

Sentence Processing

BCS 152

October 29 2018

Homework 3 Reminder!!!

- Due Wednesday, October 31st at 11:59pm
- Conduct 2 experiments on word recognition on your friends!
- Read instructions carefully & submit all of the required documents

How do we so quickly and easily understand each other's sentences?

- To understand a sentence, we need to understand its structure (**parsing**)
- Central question of sentence processing: how are words incrementally integrated into the parse?

Ambiguity Resolution

- Sentences can be ambiguous

The boy saw the detective with the telescope. **(globally ambiguous)**

The soldiers warned about the dangers...

...conducted the midnight raid.

...before the midnight raid.

(temporarily ambiguous)

- How comprehenders deal with ambiguity in sentences tells us what information and strategies they are using for parsing

Time flies like an arrow.

- (1) Time proceeds as quickly as an arrow proceeds
- (2) Measure the speed of flies in the same way that you measure the speed of an arrow.
- (3) Measure the speed of flies in the same way that an arrow measures the speed of flies.
- (4) Measure the speed of flies that resemble an arrow.
- (5) Flies of a particular kind, time flies, are fond of an arrow

Why do we seem to arrive at (1) first?

Garden-Path (GP) Sentences

The soldiers warned about the dangers
conducted the midnight raid.

The horse raced past the barn fell.

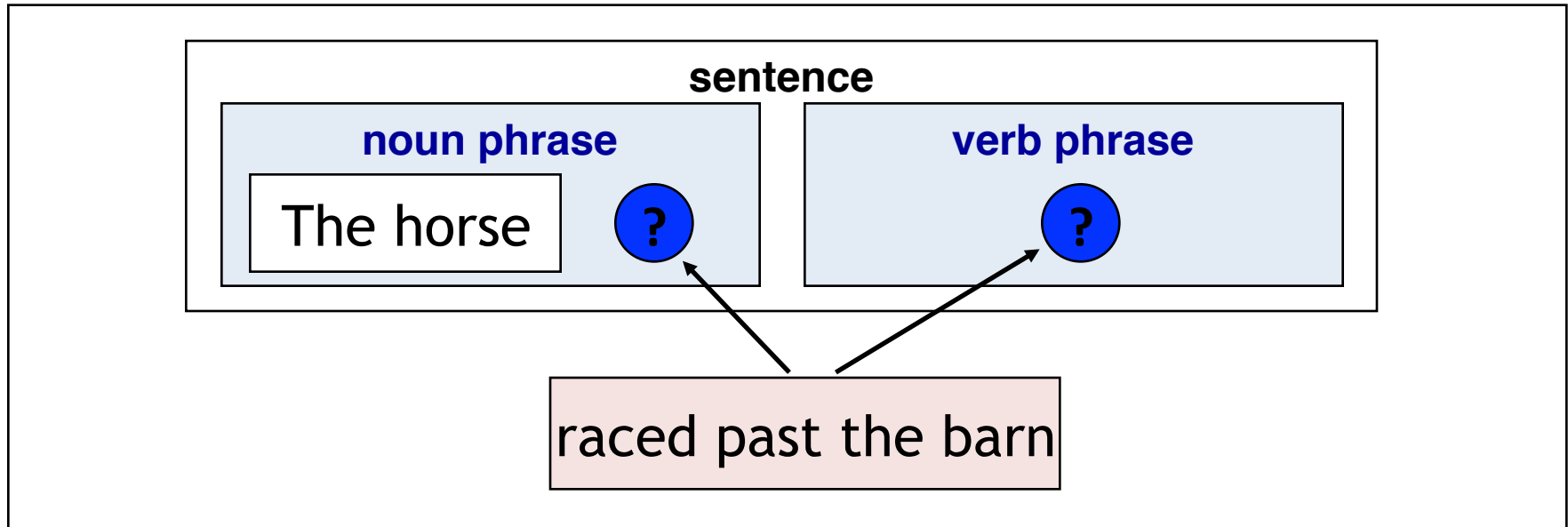
Reduced relative clause

Initially expect the verb of the relative
clause ('warned', 'raced') to be the main
verb of the sentence

What does this tell us about sentence processing?

- Investigating how people process GP sentences can tell us what information they use during parsing

Assembling syntactic phrases: ambiguity



- **Three possibilities:**

- Wait until attachment becomes unambiguous
- Commit to only one interpretation immediately (**serial processing**)
- Weigh multiple alternatives simultaneously (**parallel processing**)

Theories of Sentence Processing

2 Theoretical Axes

1. What information do comprehenders use to make parses?
 - Syntax-first theories: use **only** syntactic cues to construct parse
 - Constraint-based theories: use **all** available information to figure out parse
2. How many parses do comprehenders consider?
 - Serial processing: one at a time
 - Parallel processing: more than one

Two-Stage Model (aka Garden Path Model)



Lyn Frazier

- Serial and syntax-first
- Comprehenders **always** construct the simplest parse (based only on syntax), and only revise if they get later conflicting syntactic information
- What is ‘simple’?
 - Minimal Attachment
 - Late Closure

