Sentence Processing

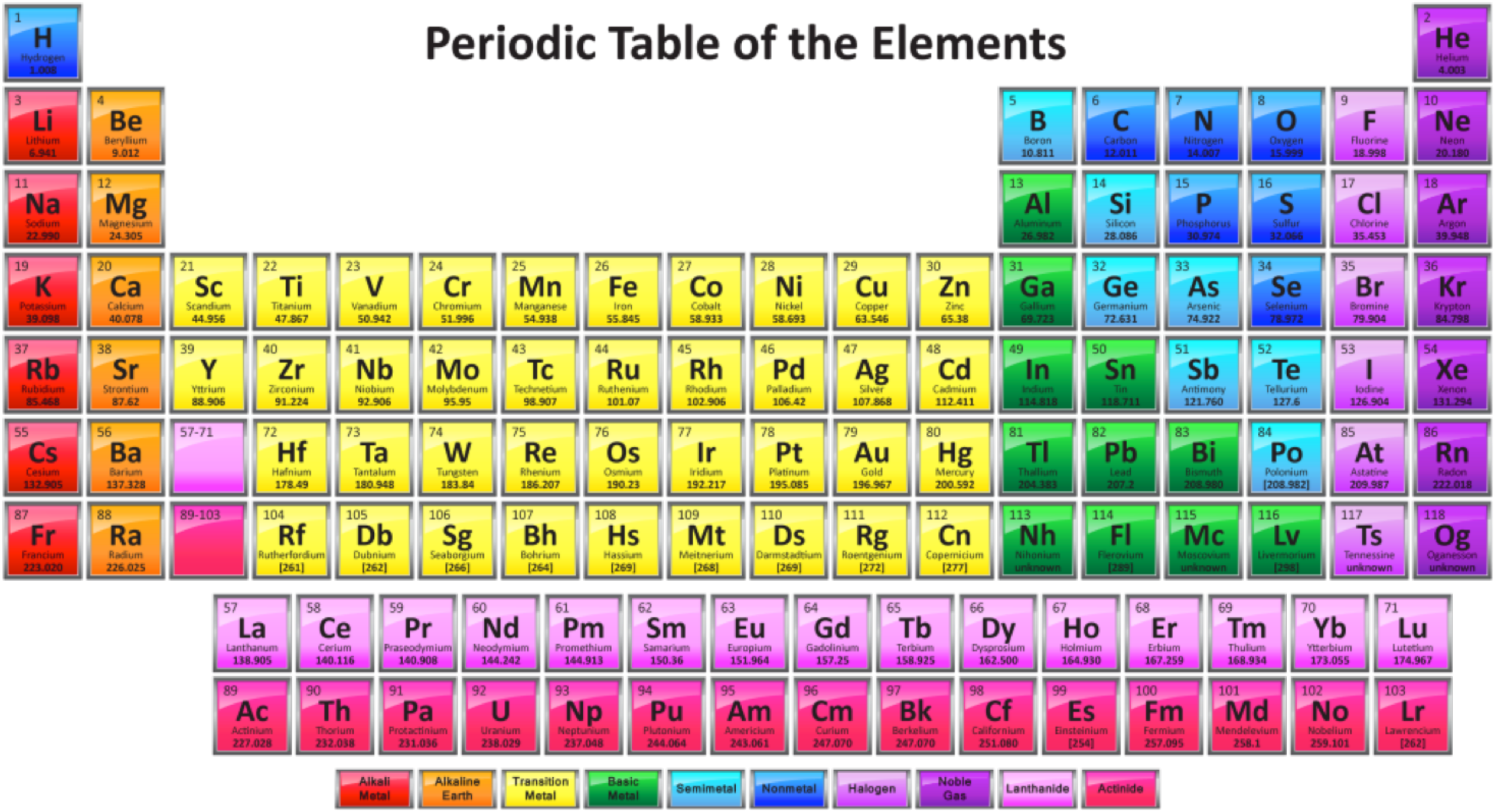
Outline

- Some terminologies/background
- How to address the question of how sentences are comprehended?
- Controversial theories
- Information sources used in sentence comprehension
- The effects of plausibility, lexical frequency, context, working memory in on-line processing

Terminologies

- Compositionality
- Parse/Parsing
- Incrementality
- Phrase structure, Syntactic analysis, Constituent, Node
- Syntactic ambiguity
- Attachment, Minimal attachment
- Modification

Compositionality



Compositionality

- Why **compositionality?**
  - Lexicon
    - N-N compound: *computer screen, car engine, door handle; baby carriage, dog bed, student center …*
  - Phrase structure, syntactic rules
  - Productivity

Compositionality: is the notion that there are fixed rules for combining units of language in terms of their form that result in fixed meaning relationships between the words that are joined together.

- Let's look at two sentences:

A. *It was all because of the lucrative but internationally reviled pink hoodie industry that the president came to abandon his campaign promise to ensure that every household parrot had recourse to free legal counsel.*

B. *Industry ensure because that internationally reviled had legal household parrot was it abandon all pink president every of campaign promise the but lucrative hoodie the came to his to that counsel recourse to free.*

Parse / Parsing

- Why **parse/parsing?**
  - Sentence meanings don't just depend on retrieving pre-stored meanings as word recognition system does;
  - The meaning of each sentence has to be constructed anew;
  - This process of structure-building during comprehension is referred to as parsing;

Parsing: the process of assigning syntactic structure to the incoming words of a sentence during language comprehension. The structure-building mechanisms and procedures collectively are often referred to as "**the parser**"; the term does **not refer to an individual**.

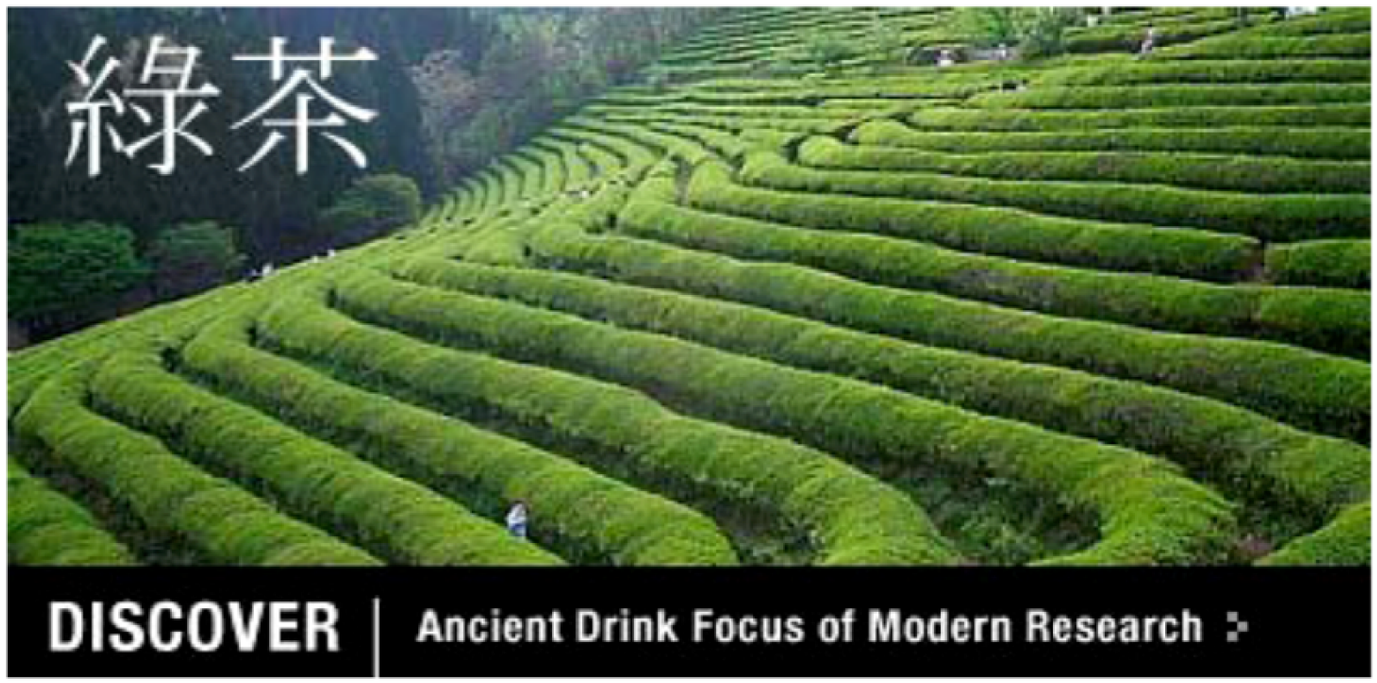
- Questions to contemplate:
  - How long does it take for the parser to build the meaningful structures?
  - Does each word in the sentence have to be uttered and fished out of the hearer's memory first before syntactic grouping and structuring can begin to take place?

