Can ACT-R Process Language in Real Time? Putting Together Syntactic and Semantic Processing

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Language Is Complex

Semantics

Syntax

Lexical Access

Perception

Challenge for ACT-R

- Computations are carried out by productions
- Only one production can be executed at once
- Each productions takes 50 ms

Our Proposal

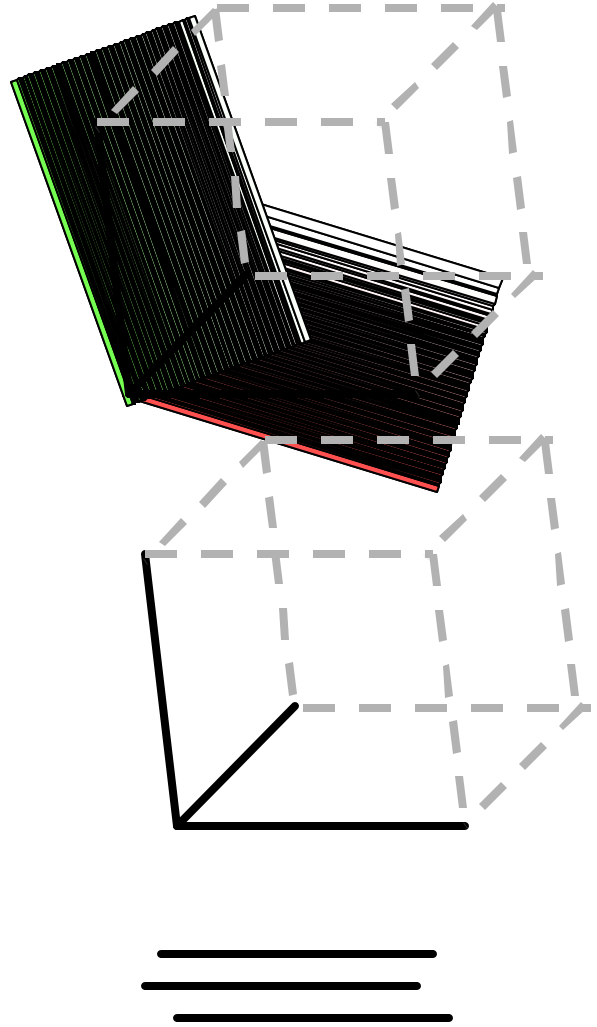
INP
(INterpretation-based Processing)

Semantic interpretation

Parsing

Words

Reading

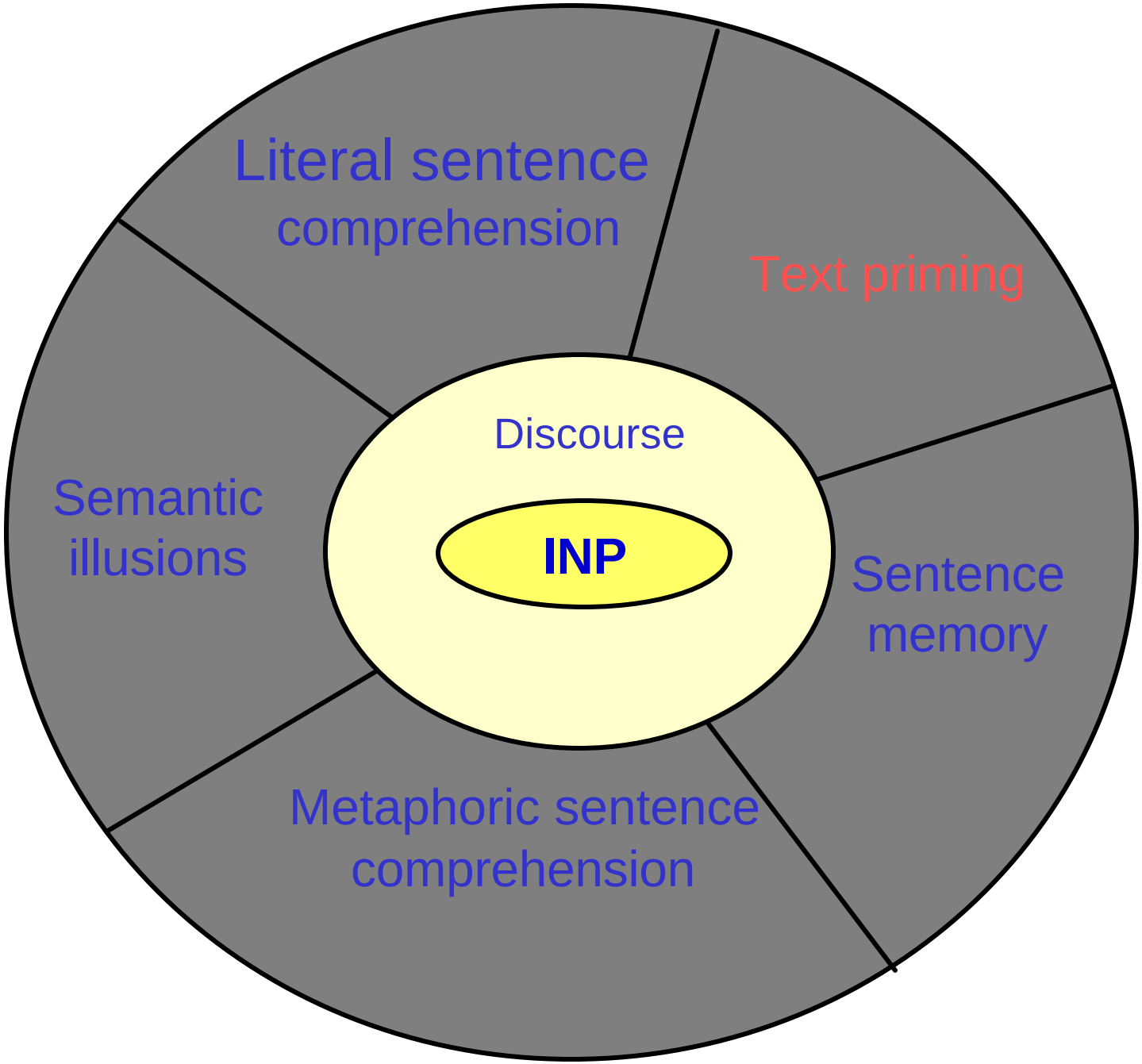


INP Is Real-Time

- ACT-R's subsymbolic, parallel activation-spreading mechanism ✍ speed

- Parsimonious processing, based on "guessing" in advance the interpretation of the sentence ✍ speed

  ✍ on-line processing effects


Literal sentence comprehension
Text priming
Discourse
INP
Semantic illusions
Sentence memory
Metaphoric sentence comprehension

