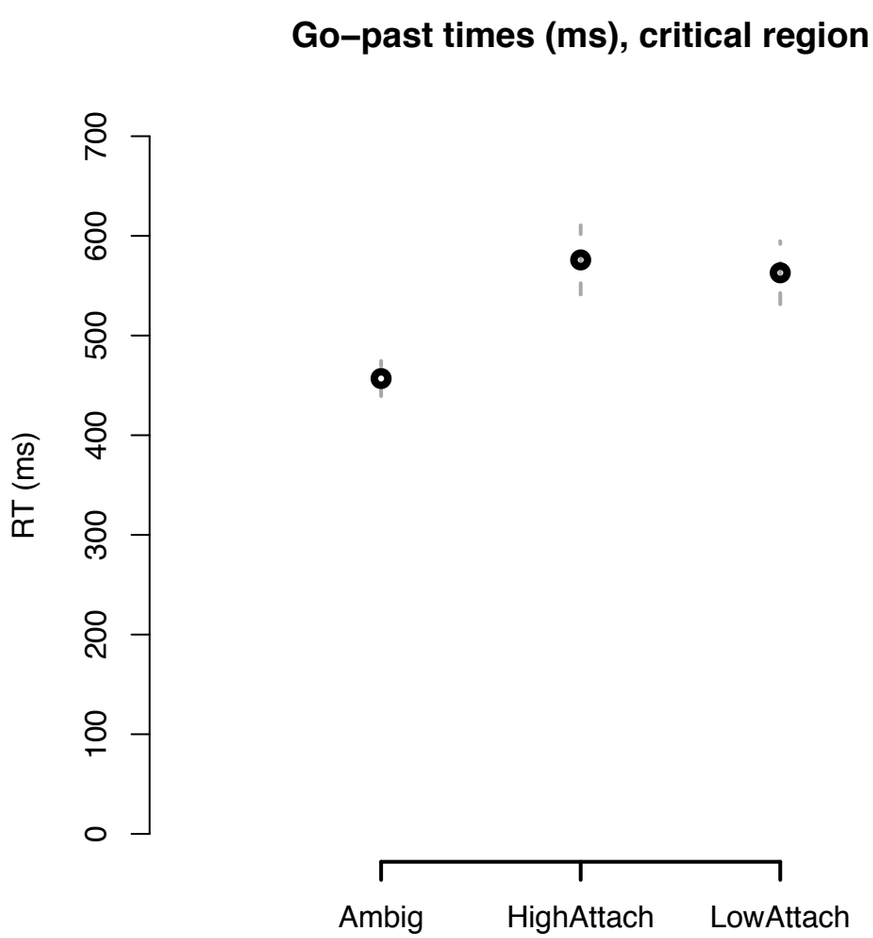
Context makes less dominant meaning more access. Competition is more acute now.

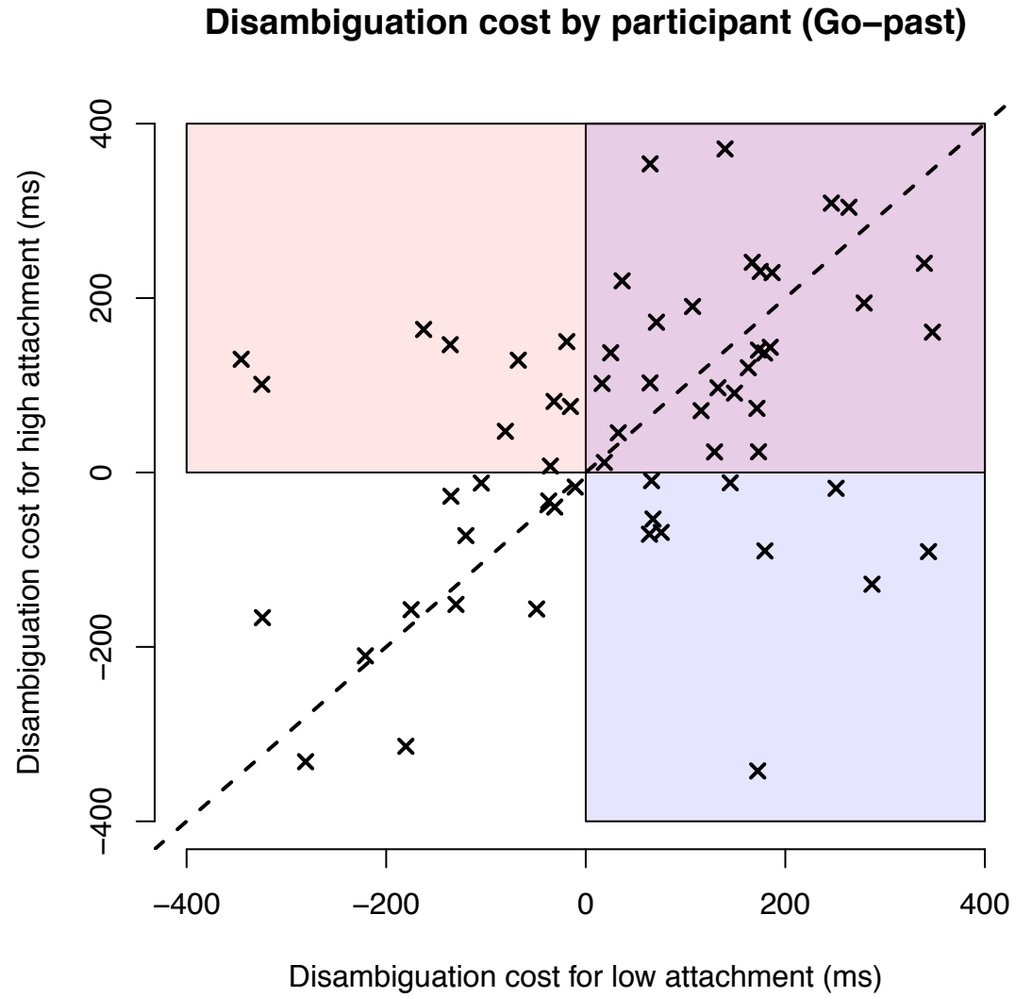
Issues for Classical theories

MULTIMATCH:
If you flipped the channel, you would see the accomplices of the thieves who were indicted for stealing the Mona Lisa.

HIGHMATCH:
If you flipped the channel, you would see the accomplices of the thief who were indicted for stealing the Mona Lisa.

LOWMATCH:
If you flipped the channel, you would see the accomplice of the thieves who were indicted for stealing the Mona Lisa.





Issues for Classical theories

Attachment paradox (Gibson 1991, Hale 2011):

DO: *I gave her earrings on her birthday.*

PD: *I gave her earrings to another girl.*

Gibson (1991) claims these are equally easy to understand - no garden path in either (not tested experimentally as far as I know).