Incrementality

- Meaning is built on the "fly" as the speech comes in
  - Evidence from **a shadowing task**
    - https://learninglink.oup.com/access/content/sedivy-2e-student-resources/sedivy2e-chapter-9-web-activity-1?previousFilter=tag_chapter-09
      - people are analyzing the sentence's meaning
      - Not just parroting words or even just the sounds of word

Incrementality: the property of synthesizing and building meaning "on the fly" based on partial information as speech unfolds, rather than delaying processing until some amount of linguistic material has accumulated.

Ambiguity



Adj/N N/V N/V

- **Syntactic category ambiguities:**
  - *Eye drops off shelf*
  - *Squad helps dog bite victim*
  - *He offered the dog meat.*
  - *What this company needs is more intelligent managers.*
- **Attachment ambiguities** (where does propositional phrase go?)
  - *Enraged cow injure farmer with ax*
  - *Two sisters reunite after 18 years at checkout counter*

How to uncover how the language processing mechanism works?

- Find input that the mechanism has little or no difficulty with
  - Easy to process (temporarily) ambiguity
    - *Is the student in the classroom?*
    - *Is the student in the classroom happy?*

- Find input that the mechanism has difficulty with
  - Hard to process (temporarily) ambiguity
    - *The dog walked to the park chewed the bone.*
      - *The dog (that was) walked to the park chewed the bone.*
    - *I put the candy on the table into my mouth.*
      - *I put the candy (that was) on the table into my mouth.*

- How does it work?

Reading methods: Self-paced reading, eye-tracking,
ERP (under the RSVP paradigm)

RSVP (Rapid serial visual presentation) paradigm **demo**

https://www.youtube.com/watch?v=5yddeRrd0hA&ab_channel=MindfulThinks

Self-paced Reading paradigm **demo**

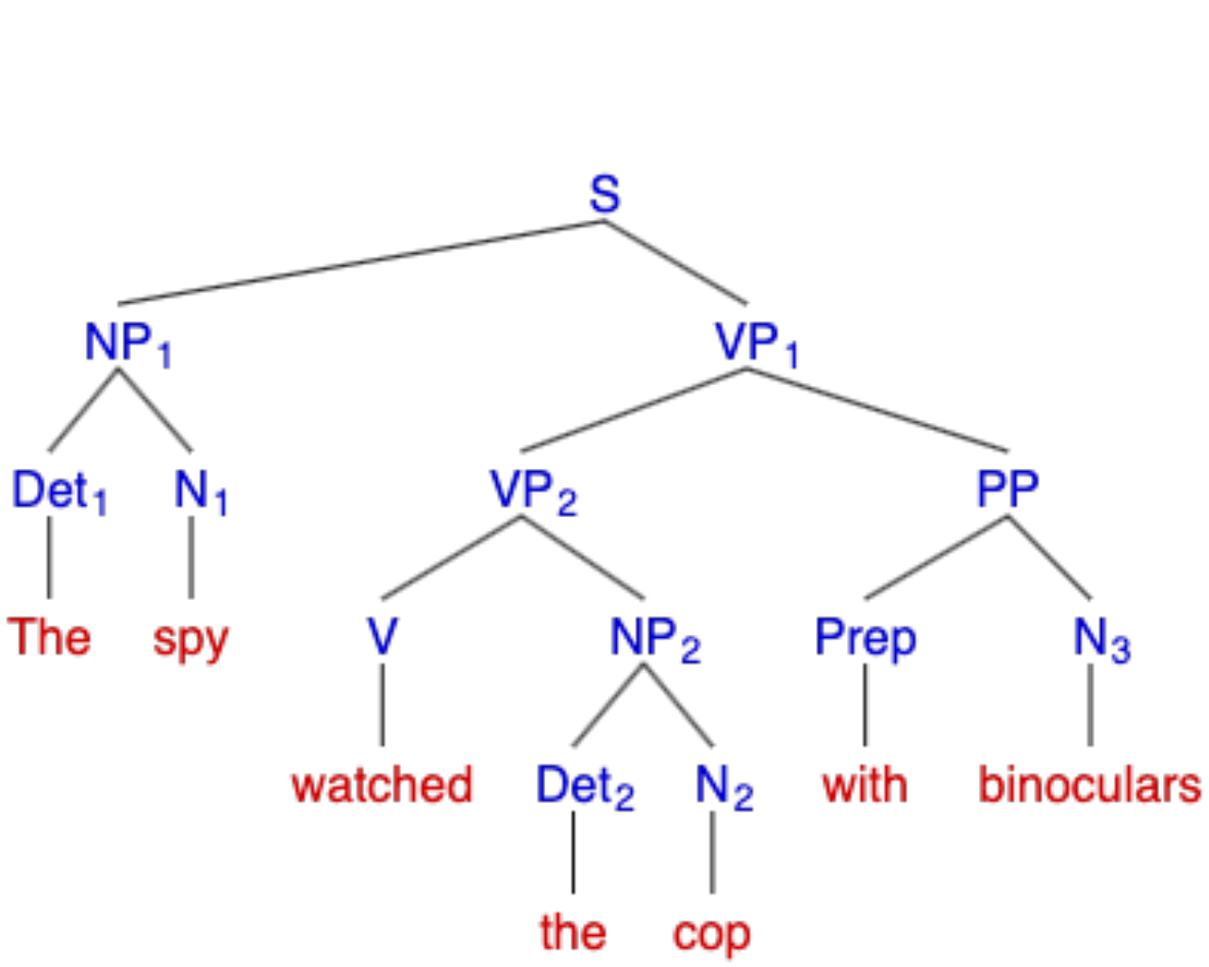
How do people comprehend sentences?