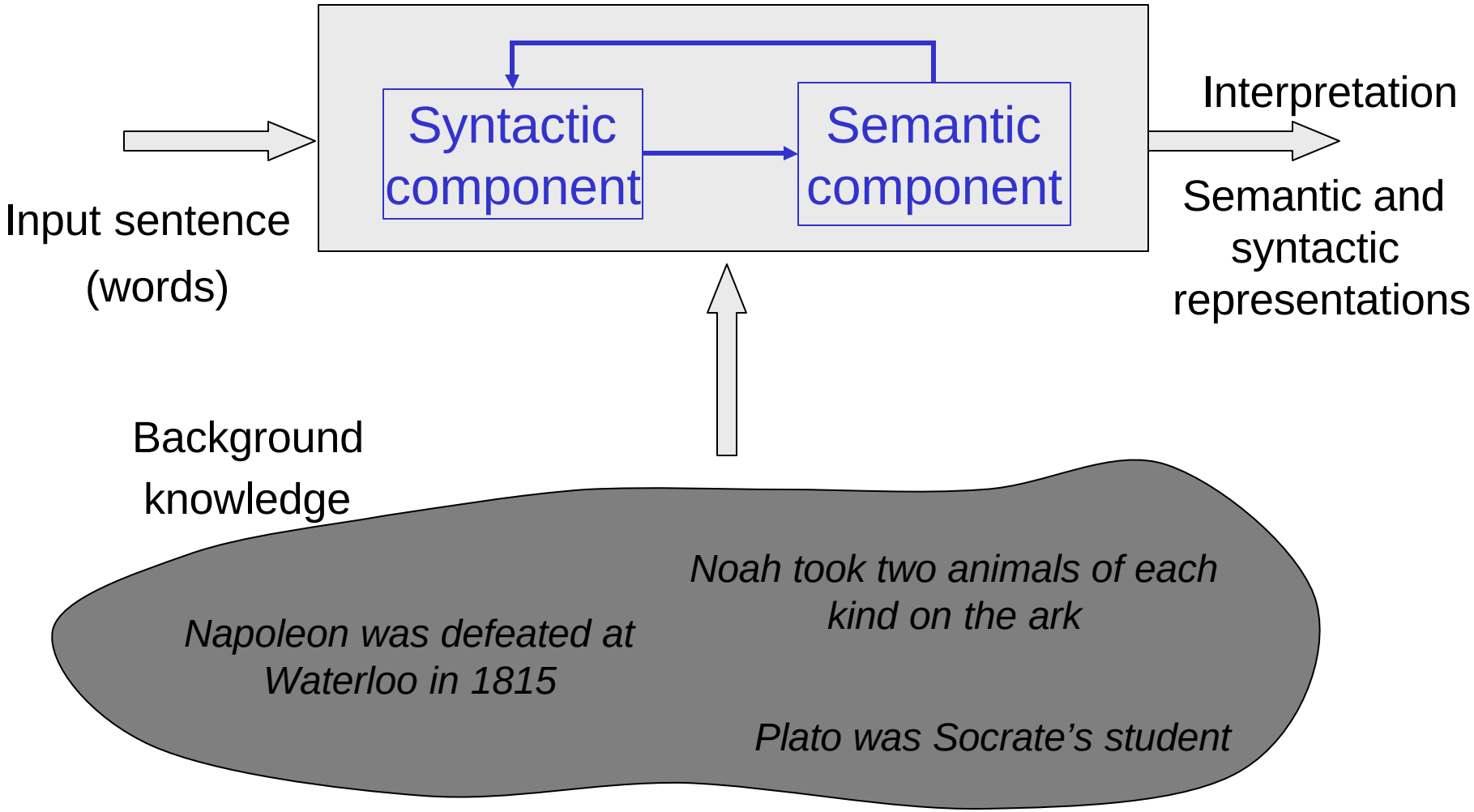
Outline

✍Introduction and motivation

- Overview of the model
- Syntactic Processing
- Semantic Processing
- Case Study: Text Priming
- Conclusions

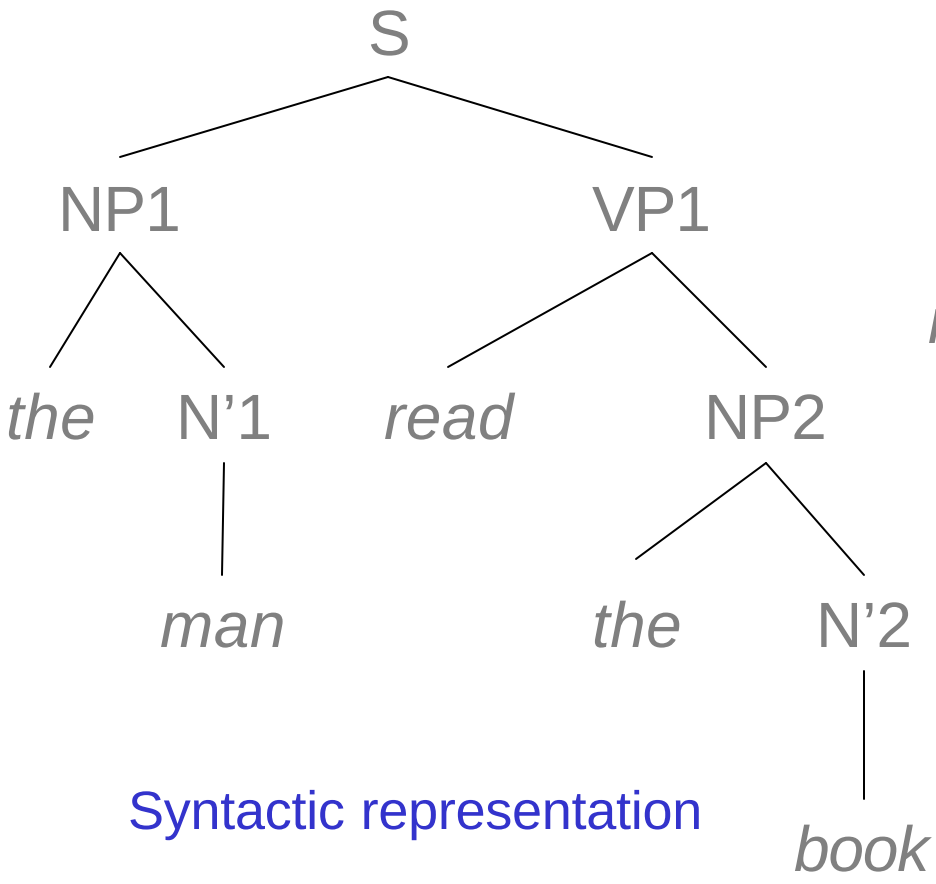
The INP Model

(Interpretation-based Processing)

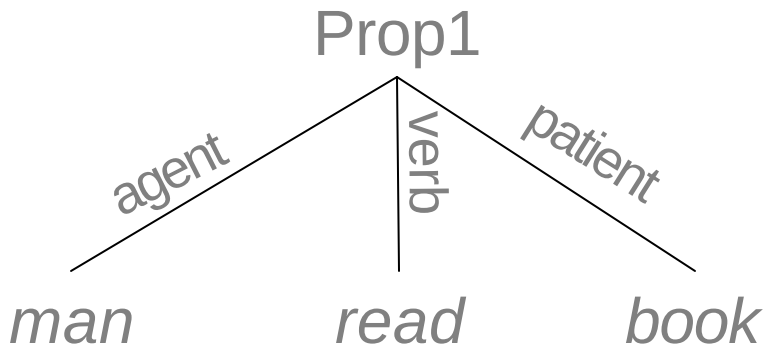


Products of Comprehension

The man read the book



Syntactic representation



Semantic representation

The Interpretation

Interpretation = a known fact that overlaps most with the current sentence

	Sentence	Interpretation
"old" information	*At the restaurant the man paid the waiter*	*The customer paid the waiter*