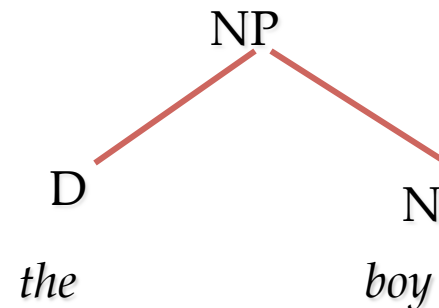
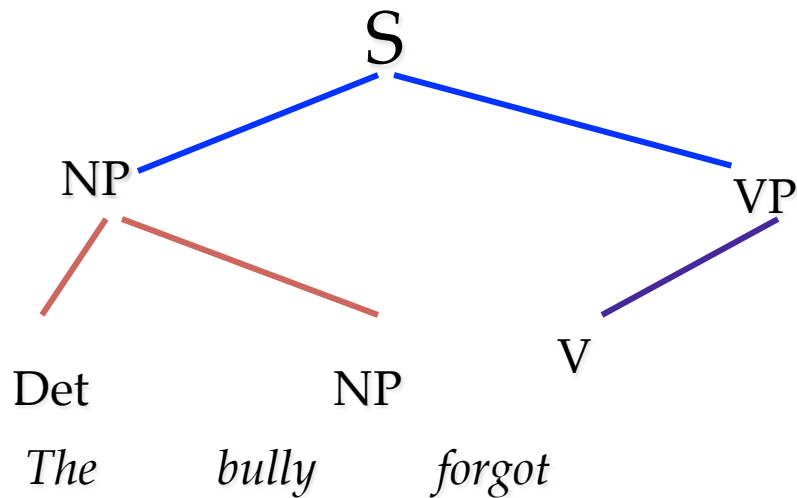
Minimal Attachment

- Rule for constructing the simplest parse
- When a new phrase come in, attach it so that you have to create the fewest number of new nodes as possible

Minimal attachment

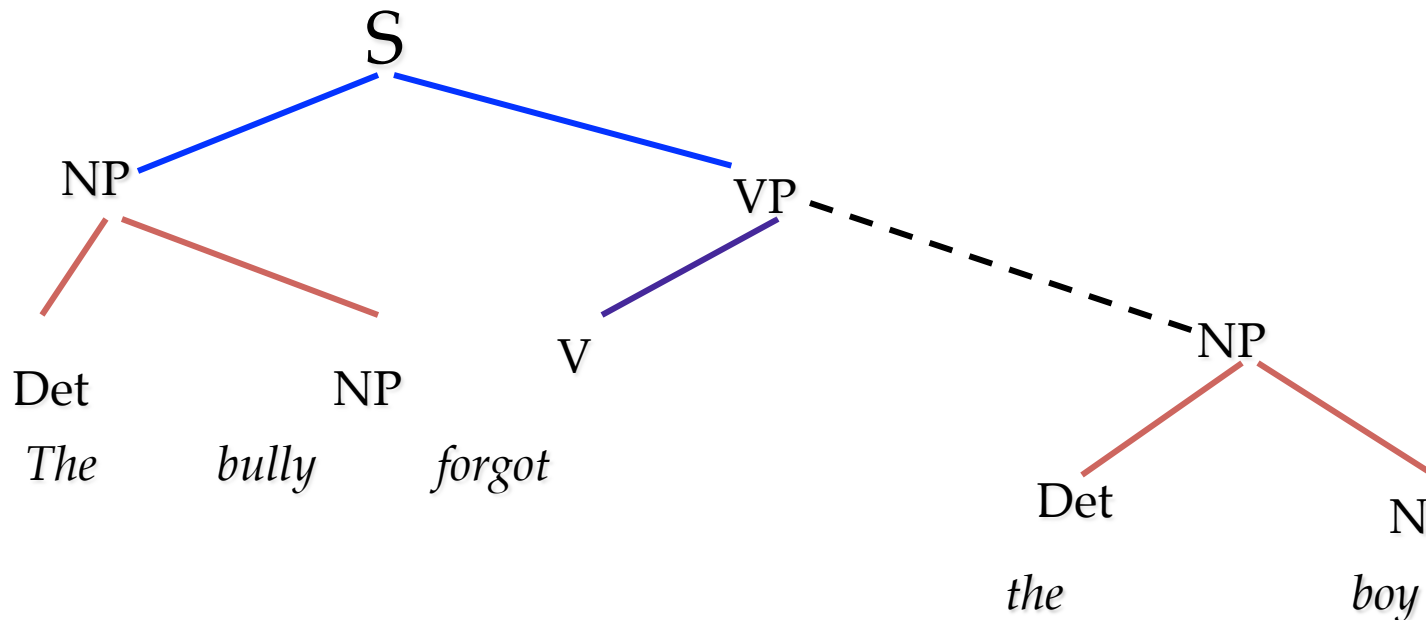
The bully forgot the boy knew judo.

The bully forgot the boy...