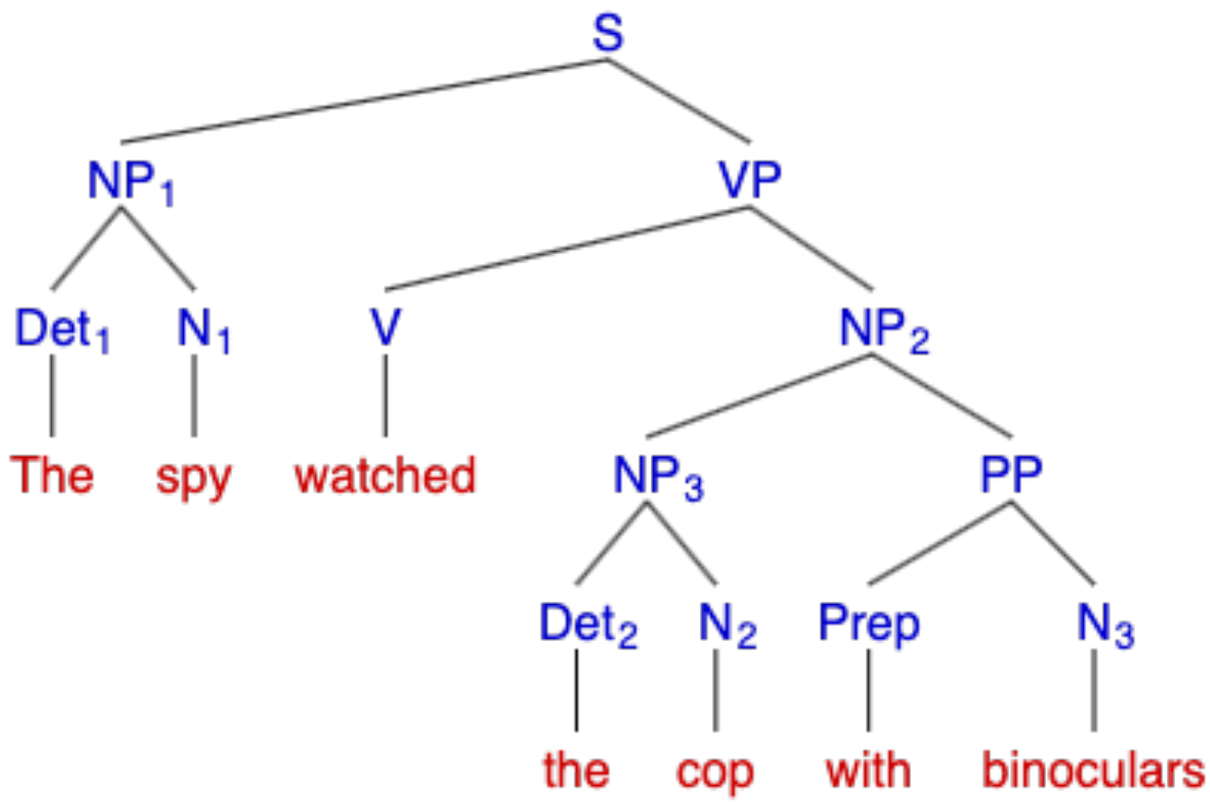
- let’s try two sentences…

- … a multi-step process:
  - Step 1: recognition of word form
  - Step2: access of other aspects of lexical item, e.g syntactic information (N, V, etc... and meaning)
  - Step 3: integrate lexical meaning into ongoing sentence meaning & integrate lexical syntax into ongoing sentence syntax

How does “parsing” work?

Words are input. Organization into a hierarchical structure…



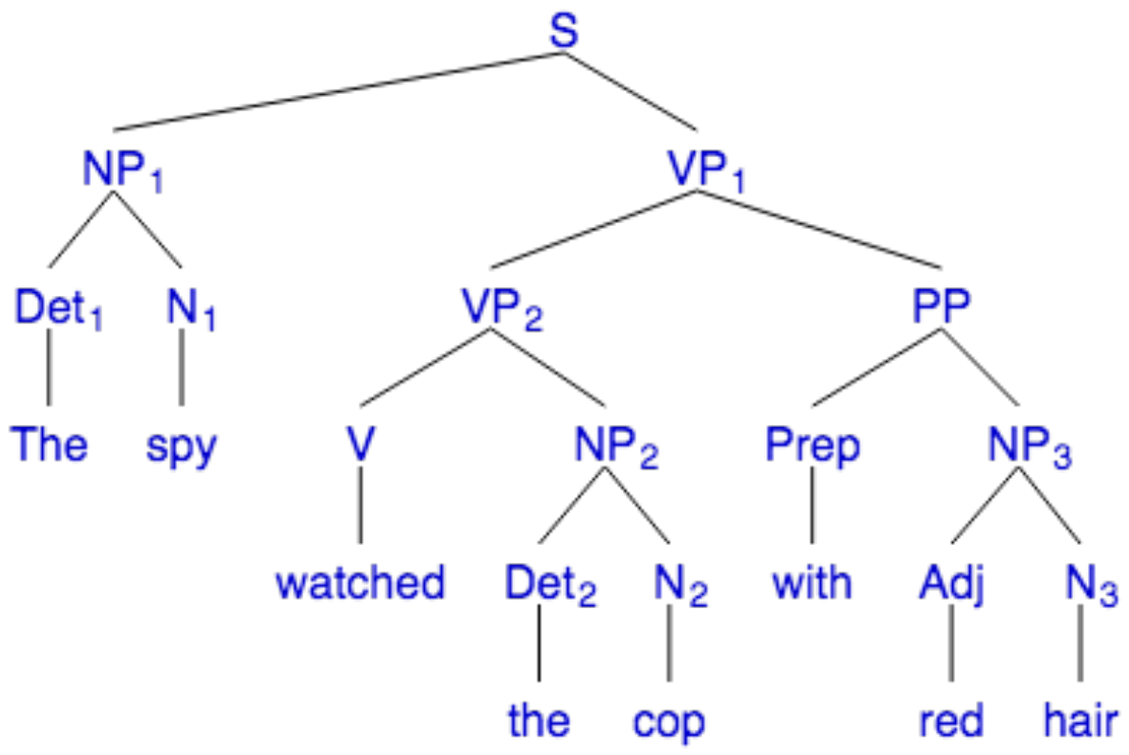


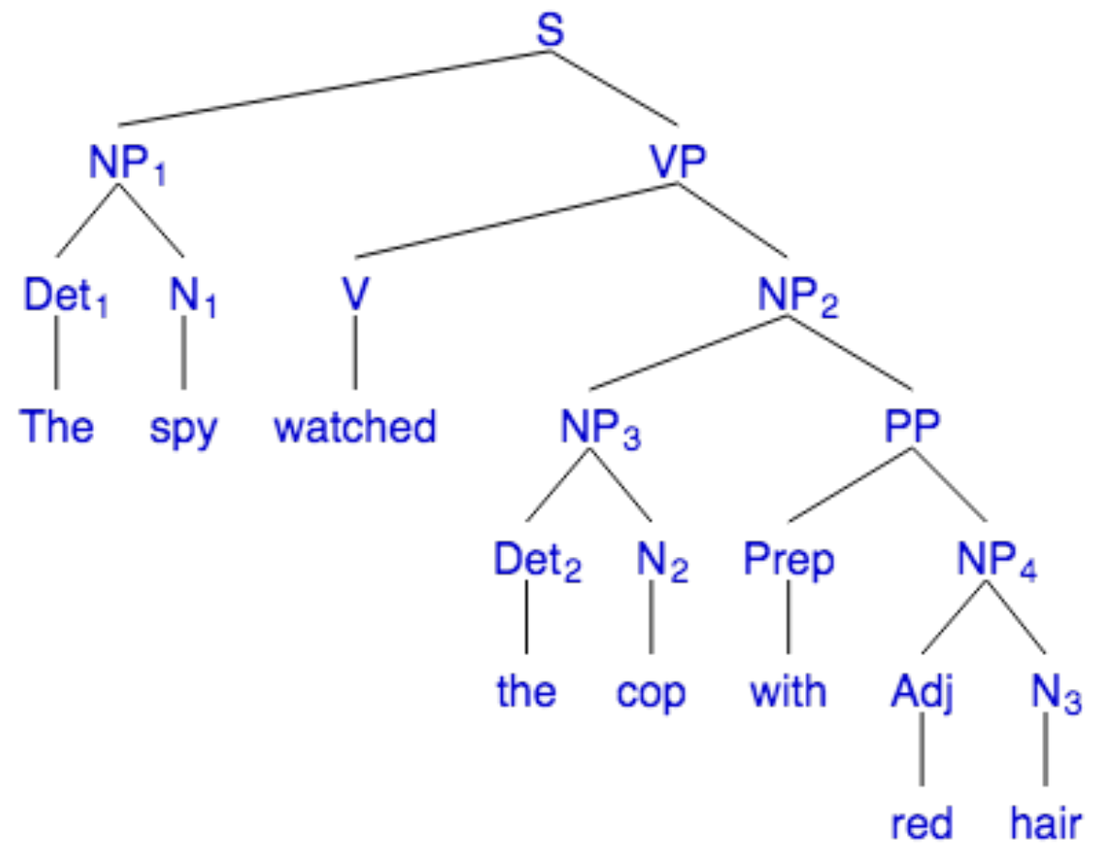
The spy watched the cop with binoculars.