The Interpretation

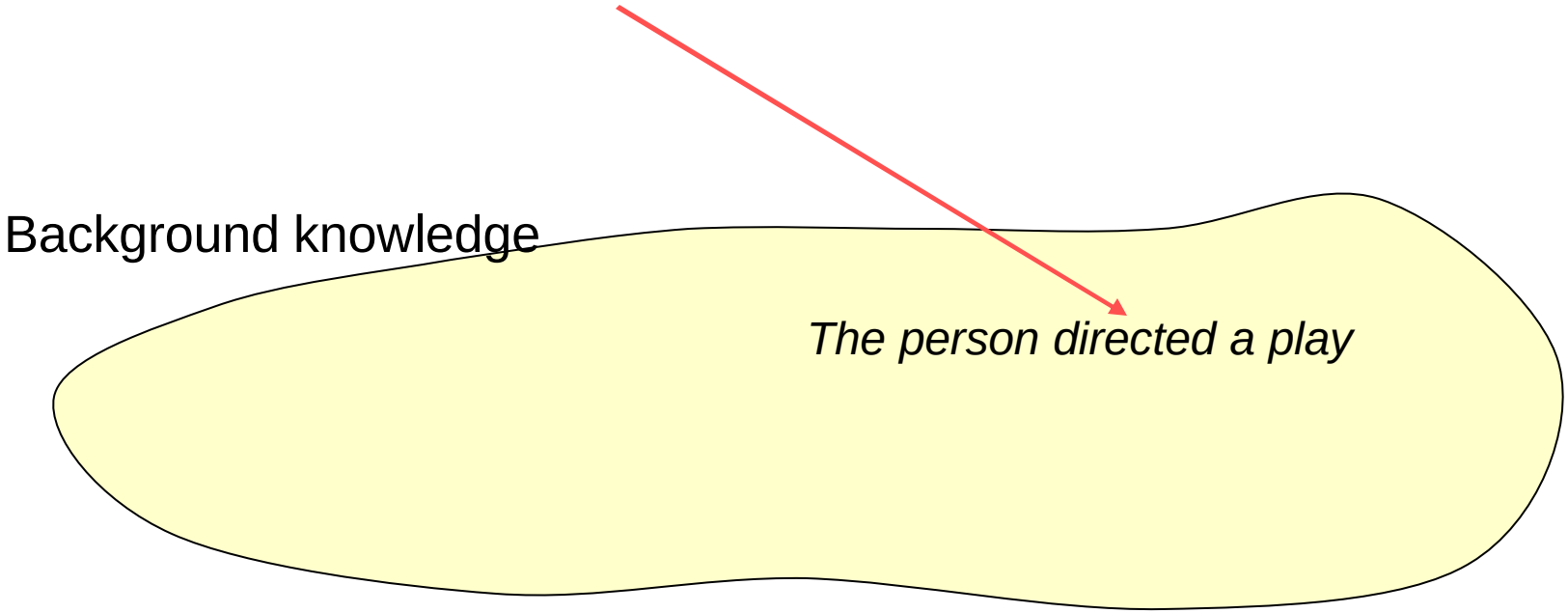
Interpretation = a known fact that overlaps most with the current sentence

	Sentence	Interpretation
"old" information	*At the restaurant the man paid the waiter*	*The customer paid the waiter*
"new" information	*Thomas Vinterberg directed "The Celebration"*	*The person directed a play*

More on Interpretation

The interpretation is NOT the meaning of the sentence, but a link with past knowledge

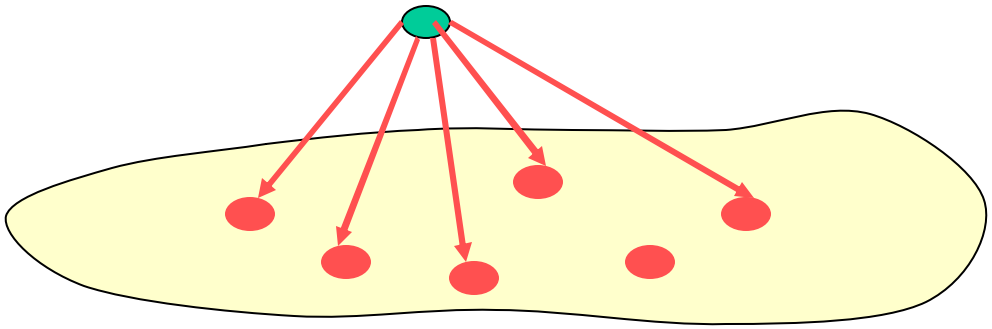
Thomas Vinterberg directed "The Celebration"