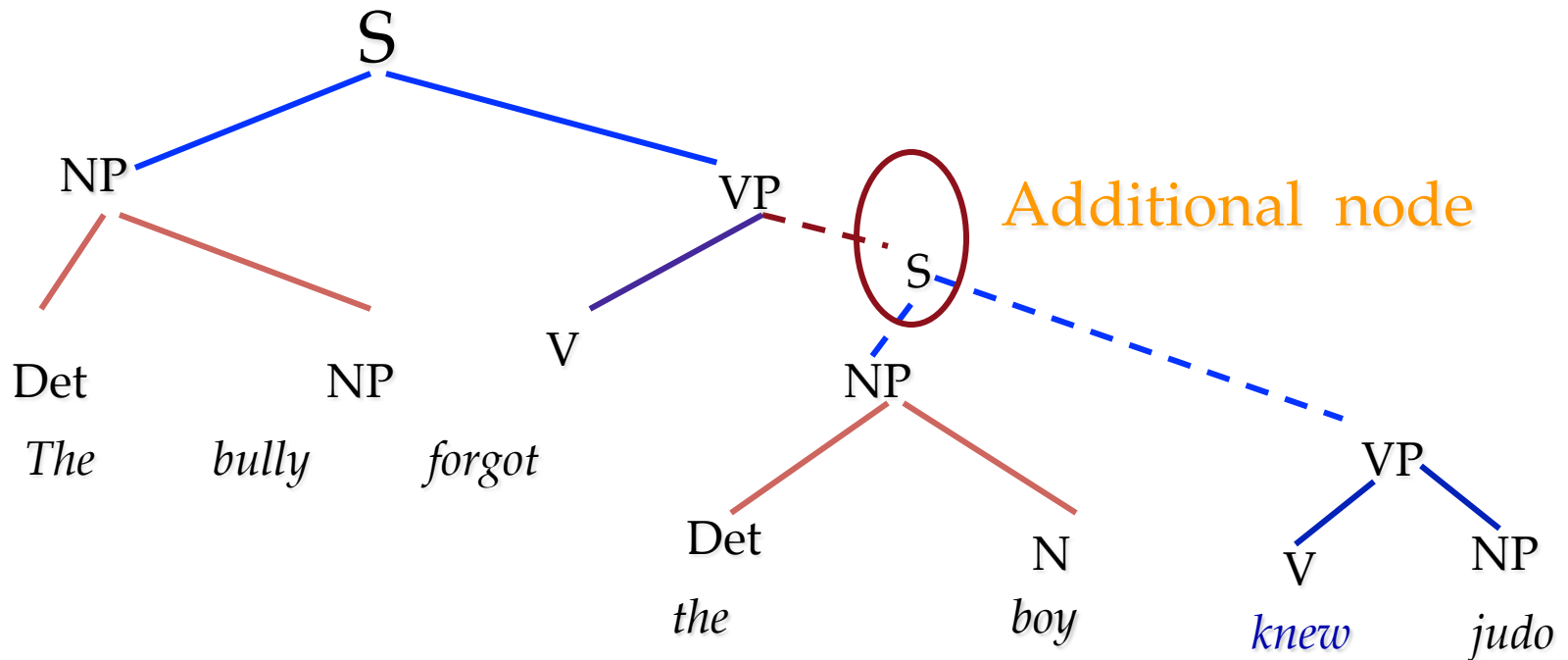
Minimal attachment

The bully forgot the boy...



Minimal attachment

The bully forgot the boy knew judo



Predictions of Minimal Attachment

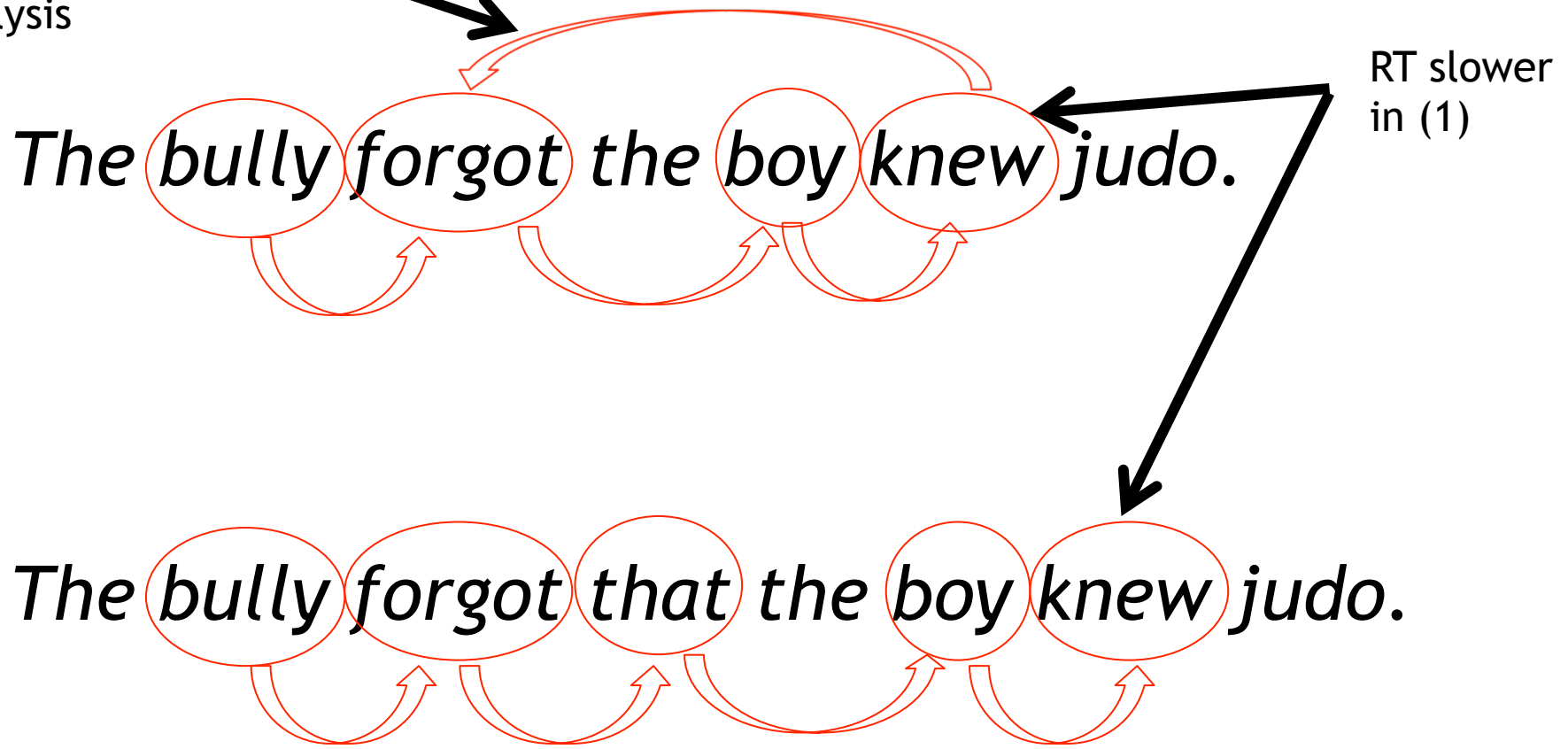
- Should be **hard** to process garden-path sentences (they don't follow minimal attachment)
 - sentence would need to be re-analyzed, which is costly
- Processing difficulty should appear at the point where structure is disambiguated

Experimental Strategy

- Construct two versions of garden-path sentence
- **Ambiguous:** The bully forgot the boy knew judo
 - disambiguated at “knew”, but ambiguous before
- **Unambiguous:** The bully forgot that the boy knew judo
 - disambiguated at “that”
- **Ambiguous** version should lead to more processing difficulty at “knew”

Eye-tracking reading evidence for minimal attachment

regression to past
input suggests re-
analysis



Late Closure

Tom said that Bill had taken out the cleaning yesterday.