How does “parsing” work?

Words are input. Organization into a hierarchical structure…

The spy watched the cop with red hair.





How does “parsing” work?

… The spy watched the cop with…

1. **Word recognised**, then information relevant to sentence comprehension available to sentence-level processes.

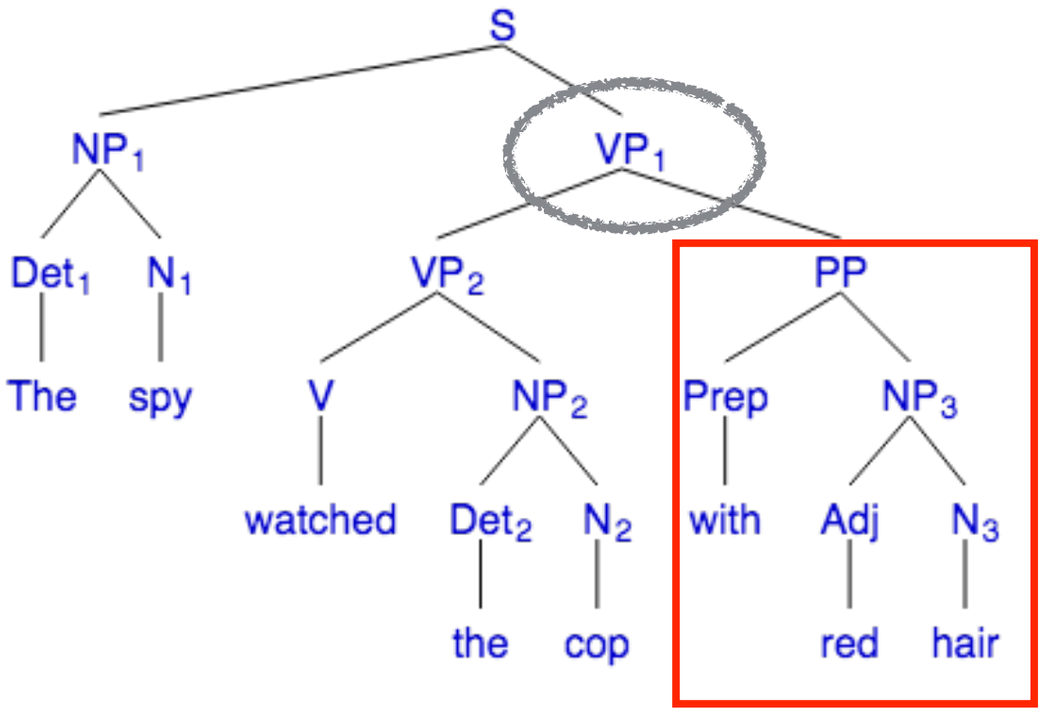
   - Such info. could include:

     - grammatical category (e.g., N, V, D (determiner), etc.)
     - subcategory information (e.g. V takes NP as object)
     - semantics
     - possible functional role (animate Ns are possible agents, etc…)
     - frequency info., co-occurrences info., probability info.

2. **Items grouped together** (into phrases/“constituents”, such as NPs, VPs, etc…)

3. **Incoming words attached into structure** (parse tree) currently being built.

How does “parsing” work?

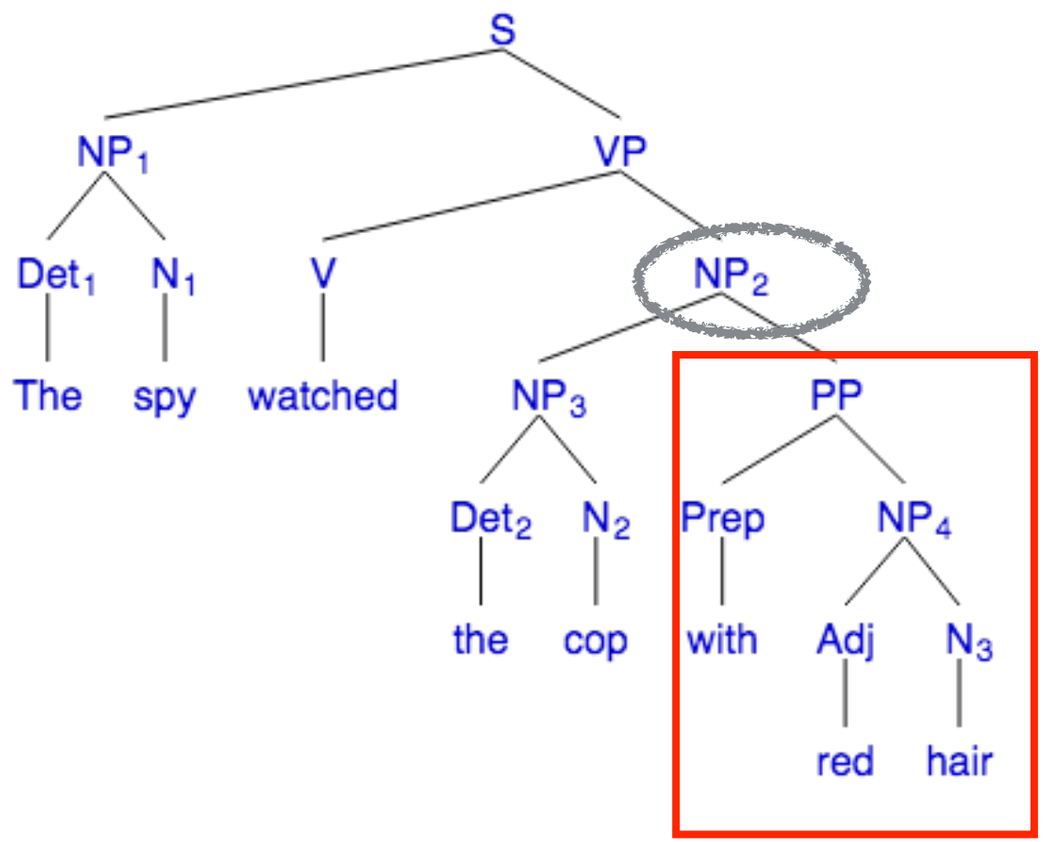


The spy watched the cop with red hair.

Initial syntactic analysis: “*with*...” part of a PP. Attach PP directly into VP.

NP “*red hair*” part of PP attached directly into VP.

BUT this syntactic analysis produces semantic anomaly (you can't watch with red hair).



Must reanalyze the structure of the sentence so that the PP is no longer directly associated with the verb.

=> **Garden path sentence**. Initial analysis (which later turns out to be wrong) led the perceiver “down the garden path”.

How does “parsing” work?