More on Interpretation

INP tries to guess the interpretation while it reads the sentence

This sentence is about interpretation



A single “inference”: the interpretation

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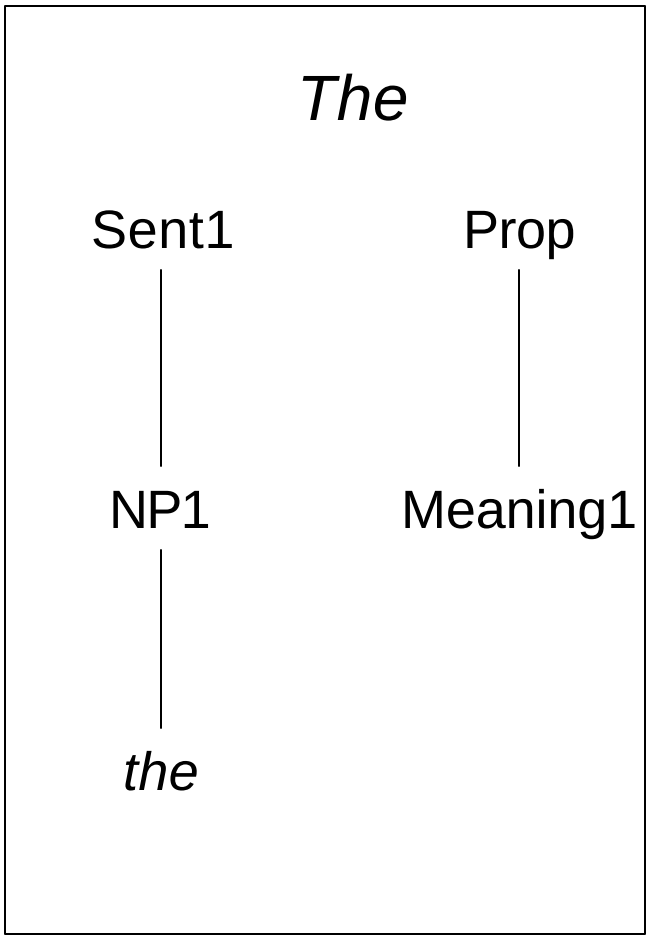
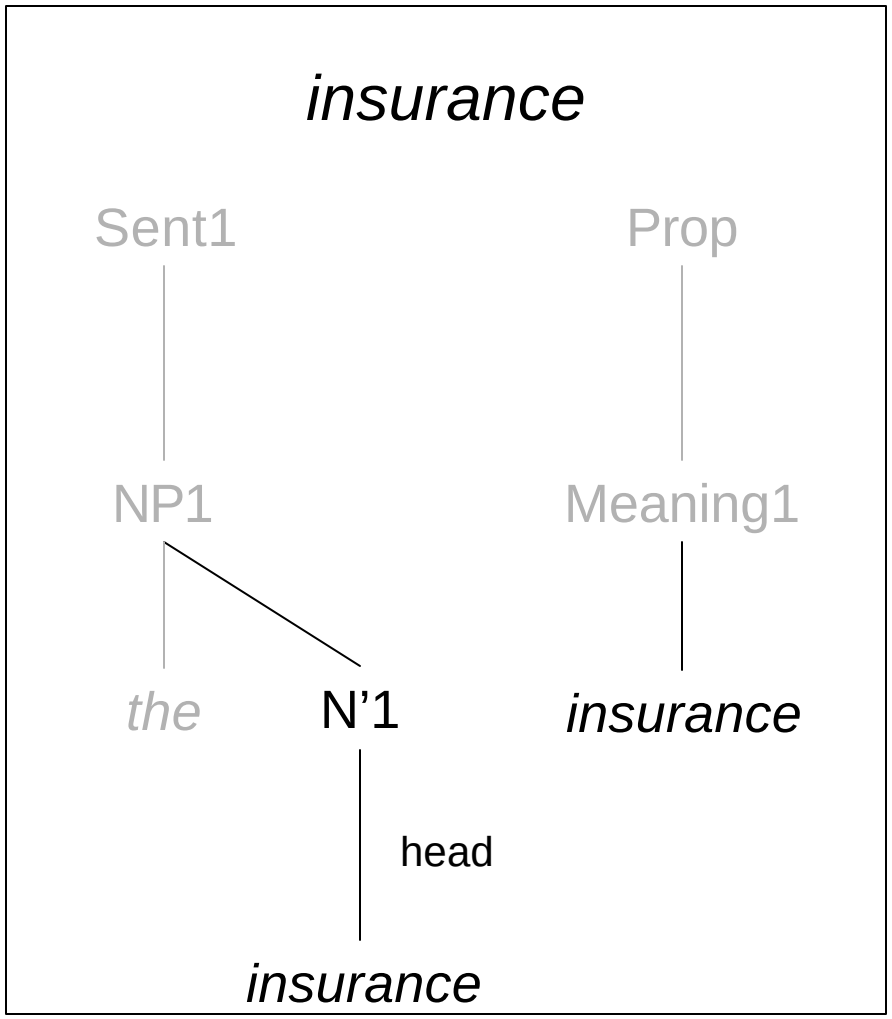
The Syntactic Processor

The insurance man from Boston drove the student of Physics





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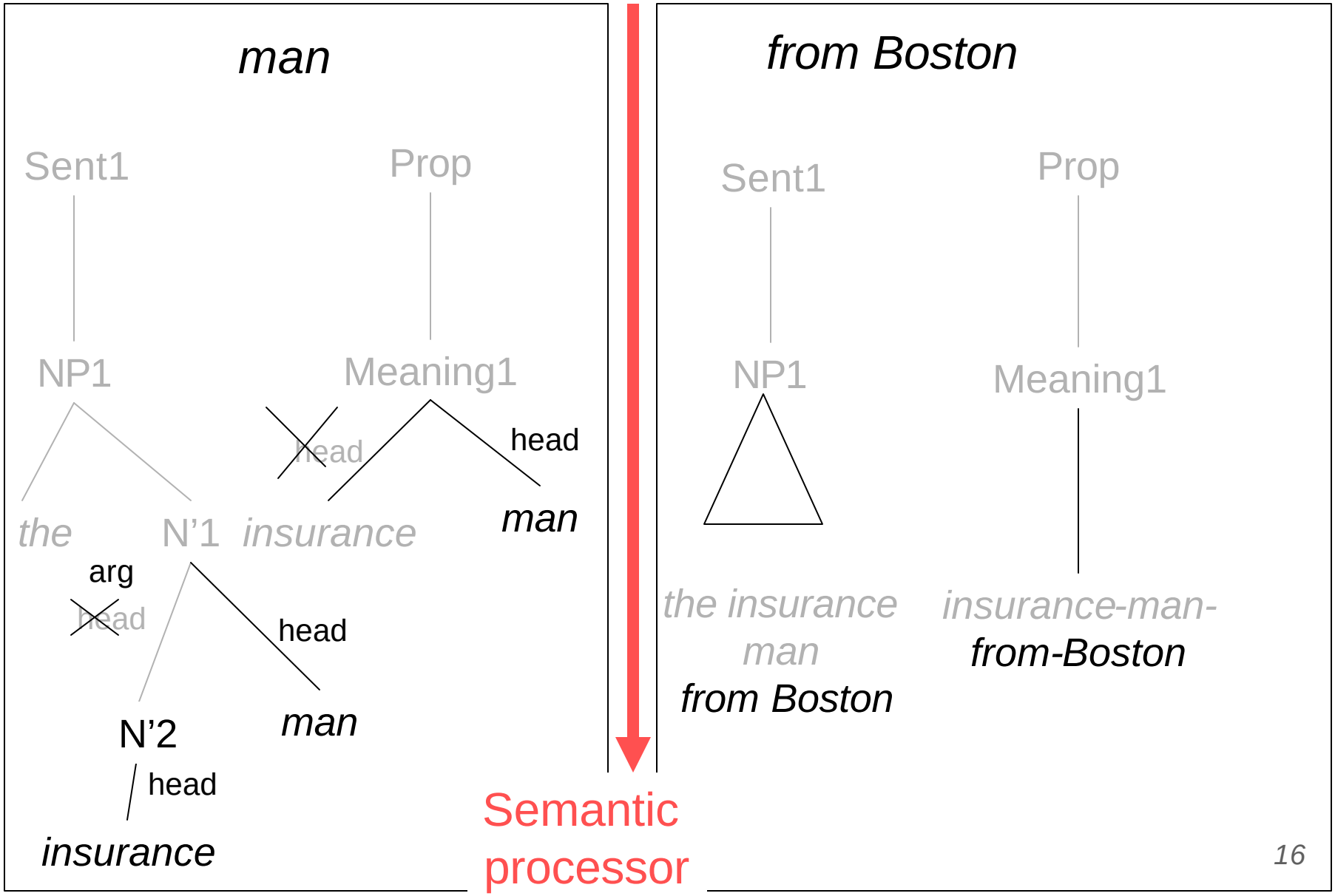