Did Tom say that yesterday? Or did Bill take out the cleaning yesterday?

Late Closure

- Late closure: input should attach to the phrase that is currently being processed

Tom [said that Bill had [taken out the cleaning yesterday.]]

Tom [said that Bill had [taken out the cleaning] yesterday.] → requires ending the current phrase (violates late closure)

Evidence for Late Closure

Since Jay always jogs a mile this
seems like a short distance to him. Late
Closure

read faster than

Since Jay always jogs a mile seems
like a short distance to him. Early
Closure

Constraint-Based Models



Mike Tanenhaus

- Comprehenders use **all** possible sources of information to construct a parse (not just syntactic)
- Lexical, semantic, visual, etc. information provide **constraints** on what the parse could plausibly be
- We weigh these constraints to figure out the right parse

Lexical biases

The horse raced past the barn fell.

- *race* occurs as a main verb more frequently than as a past participle
- *horse* is most often the agent *racing* actions, not the theme
- The constraints are biased against reduced relative
- **What happens if the biases (subject plus verb) go the other way?**

Lexical biases

The salmon released in the stream spawned

The landmine buried in the sand exploded

- GP effect completely goes away for these sentences!
- Evidence **against** two-stage model - more than just syntactic information is considered

- Comprehenders use the *frequency* of a structure during processing
- People simply don't say things like '*The horse raced past the barn fell*' that often!

Put the apple on the towel ...

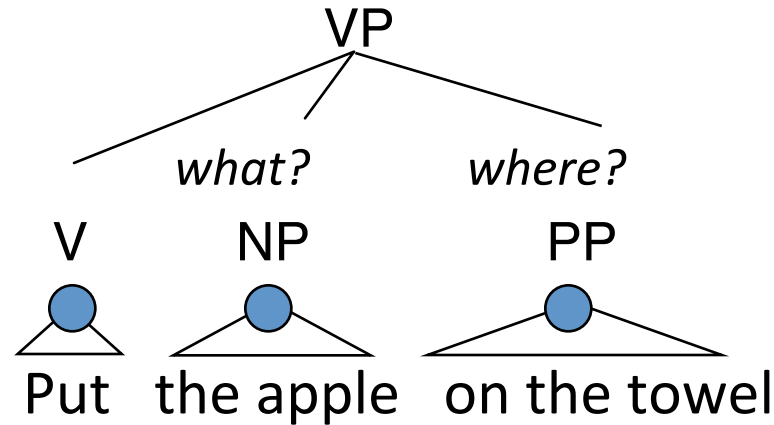
Put the apple on the towel.

Destination

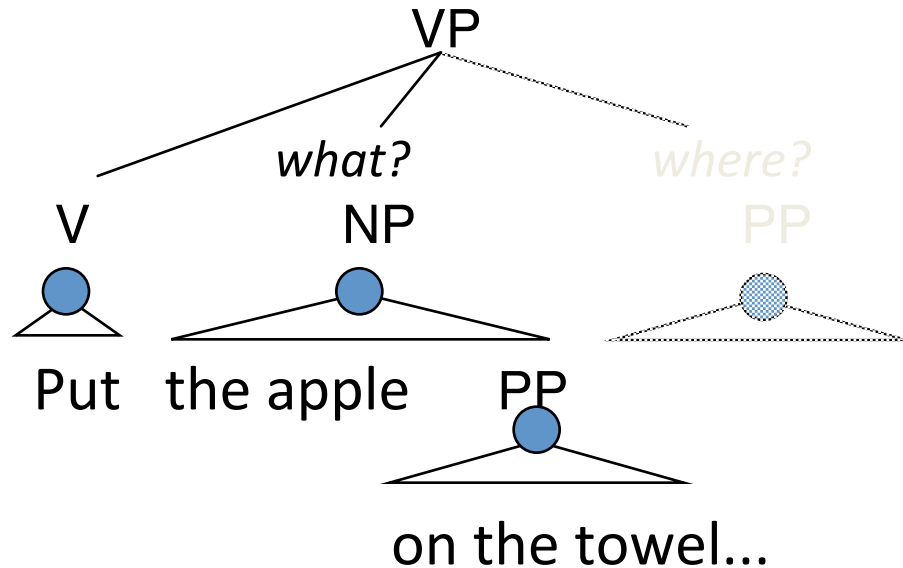
Put the apple on the towel into the box.

Modifier

Syntactic simplicity prefers destination interpretation

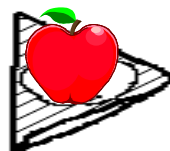
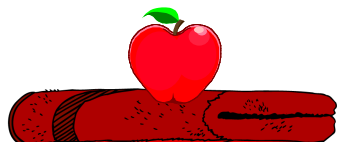


Destination



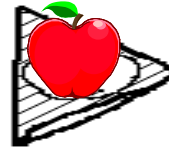
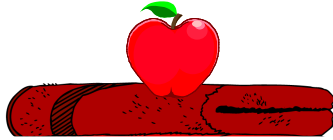
Modifier

Visual context



Put the apple

Visual context

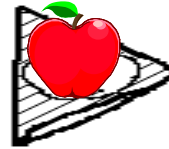
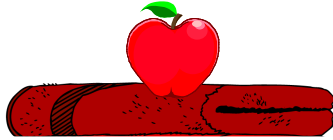


Put the apple on the towel.

Destination

“The apple” description fails to pick out a unique object! (which apple?)

Visual context



Put the apple on the towel.