Big PROBLEM for a parser is that input is often ambiguous, often multiple attachments possible.

AND often have to make an attachment decision before all the crucial information becomes available.

- **Main point of contention:** What kind of information informs how new input is attached.

How does “parsing” work?

- Two controversial theories of ambiguity resolution

Garden-path Theory: a theory of parsing that claims that an initial “first-pass” structure is built during comprehension using a restricted amount of grammatical information and guided by certain parsing principles or tendencies, such as the tendency to build the simplest structure possible. Evaluation of plausible meanings or consideration of the context only come into play at a later stage of parsing.

The constraint-based approach: the main competitor to the garden path theory, this approach claims that multiple interpretations of an ambiguous structure are simultaneously evaluated against a broad range of information sources (or constraints) that can affect the parser’s early decisions.

How does “parsing” work?

Garden-Path Model (Frazier & colleagues)

“2 pass/stage” parser: syntactic information first, discourse and semantic information becomes available later.

- ***In the first pass:***

1.Serial parse (compute only one structure at a time)

2. Attach incoming words into ongoing structure immediately

3. Only syntactic information available

Syntactic Analysis dictated by Parsing Strategies that are syntactic in nature.

- ***In the second pass:***

Semantic assessment of first pass parse. Revision may be necessary.

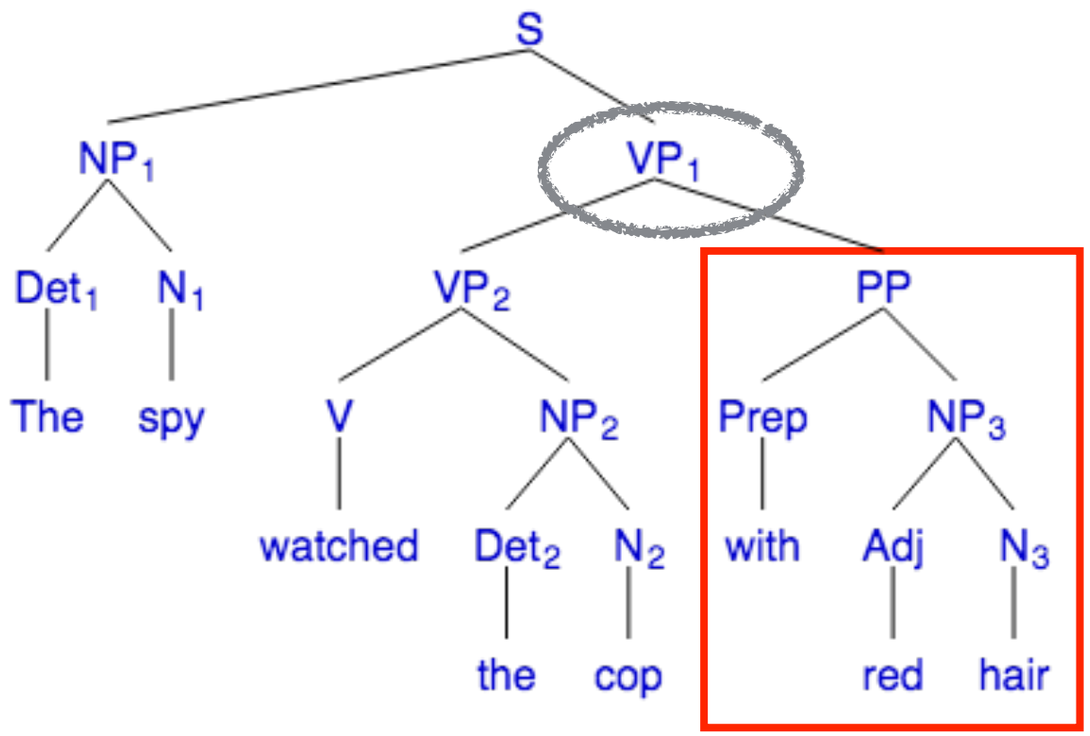
How does “parsing” work?

Parsing Strategies that dictate parsing decisions:

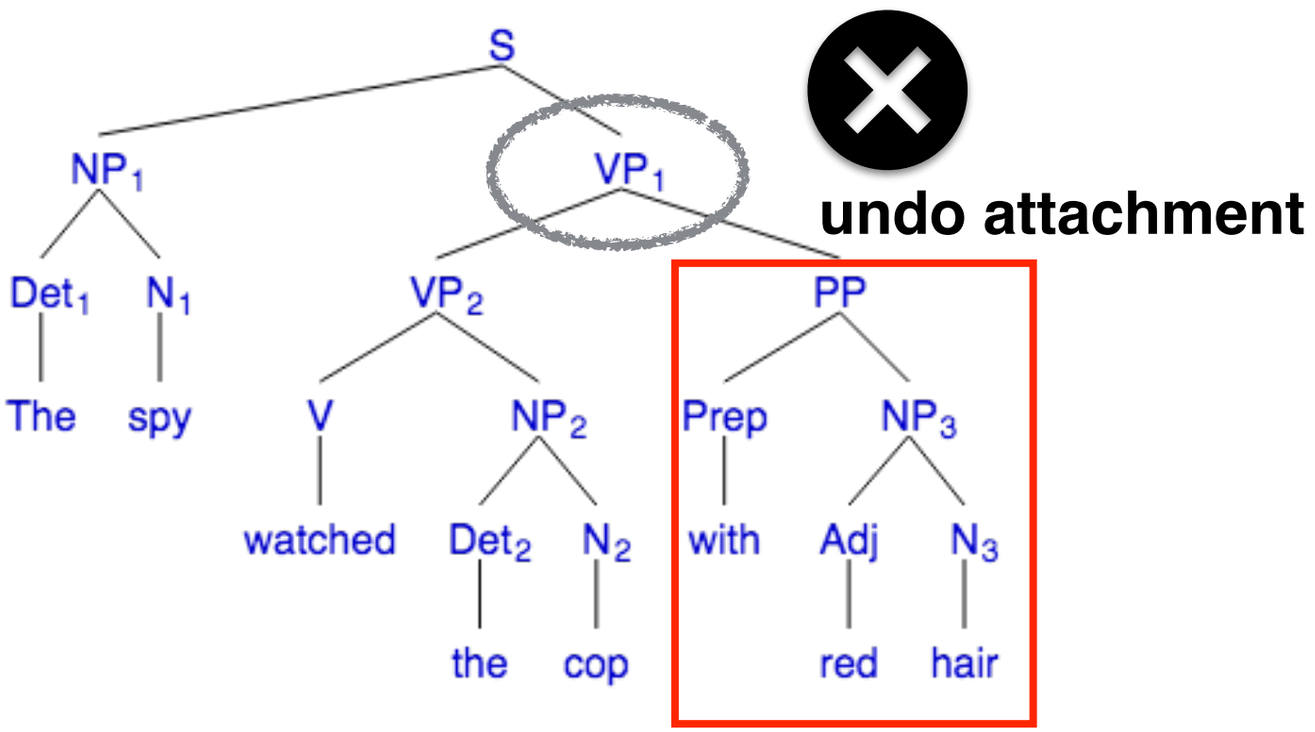
e.g. **Minimal Attachment**: Perceivers structure incoming linguistic material using the fewest nodes possible.