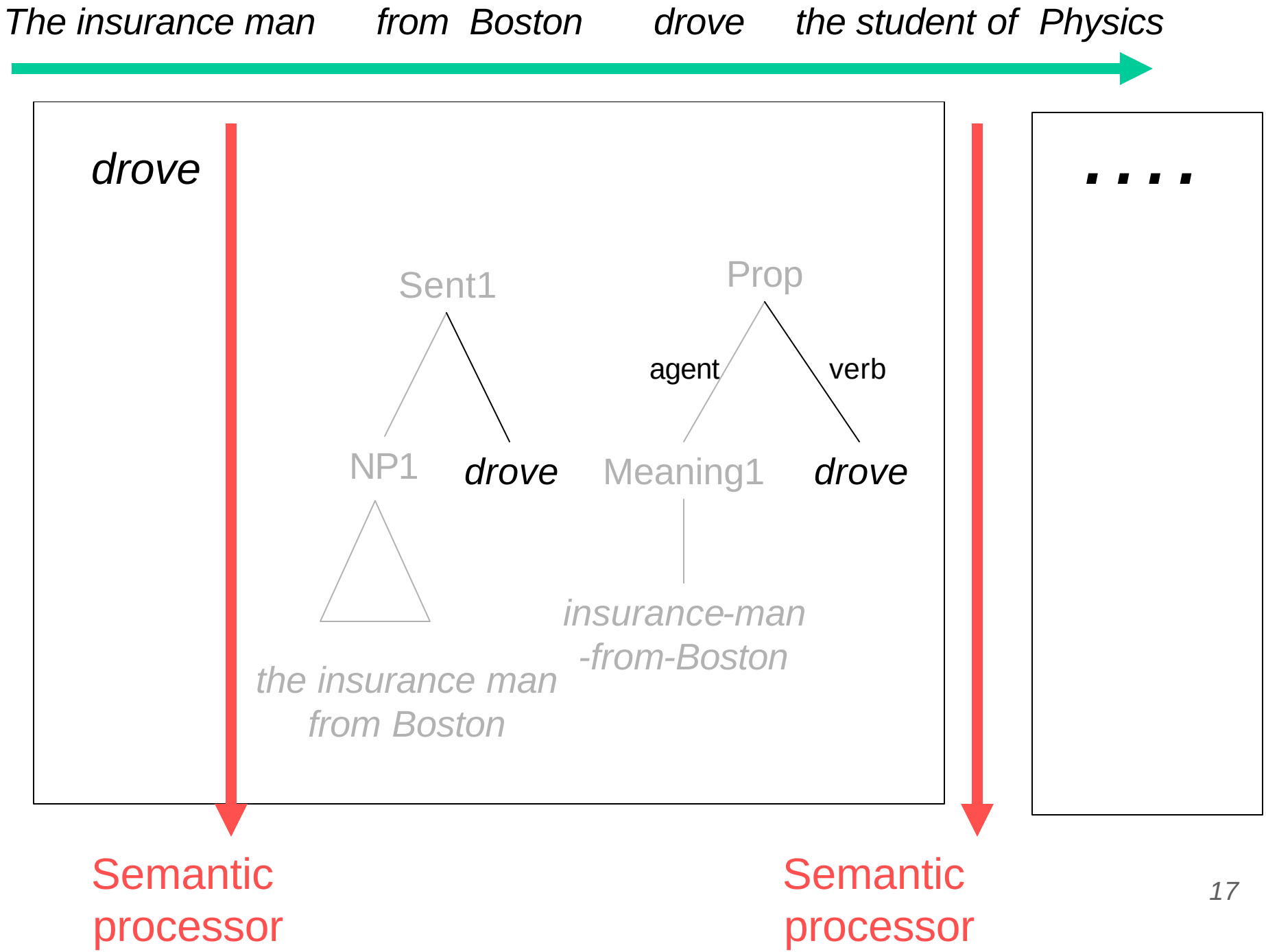
The insurance man
from Boston
drove
the student of
Physics
drove
Sent1
NP1
drove
the insurance man
from Boston
Prop
agent
verb
Meaning1
drove
insurance-man
-from-Boston
. . . .
Semantic
processor
Semantic
processor

The Syntactic Processor: Summary

- Builds the syntactic and semantic representation
- Forms complex meanings from simple meanings (e.g., insurance-man-from-Boston)
- Repairs wrong syntactic assignments (but not semantic-role assignments)