Destination

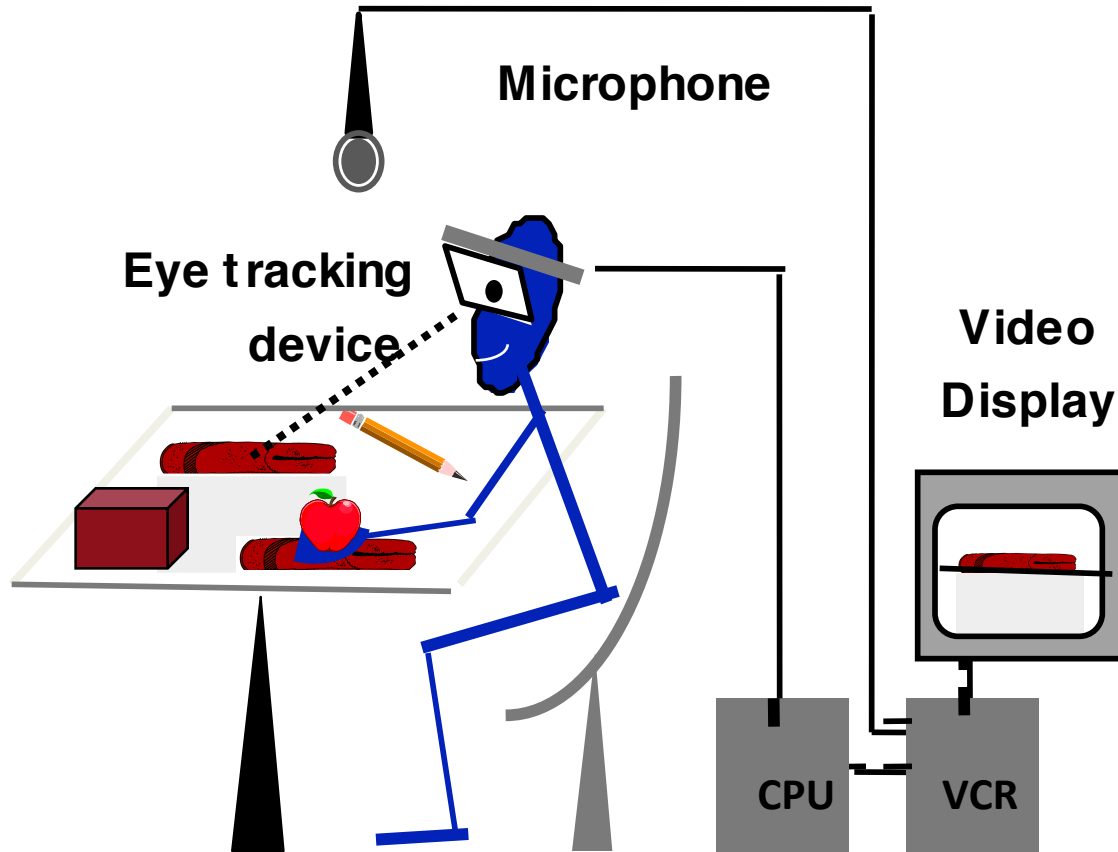
“The apple” description fails to pick out a unique object! (which apple?)

Put the apple on the towel into the box. **Modifier**

Successful reference!

Tanenhaus et al. (1995)

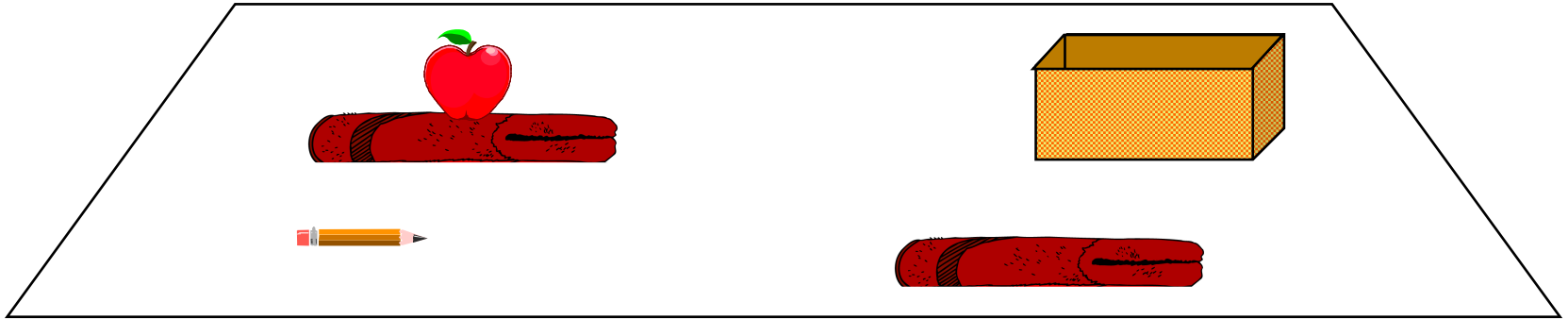
- Instead of reading, track what objects participants are looking at in a display
- Gives window into what interpretation they're considering



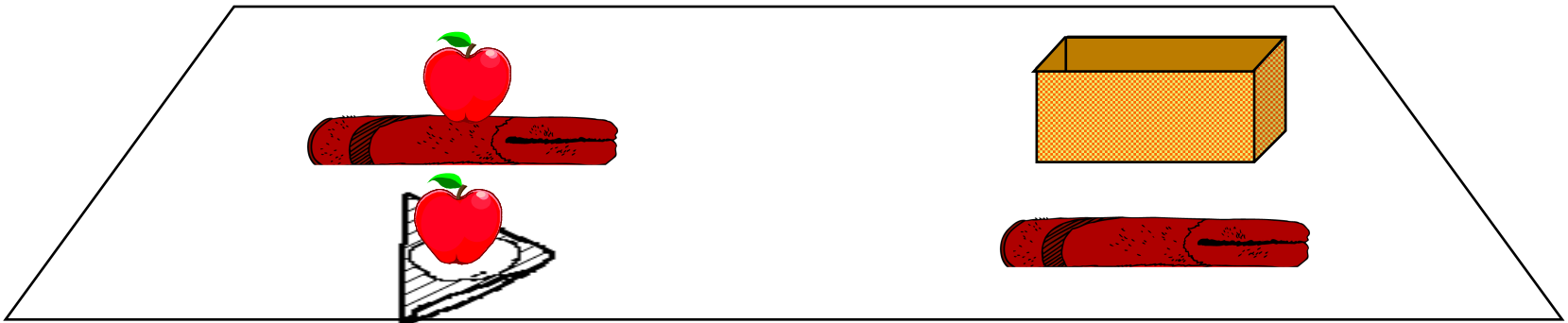
Tanenhaus et al. (1995)