Predicts incorporation of the PP into VP in the following sentence:

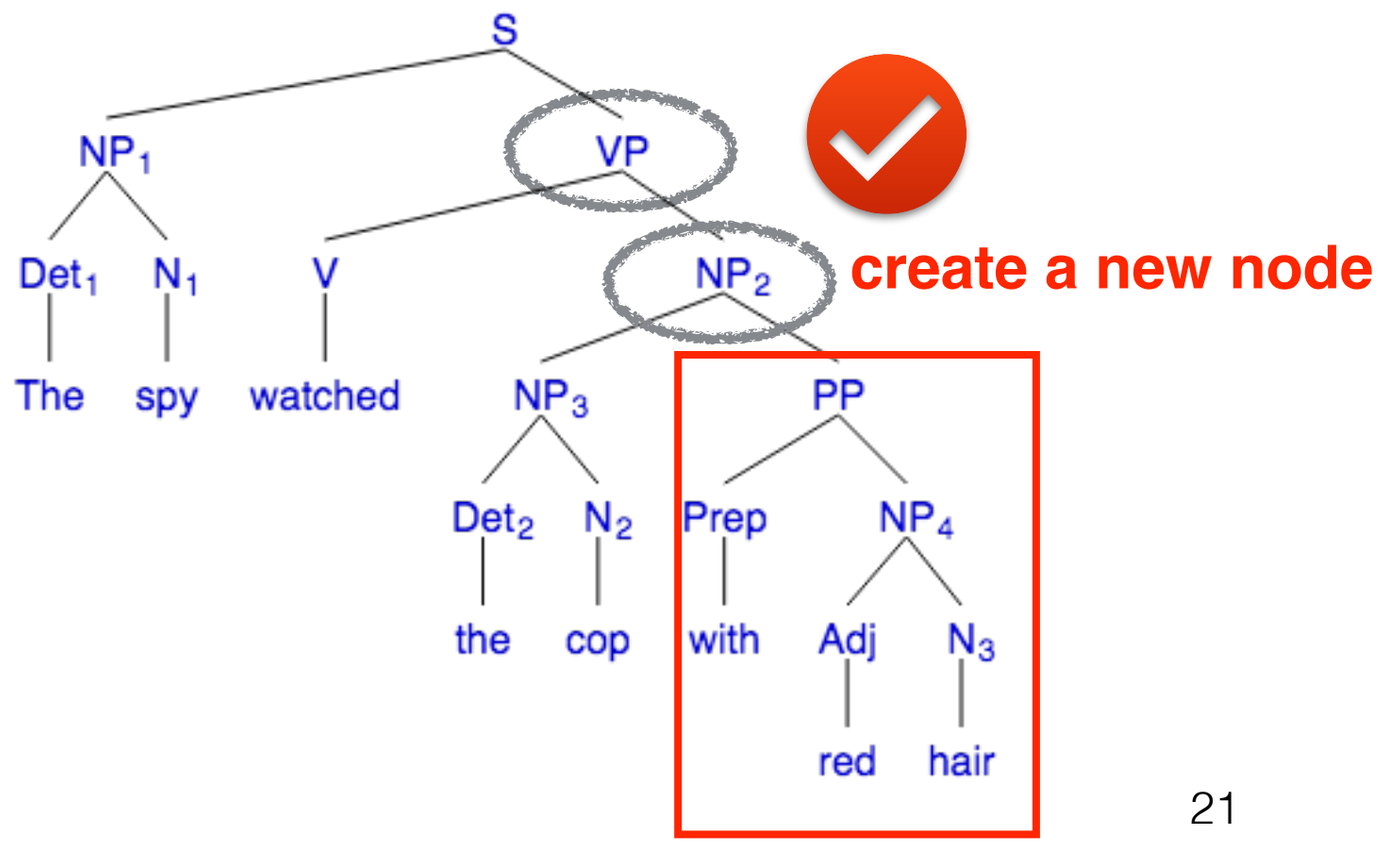
- The spy watched the cop with red hair.



How does “parsing” work?



undo attachment



create a new node

The spy watched the cop with red hair.

When an error is detected (based on subsequent syntactic material that doesn't fit or based on subsequent semantic analysis) --

Reanalysis ensues.

<u>Virtues of Garden-Path Model:</u>
Quick, principled, doesn't burden Short Term Memory (in first pass)

<u>Liabilities:</u> Great potential for error; requiring backtracking and re-analysis.

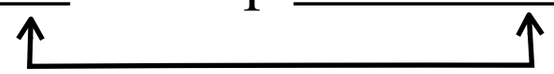
Test of Minimal Attachment

- Sentence that is ultimately compatible with ***Minimal Attachment:***

The spy saw the cop with binoculars, but the cop didn't see him.

- Sentence that is ***not*** ultimately compatible with ***Minimal Attachment:***

The spy saw the cop with a revolver, but the cop didn't see him.



» The spy saw the cop with a revolver, but the cop didn't see him.

Rayner, Carlson, & Frazier (1983)

Test of Minimal Attachment

- **Prediction:**

  - The Non-Minimal Attachment (NMA) sentence should take longer to read than the Minimal Attachment (MA) sentence.

  because "arriving at the most plausible analysis of the NMA sentence will **involve reanalysis of the syntactic structure initially assigned** to the sentence."

- **Assumption about processes:**

  - Attachment, then semantic check (i.e. does this attachment make sense?), then reanalysis if necessary.

Rayner, Carlson, & Frazier (1983)

Test of Minimal Attachment

- **Method:** Eye-tracking in reading
  - Assumption behind task: Relatively longer reading times & more regressions reflect processing difficulty.
- **Results:** (first fixations and total reading time in milliseconds per word)
  - Non-Minimal Attachment (NMA) sentence longer to read than Minimal Attachment (MA) sentence.

Rayner, Carlson, & Frazier (1983)

Test of Minimal Attachment

- **<u>Conclusions:</u>**
  - **The results support the Minimal Attachment in Garden-path model.**
    - Readers attach PP into verb phrase prior to evaluating the semantic contents of the PP.
      - Once evaluated, then may have to reanalyze structure.
        - Reanalysis takes time.

<u>- BUT…Alternative:</u>

"...the cop with a revolver..."

implication that there's another cop who doesn't have a revolver.

Rayner, Carlson, & Frazier (1983)

- If 2 cops in “discourse context", need to provide further identifying information about one of them (e.g. with a revolver).
- If no discourse context, then“infelicitous" to provide this info.: sufficient to just say“the cop".
- Noun phrase modification typically => Non-minimal attachment: these are confounded.

How does “parsing” work?

Interactive-activation Model (Tyler & Marslen-Wilson, 1977; MacDonald, Pearlmutter, & Seidenberg, 1994; Tanenhaus & Trueswell, 1995)

- Multiple alternative analyses are available during initial sentence parsing, but their availability undergoes continuous changes caused by the strength of probabilistic syntactic and non-syntactic cues.

This model is **Parallel**

- Requires early commitment
- Highly interactive, multiple sources of info. dictate how the system ultimately settles.

Constraint-based View

- **Constraint-based satisfaction models** (MacDonald, Pearlmutter, & Seidenberg, 1994; Tanenhaus & Trueswell, 1995)

  e.g. *When John left <u>the house</u> was dark.*

  When John danced <u>the house</u> was dark.

- **Late closure (from garden-path theory) would predict** that *the house* in both sentences would initially be thought as the direct object of the verb *left/danced*.

- **Constraint-based models** would argue that the house would be considered as the direct object only when the verb is *left* and not *danced* because verb information should be available.

- Also, prosody might play a role.

How does “parsing” work?

Interactive-activation Model (Tyler & Marslen-Wilson, 1977; MacDonald, Pearlmutter, & Seidenberg, 1994; Tanenhaus & Trueswell, 1995)

- Syntactic structure computed for any given sentence based on:

  - grammatical category info.
  - grammatical rules
  - the frequency with which specific **words** occur in particular structures
  - semantic/real world information
  - prior context
  - etc...