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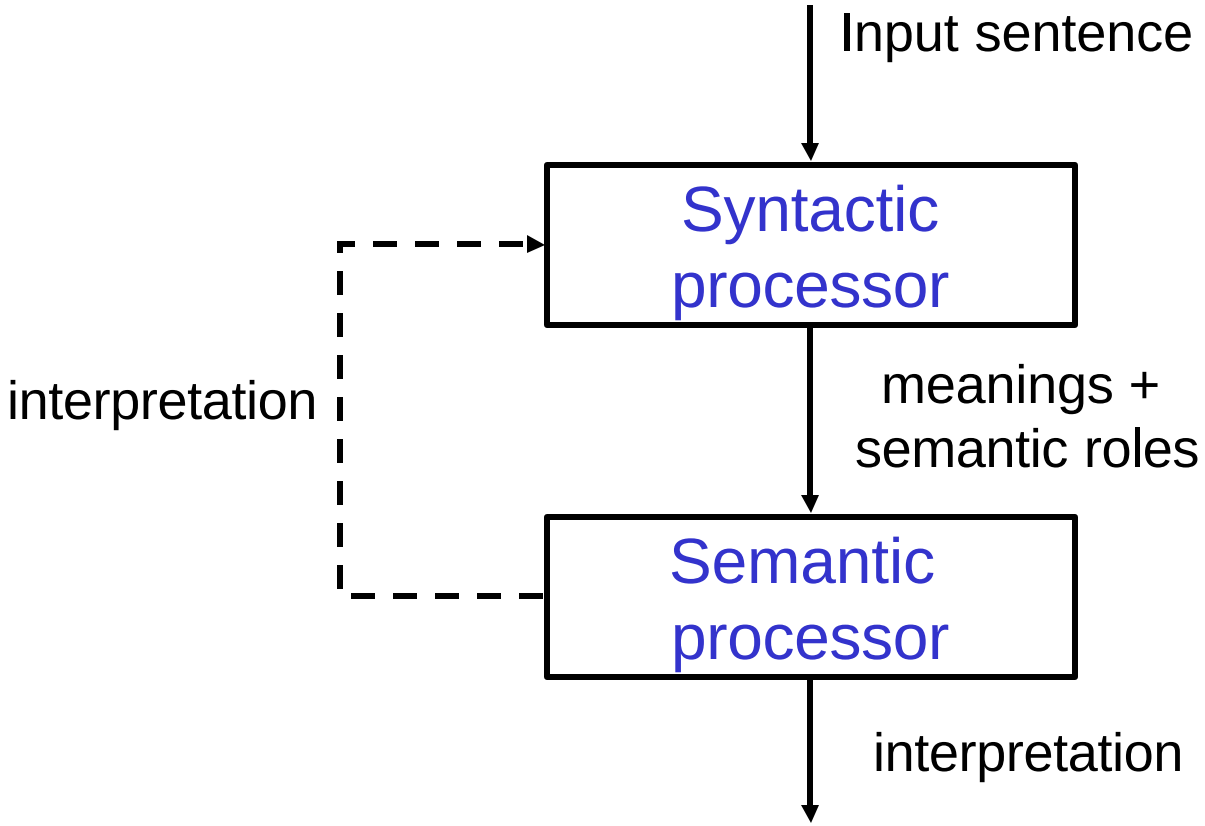
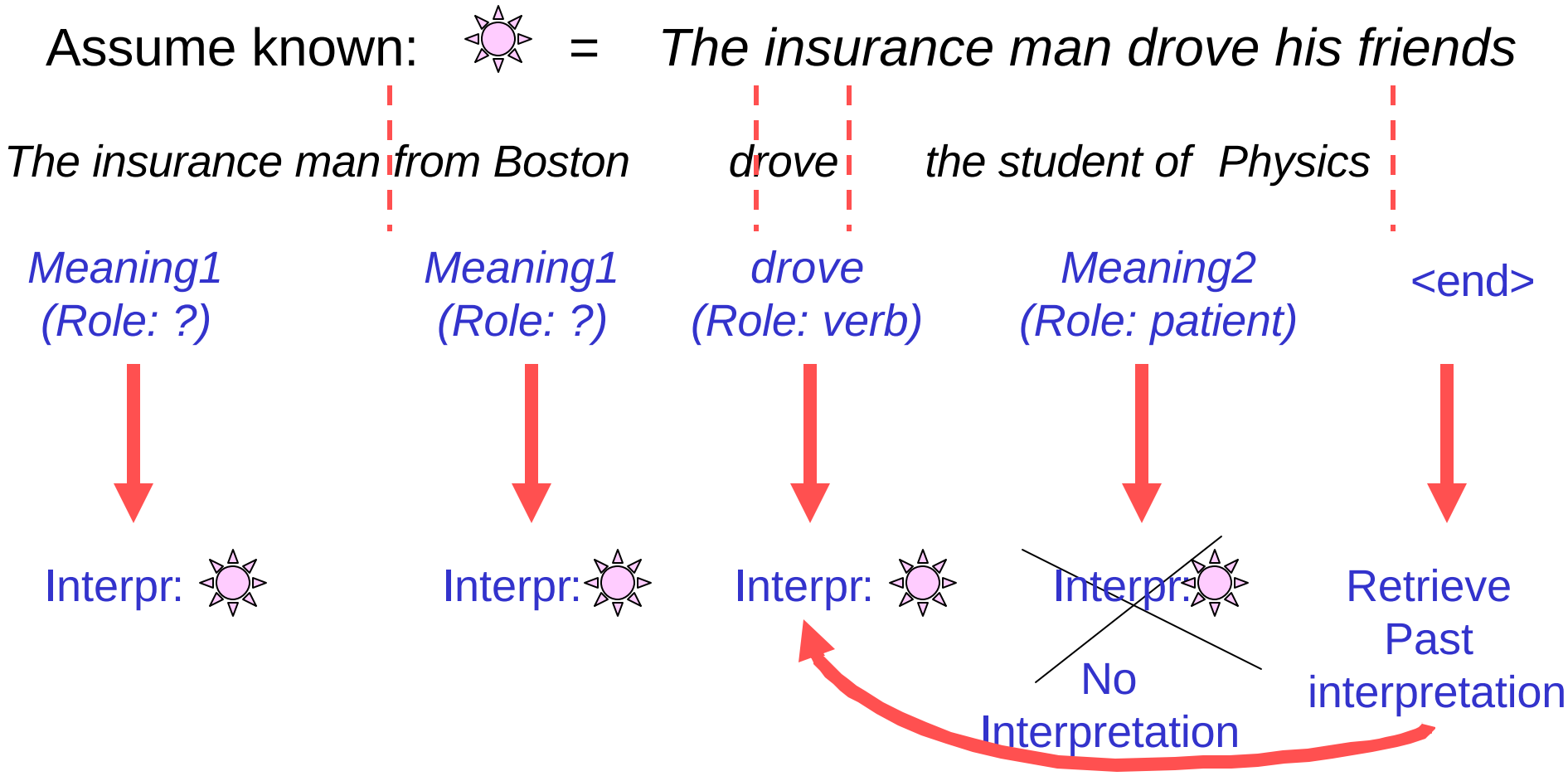
The Semantic Processor

The job of the semantic processor is to find an interpretation as it receives meanings and semantic roles from the syntactic processor.



Semantic Processing



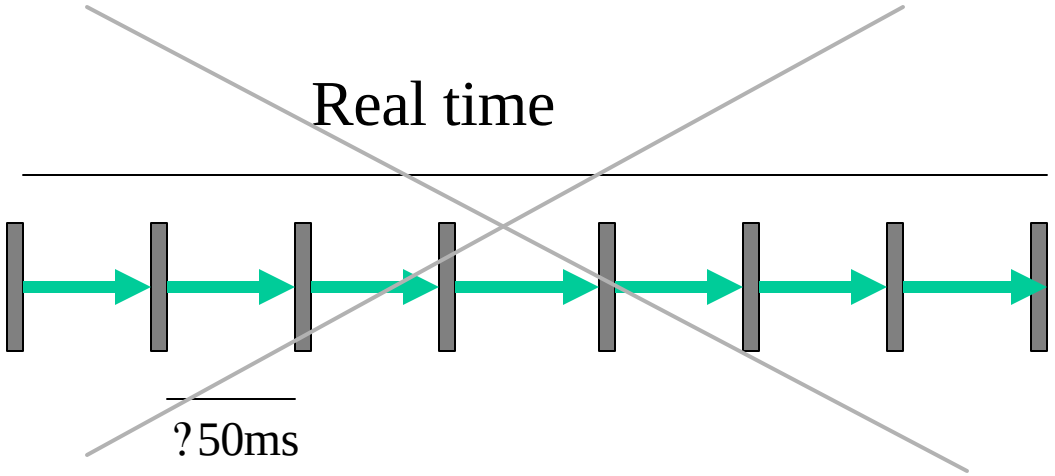
connects the sentence to the past knowledge

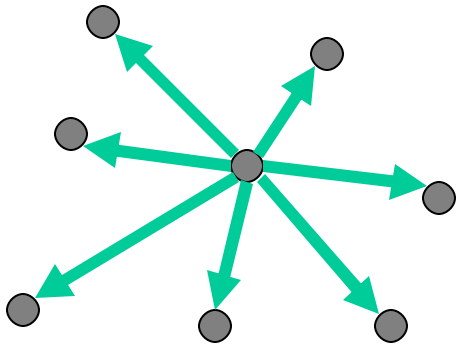
Semantic Processing: Internals

Search-and-match process:

- Search for an interpretation
- Match the interpretation against the current word

- Parallel, subsymbolic activation spreading processes enable high speed

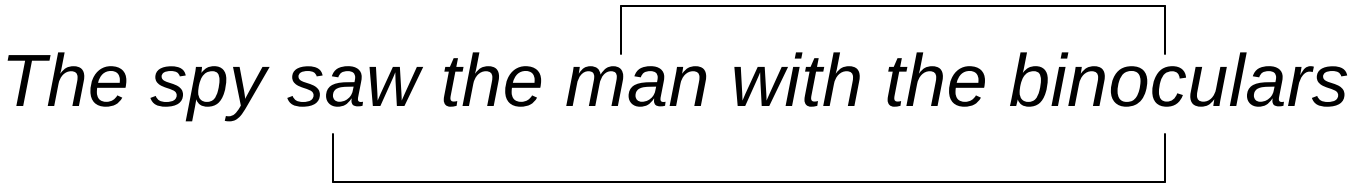




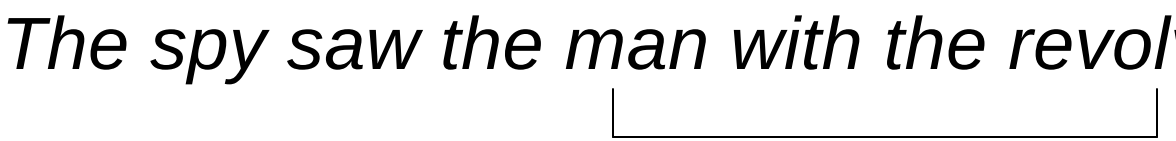
- Activation spreading ✍ associations ✍ semantic similarities (set as LSA distances)

Does Semantics Affect Syntax?