- Instruction either ambiguous or not
 - Put the apple on the towel into the box
[ambiguous]
 - Put the apple *that's* on the towel into the box
[unambiguous]
- Visual context either requires modification of “apple” or not
 - One-referent context (one apple in display)
 - Two-referent context (two apples in display)

One-referent context

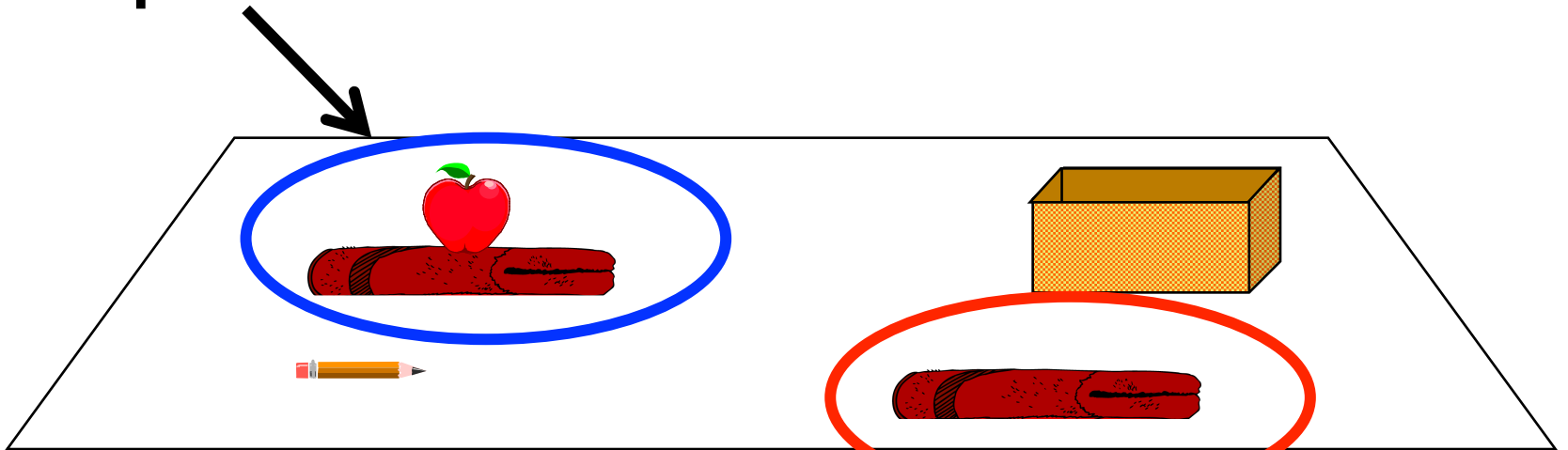


Two-referent context



Put the apple on the towel...

**Modifier
Interpretation**



**Destination
Interpretation**

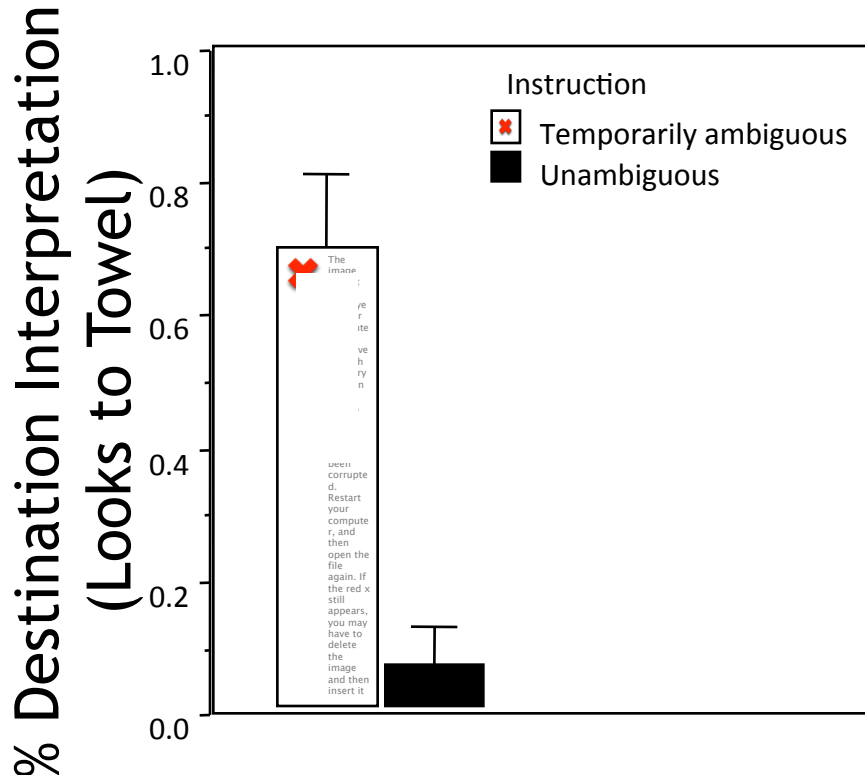
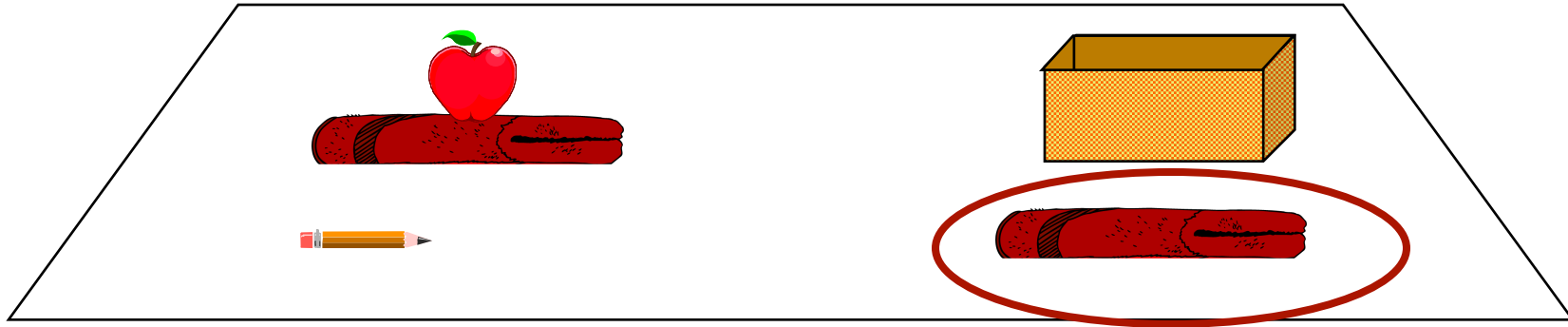
Predictions of Constraint-Based Theories