N/V-transitive, N more freq., animate, likely “agent” of upcoming action

N/V-trans1/V-trans2, V-trans1 more freq., needs animate subj.

N/V, N more freq.

The spy saw the cop with a revolver

N, not a good instr. for “saw”; OK as accompaniment of “the cop”. Reanalyze.

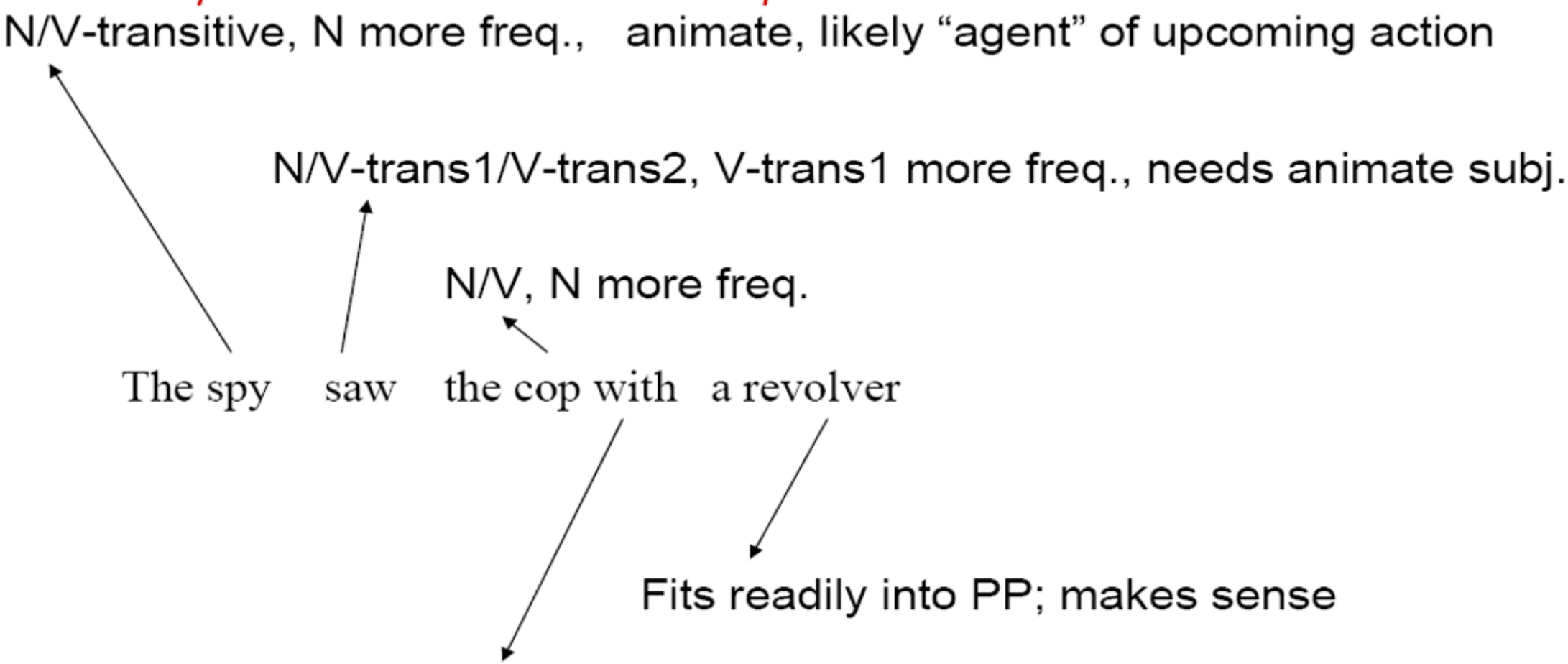
P, instrument/”accompaniment”, equally frequent?

“saw with” vs. “the cop with” => “saw with” more freq.

no prior discourse about 2 cops; probably not a modifier of “cop”

attach into VP

What if prior context mentions 2 cops?



"saw with" vs. "the cop with" => "saw with" more freq.

Prior discourse about 2 cops; probably a modifier of "cop"

Conflicting info; both attachments considered in parallel; resolution depends on weighting of different "constraints".

Assume that context forces attachment to NP "the cop".

- Experiments that have looked at context effects on sentence processing have produced varying results.

In the PP-attachment case ("with the revolver"), evidence that context (i.e. 2 cops mentioned in prior context) **DOES** affect sentence processing: it can prevent a garden-path.

But other ambiguous structures are less affected by context:

e.g. "Reduced relative clause" sentences:

The horse (that was) raced past the barn fell.

"John raced a horse past the barn & Jenny raced a horse past the duck pond. Then a bunch of other things happened...

The horse raced past the barn fell, and had to be taken to the vet."

Context doesn't seem to help avert garden-path.

Variables that predict the difficulty of ambiguous sentences

1. Thematic relations

- Knowledge about verbs that captures information about the events they describe, including how many and what kinds of participants are involved in the events, and the roles the various participants play.

The treasure buried …
(treasure: unlikely to be the subject, so not likely a garden path sentence)

The dog walked …
(dog: subject, or object)

The dog walked to the park wagged its tail happily.

2. Syntactic frames of verbs (subcategory information)

Please explain why these sentences are ungrammatical?

* The soldier buried.
* Alice fell the ball.
* Samantha sneezed that Billy was in prison.
* The mom put the cookies.
* The mom put the cookies about the jar.
* Frank said the report.

2. Syntactic frames of verbs (subcategory information)

- **Transitive verbs** (e.g., *bury*) : verbs that take both a subject and a direct object;

  I rarely wear socks.

  The engineer inspected the plans.

- **Intransitive verbs** (e.g., *fall*): verbs that occur with a subject but no direct object;

  Mariah sings beautifully.

  the magician vanishes.

- **Ditransitive verbs** (e.g., *put*): verbs that occur with a direct object and an indirect object (which may be introduced by a preposition)

  Devon presented his fiancée with a ring.

- **Sentential complement verbs** (e.g., *said*): verbs that introduce a clause rather than a direct object noun phrase (NP)

  the workers complained that their bosses harassed them.

- **Verbs that fall into more than one category**
  - **NP-bias verbs:** e.g., *accept, repeat, advocate, maintain, reveal, …*
  - **S-bias verbs:** e.g., *conclude, decide, promise, worry, prove, …*

3. Frequency-based information

- Frequency of structure:

  e.g., *Someone shot the maid of the actress who was standing on the balcony with her husband*.

  - Who was standing on the balcony with her husband?
  - NP1 (“the maid”) or NP2 (“the actress”)?
  - English: *the actress*
    Spanish: *the maid*