- Domain: syntactic ambiguity



- Traditionally, robust verb-attachment preference



- Question: does the interpretation help make decisions in syntactic-ambiguity cases?

Syntax-Semantics Experiment

NP-passage	VP-passage
<text>	*<text>*
She inspected the vase that she wanted to give to her mother	*She inspected the vase to see the gold mark*
<text>	*<text>*

Targets:

She inspected the vase for her mother once again (NP)

She inspected the vase for the mark once again (VP)

Results: targets congruent with passages are fastest

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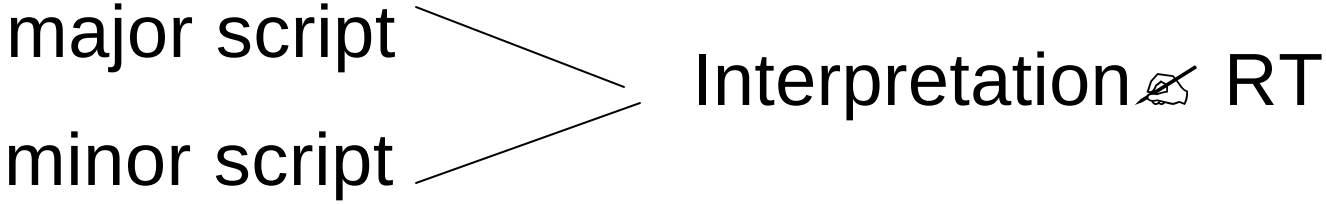
Case Study: Text Priming

(Schwanenflugel & White, 1991)

- Lexical decision after reading a passage
- Passages containing one major theme or two themes (one major, one minor)
- Expectancy of target: with respect to major or minor theme
- Result for people and model:
  - priming effect of major theme (I.e., paragraph context): larger
  - priming effect of minor theme (I.e., local context): smaller

Explanation:



Case Study: Text Priming
(Schwanenflugel & White, 1991)

The equipment they carried was heavy. They had gotten an early start at dawn. It had been a long day for the guys.

Major-theme passage

The hiking trip was the most strenuous the group had had.

Minor-theme passage

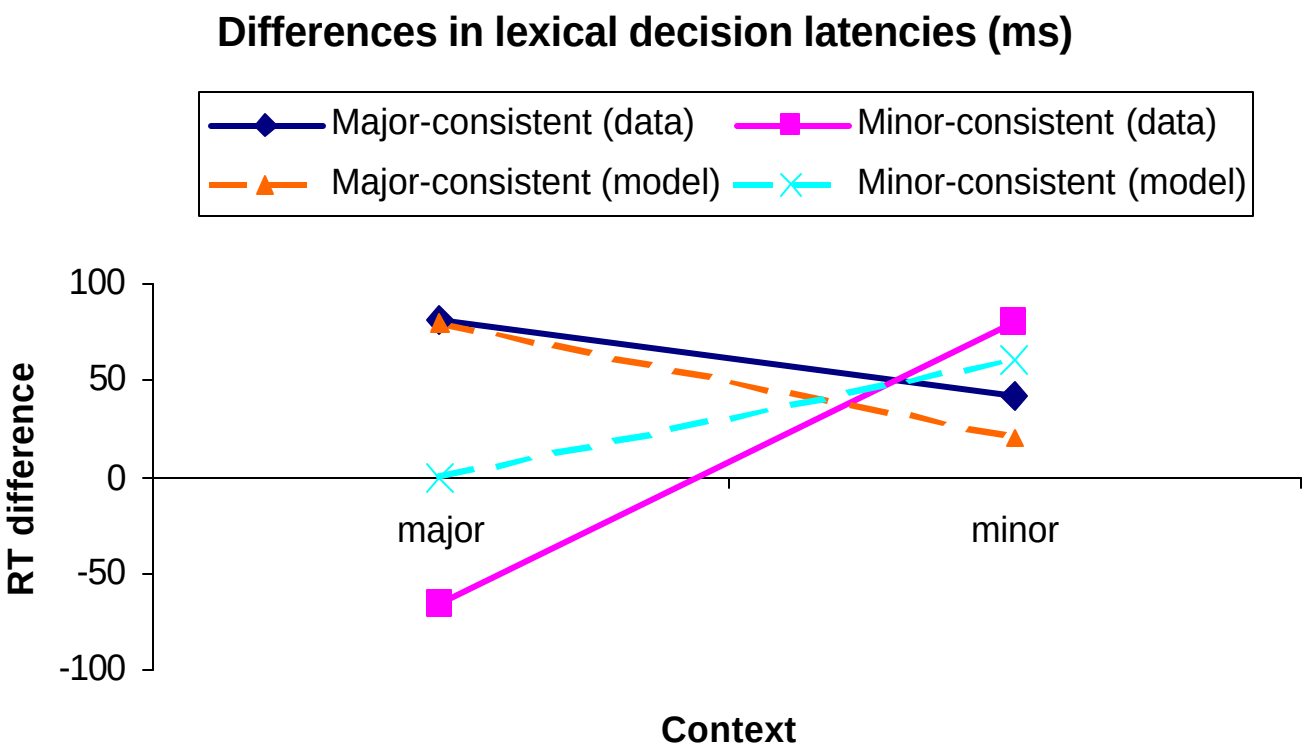
After a treacherous hike, Bill and his friends sluggishly entered their apartment lobby.