- Fewer ‘garden-paths’ (**destination** interpretations) in **unambiguous** instructions than **ambiguous** instructions
- Fewer garden-paths in two-referent than one-referent context

*Put the apple **on the towel** in the box.*



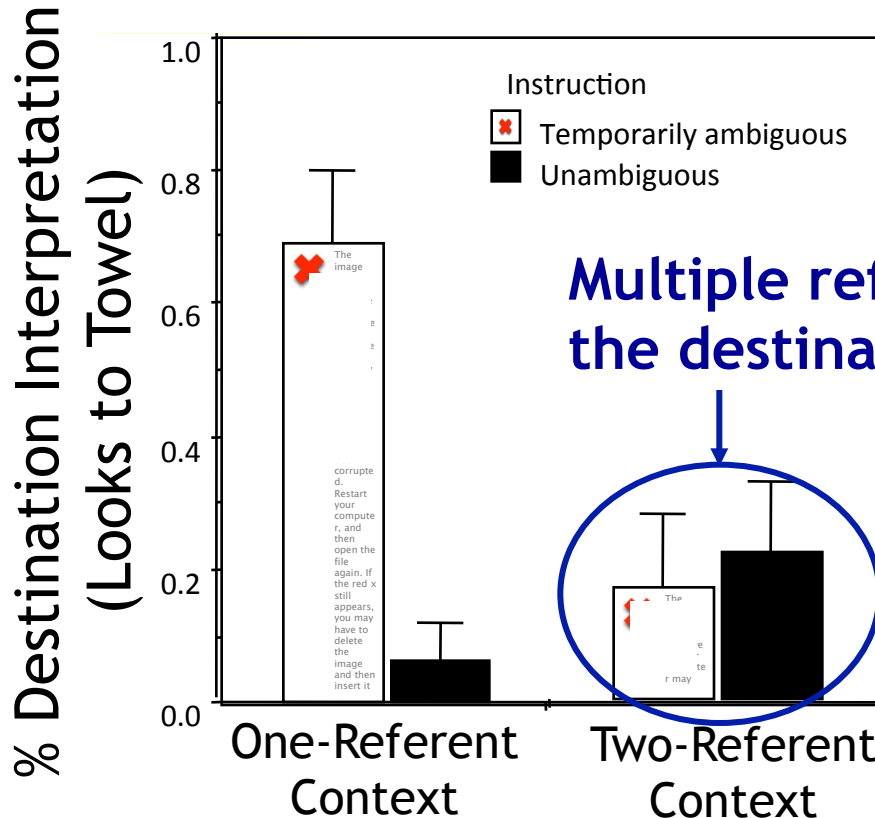
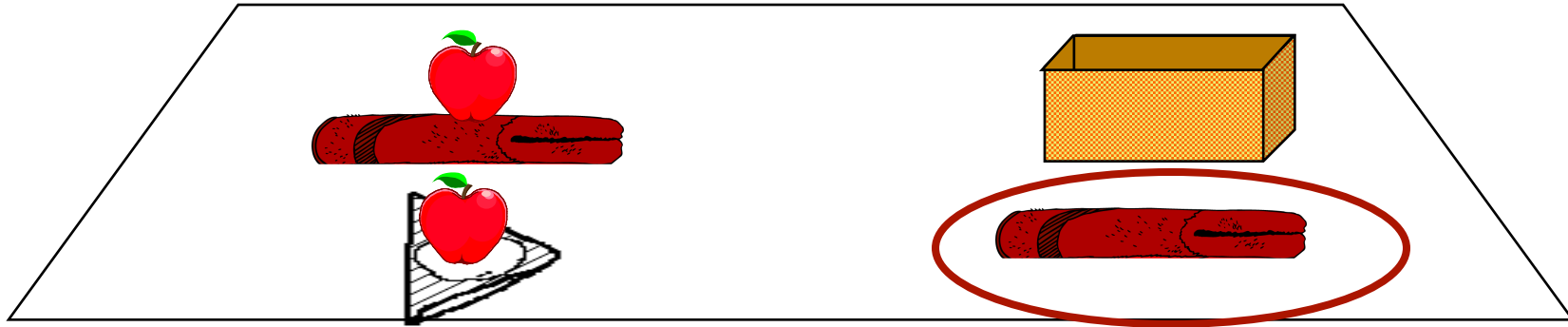
*Put the apple **that's** on the towel in the box.*



*Put the apple **on the towel** in the box.*



*Put the apple **that's** on the towel in the box.*



Tanenhaus et al. (1995)

- Minimal attachment doesn't always apply
- Visual context influences the parse

Syntactic-category ambiguity

- (1) The union told reporters that the corporation fires many workers each spring without giving them notice.
- (2) The union told reporters that the warehouse fires many workers each spring without giving them notice.