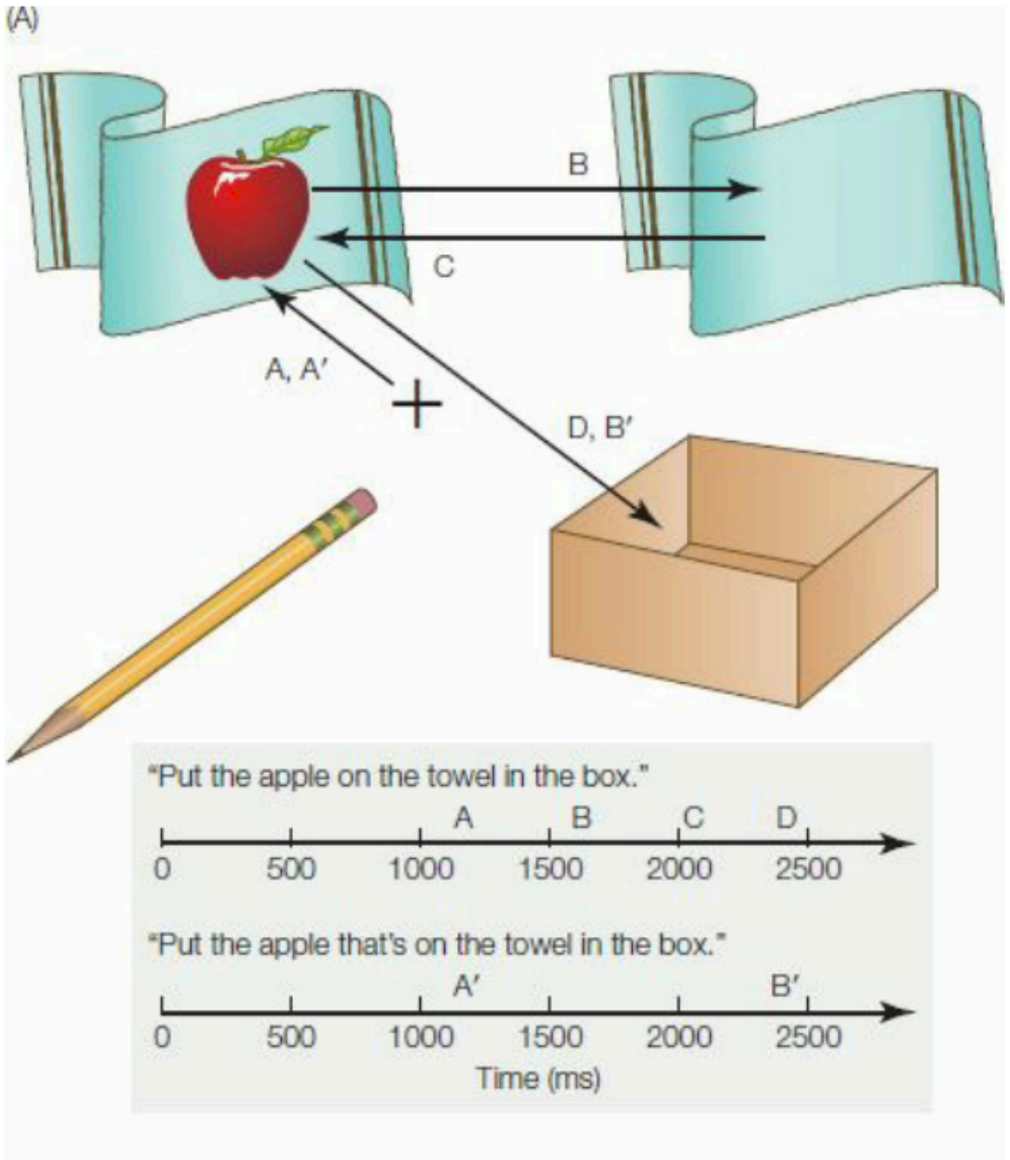
- Frequency of verbs (use):

  e.g., *The audience* ***entertained*** *at the gala left in high spirits*.

  The suspect ***accused*** *at the crime scene was soon released*.

  Prediction: Since *entertained* rarely show up in passive structures, we might expect it to lead to a much stronger bias for the main clause interpretation than *accused*, resulting in a stronger garden path effect.

4. The importance of context



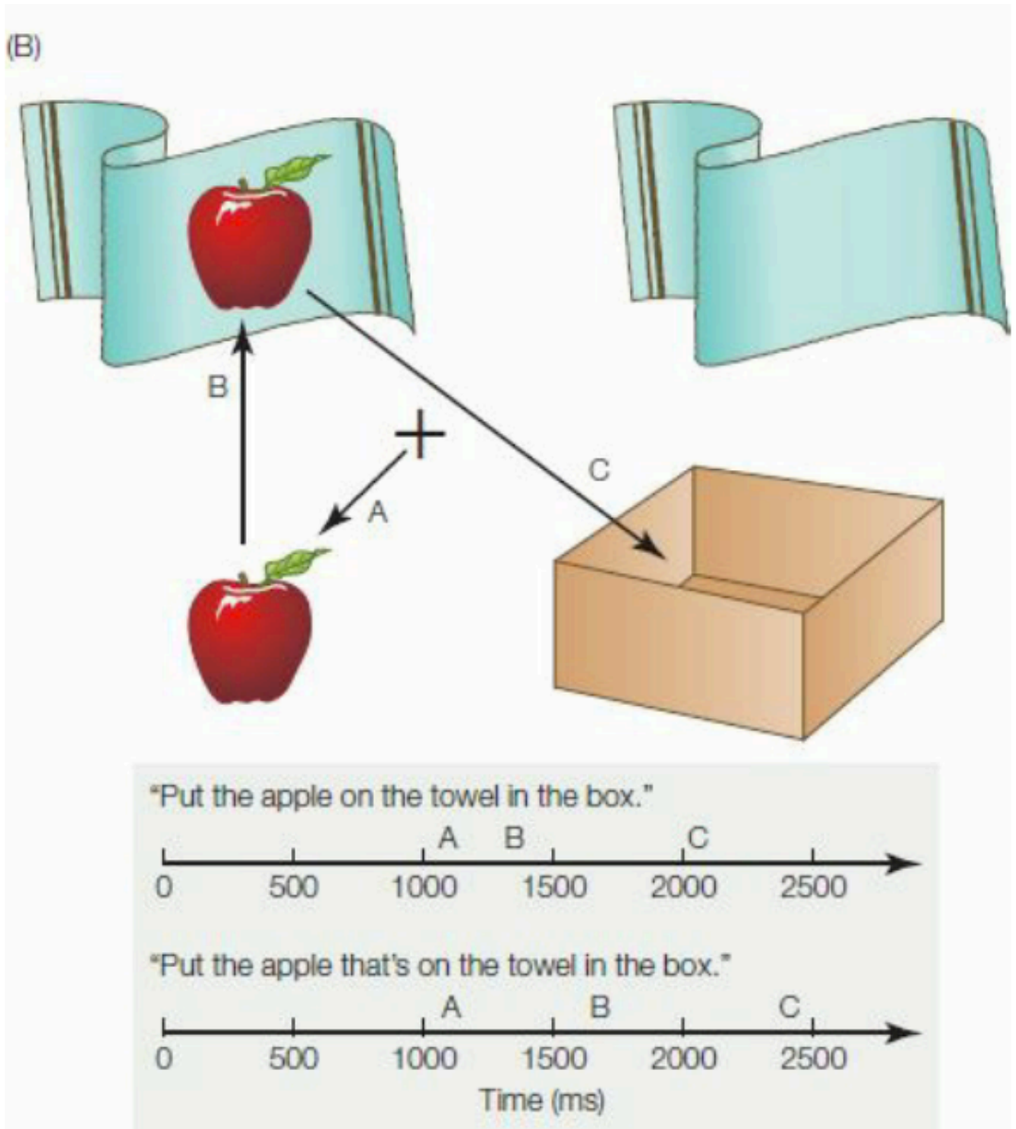
1. Letters indicate the typical sequence of eye movements;

2. A' and B' corresponds to the unambiguous version of the instruction;

Findings:

1. In the ambiguous version, people look at the irrelevant towel more often than in the unambiguous version;
2. The eye movements to the irrelevant towel can be used as evidence of a garden path interpretation

Tanenhaus et al. (1995)



Findings:

1. Subjects very rarely look at the empty towel --- no more so than when they hear the unambiguous version;

2. The eye movement record shows no evidence of a garden path interpretation when the context is appropriate to the normally less preferred structure.

Tanenhaus et al. (1995)

Bilingual Syntactic Processing

(See lecture slides on bilingualism)