The hikers slowly climbed up the

Target words

Major-consistent	*mountain*
Minor-consistent	*stairs*

Text Priming: Data and Model

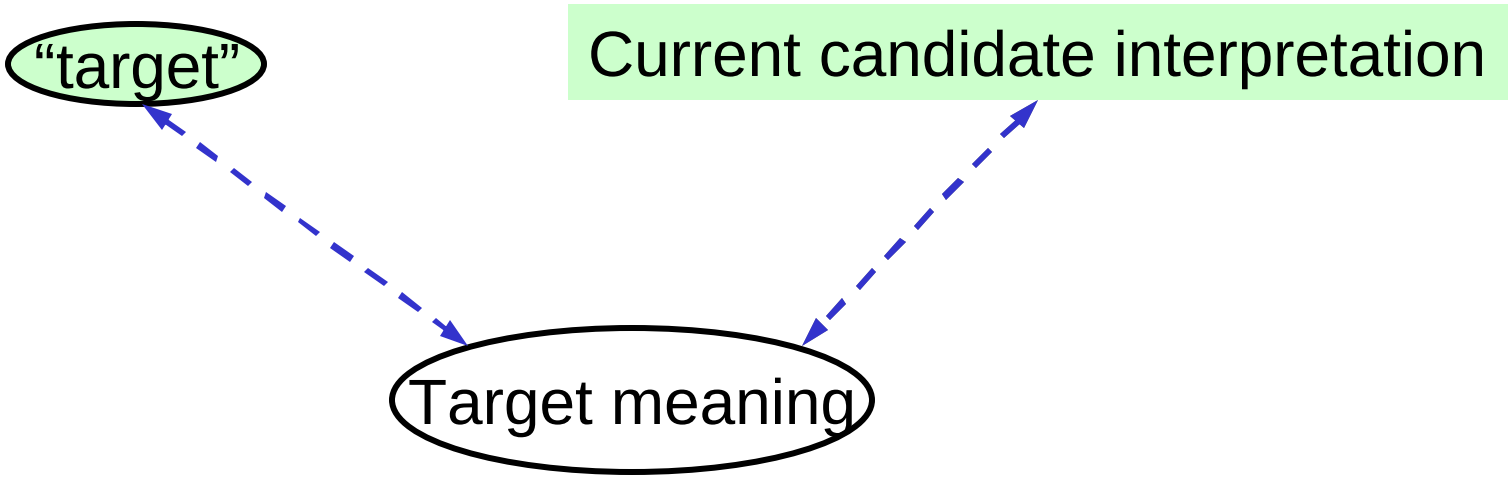


Differences are with respect to the neutral context.
Positive = faster than neutral

Lexical Decision

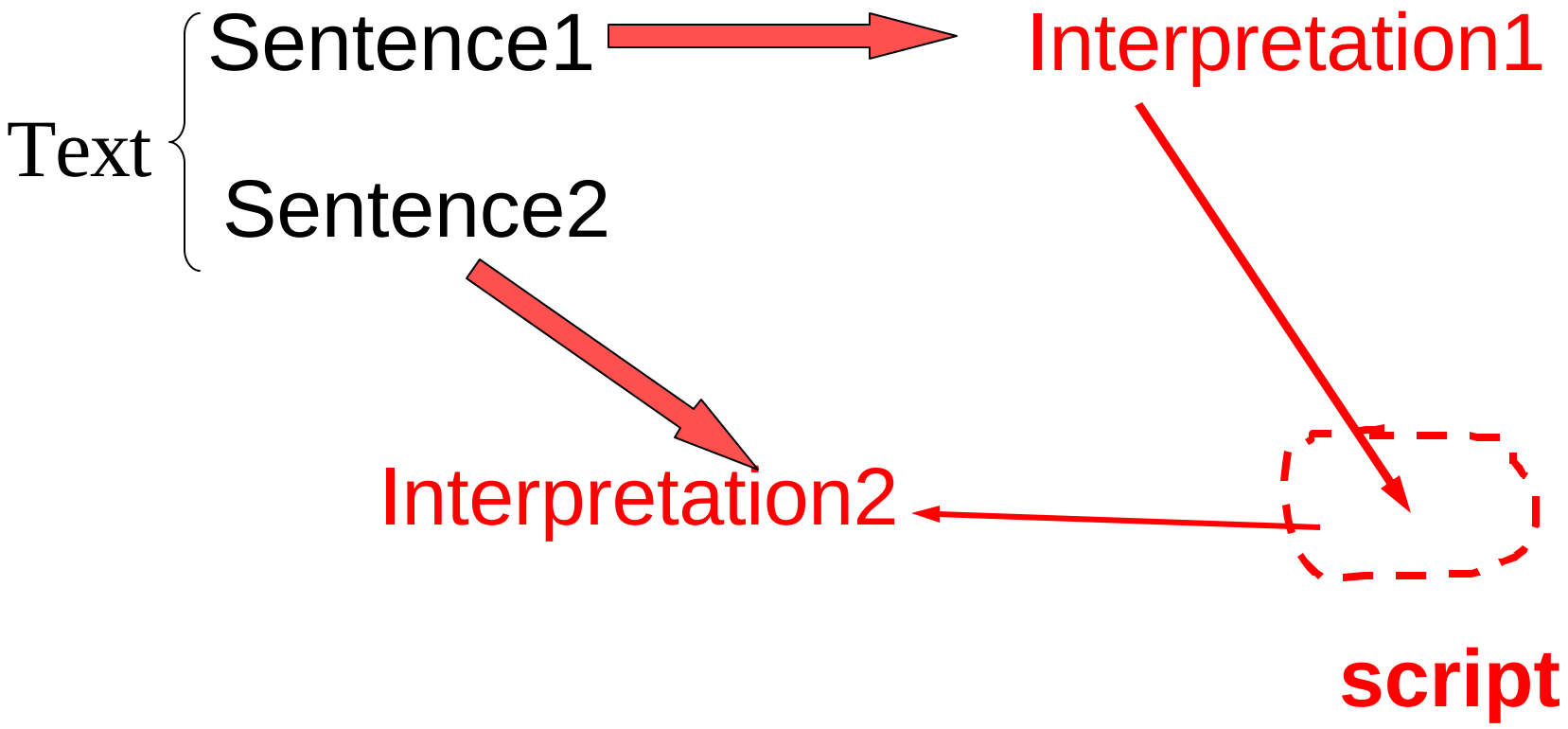
Extract the meaning of the target string

- success of retrieval: word
- failure of retrieval: nonword



More activation ✍ faster response time

Locality of Interpretation



Text Priming Simulation

The equipment they carried was heavy. […]

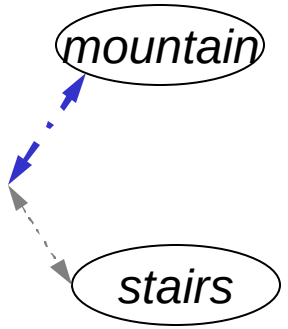
Hike script

The hiking trip was the most strenuous the group had had.

Hike script

The hikers slowly climbed up the

The hikers climbed up the mountain



The equipment they carried was heavy. […]

Hike script

The friends sluggishly entered the apartment lobby.

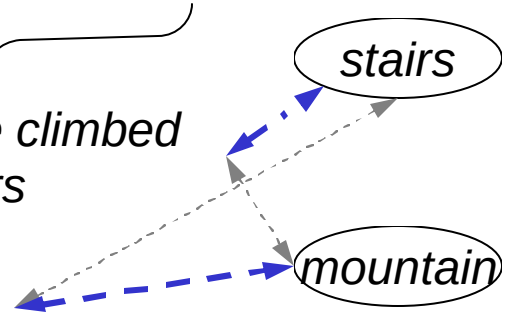
Lobby script

The hikers slowly climbed up the

The people climbed up the stairs

Ç

The hikers climbed up the mountain



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INP and the Real World

- Limited parsing
- Accuplacer reading comprehension test
  - Multiple-choice questions (4 choices)
  - INP: about 60% correct
- Psychology textbook questions
  - Multiple-choice questions and true/false questions
  - INP: about 80%
- LSA for word similarities

Summary

• Real time language processing (from parsing to semantic interpretation) can be achieved by virtue of the parallel, subsymbolic mechanisms of ACT-R.

• Guessing in advance the interpretation of the sentence enables our model to capture on-line language processing effects.