Syntactic-category ambiguity

(1) The union told reporters that the
corporation fires many workers each
spring without giving them notice.



more likely to be verb

(2) The union told reporters that the
warehouse fires many workers each
spring without giving them notice.



more likely to be noun

Syntactic-category ambiguity

(1) The union told reporters that the corporation fires many workers each spring without giving them notice.

read faster than

(2) The union told reporters that the warehouse fires many workers each spring without giving them notice.

Prosodic Information

Since Jay always jogs a mile this seems like a short distance to him. (Late Closure)

Since Jay always jogs a mile seems like a short distance to him. (Early Closure)

- Early closure interpretation is easily available if the prosody is right!

- Constraint-based theories explain sentence processing better than syntax-first theories
- Comprehenders able to use all kinds of information to construct parses, **not** just semantic information
- ‘Garden-path’ sentences aren’t always hard to process!

Why were we garden-pathed into believing the garden-path theory for so long?

- Early studies used out-of-context sentences that lack many of the usual cues we get in normal conversation
 - Great for making highly controlled stimuli
 - Bad for simulating what typical language processing is like!

"Garden path" sentences are those that trick you into thinking that they will mean one thing, but then as you read more of the sentence, that meaning is shown to be false!



For instance:
"The horse
raced past the
barn fell!"



why, that sentence is senseless!

Aha, my friend, so it would seem! But it actually refers to a horse, which at some point in the past was raced past a barn, and now that same horse has fallen over!



That sentence is stupid!

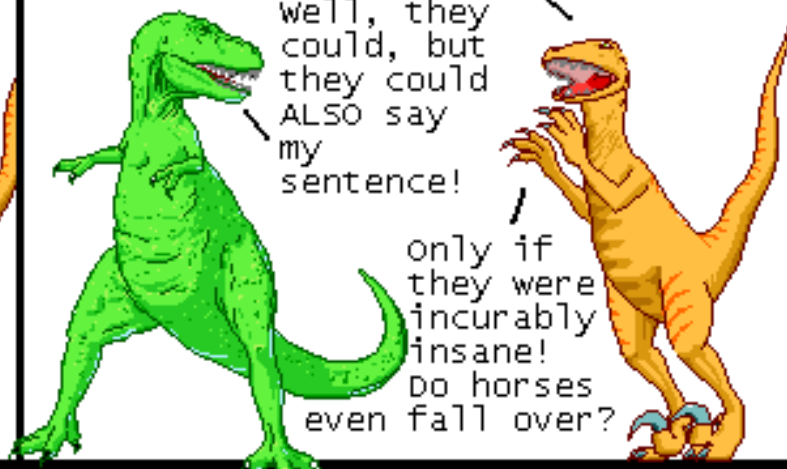
what are you saying?



What I'm SAYING is that nobody would ever say that. They'd say, "The horse that I raced past the barn has now fallen over!"

well, they could, but they could ALSO say my sentence!

only if they were incurably insane! Do horses even fall over?



Sure man, all the time!

Farmers call them nature's dominoes!



Is Parsing Always Right?

- By the end of a sentence, is the comprehender guaranteed to have gotten the right parse?
- Not always! Initial parses and local cues can mess us up

‘Good-Enough’ Processing

While the man hunted the deer ran into the woods.

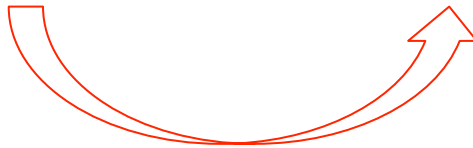
- ‘the deer’ initially biased toward being the object of ‘hunted’
- after the sentence, people often retain the incorrect interpretation

- Comprehenders often reject the right analysis if it doesn't seem plausible, especially if it's in an infrequent syntactic construction
- Who did the hunting?
 - (1) 'The man was hunted by the deer'
 - (2) 'The deer hunted the man'
 - (3) 'The deer was hunted by the man'
 - (4) 'The man hunted the deer'

A lot of 'man' responses in (1)!

Agreement Attraction

‘Which trees are the gardener planting?’



incorrect agreement

- often rated as grammatical!
- plural is ‘attracted’ by the previous noun

Summary

- Ambiguous sentences allow us to understand how comprehenders build up parses
- Early evidence from garden-path sentences suggest that listeners *only* use syntactic information during parsing
 - But studies used strange, infrequent sentences that lacked context

- Comprehenders can actually use all kinds of context to construct parses
 - Lexical bias/structural frequency of specific verbs
 - Visual context
 - Spoken prosody
 - etc
- Evidence overall is in favor of constraint-based models over two-stage/garden-path models

- Parsing isn't perfect - people often get the wrong parse of a sentence
- These incorrect parses typically skew in favor of more plausible/frequent interpretations

For next time

- Frequency seems to be pretty important, but what exactly is its role in sentence processing?
- Many of the processing effects we've seen today can be boiled down to word-by-word predictability, or *surprisal* (Levy, 2008)
 - How does this theory relate to two-stage and constraint-based models?

For next time

- Serial vs. parallel processing
- How can we tell whether comprehenders are entertaining just one parse or many?

For next time

- How do we incrementally *produce* sentences?
- Is production subject to the same or different constraints as comprehension?
- Do speakers produce sentences so that they are easy for the listener to understand, or do they just produce what's easiest to produce?