What can Pseudo-relative clauses tell us about principles of parsing?

Aniello De Santo
he/him
(joint work with Dr. So Young Lee)

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Yale Linguistics, April 2024

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Ambiguity All the Way Down

mcsnuggie

true self control is waiting until the movie starts to eat your popcorn

---

leftforbed

why would the movie eat my popcorn

leftforbed

nevermind i get it

Ambiguity All the Way Down

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Ambiguity is ubiquitous in natural language!

- How do parsing mechanisms handle multiple structural representations?
- What kind of principles guide ambiguity resolution cross-linguistically?
- Language specific properties vs. general parsing mechanisms?

In this talk

- Relative clauses as an optimal testing ground
- Computational models to help theory building

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Outline

Attachment Ambiguity and Relative Clauses (RC)

- They saw the daughter of the actress that was on the balcony

NP_1	**The daughter** was on the balcony	HA
NP_2	**The actress** was on the balcony	LA

Universal locality principles?

- English: **LA** interpretation (off-line)
  - Late Closure (Frazier, 1978), Recency (Gibson, 1991; Gibson et al., 1996), etc.

But:

- Spanish: **HA** interpretation (off-line: Cuetos & Mitchell, 88)
  - Tuning Hyp. (Mitchell & Cuetos, 1991), Construal (Frazier & Clifton, 1996), etc.

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Cross-linguistic Differences

Language	Attachment
English	Low
Romanian	Low
Basque	Low
Chinese	Low
German (?)	High/Low
Russian (?)	High
Bulgarian (?)	High/Low
Norwegian (?)	Low
Swedish (?)	Low
Spanish	High
Galician	High
Dutch	High
Italian	High
French	High
Serbo-Croatian	High
Japanese	High
Korean	High
Greek	High
Portuguese	High

Figure: Survey of Attachment preferences from Grillo & Costa (2014)

A Complex Cross-Linguistic Scenario

HA vs LA languages?

RC preferences cross-linguistically affected by a variety of factors

- Syntactic environment
  (Fernandez 2003, Gibson et al. 1996, De Vincenzi and Job 1993)
- Prosodic effects (Teira and Igoa 2007, Hemforth et al. 2015)
- Lexical-semantic properties of the DPs
  (MacDonald et al. 1994, Gilboy et al. 1995)
- Online vs. Offline Differences
  (Fernandez 2003, Wager et al. 2009, Lourenco-Gomes et al. 2011)
- Individual WM effects (Swets et al. 2007)

None of these fully accounts for the LA vs HA variation

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- Individual WM effects (Swets et al. 2007)

None of these fully accounts for the LA vs HA variation

Grillo and Costa (2014)

- HA languages have a a string identical, but structurally and interpretatively distinct, representation from the RC: the *pseudo-relative*

Table 4
Attachment preferences and PR availability.

Language	Attachment	PRs
English	Low	*
Romanian	Low	*
Basque	Low	*
Chinese	Low	*
German (?)	High/Low	*
Russian (?)	High	*
Bulgarian (?)	High/Low	*
Norwegian (?)	Low	✓
Swedish (?)	Low	✓
Spanish	High	✓
Galician	High	✓
Dutch	High	✓
Italian	High	✓
French	High	✓
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Grillo & Costa: Pseudo-RCs in Italian

(1) (Io) Ho visto **[la nonna della ragazza che gridava]**
(I) have seen the grandma of the girl that screaming
'I saw **[the grandma of the girl that was screaming]**"

- RC: HA
- RC: LA

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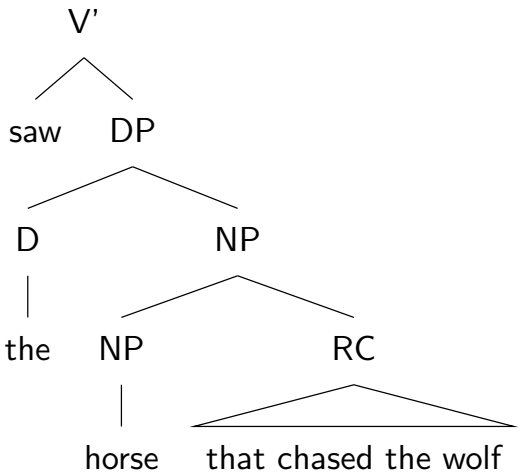
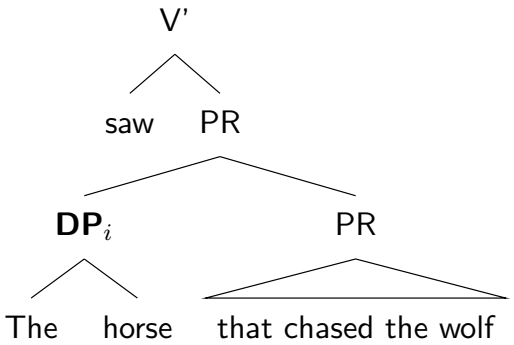
- RC: HA
- RC: LA
- PR





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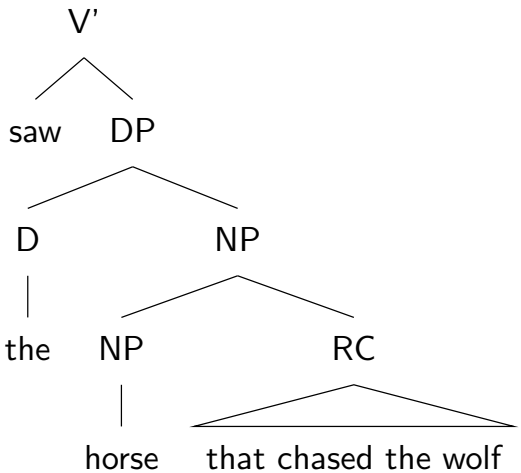
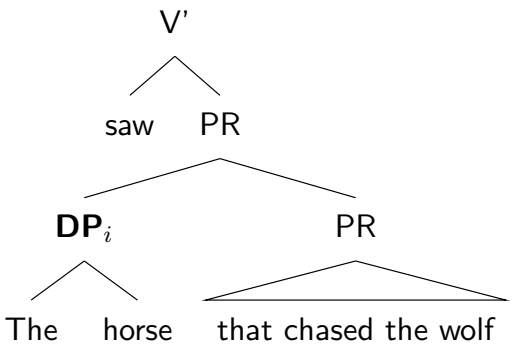
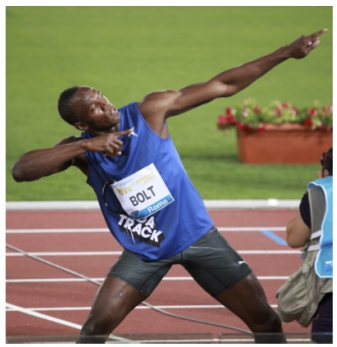




PRs vs RCs: Interpretative Differences[1]

(6) RC: *John saw the man that runs*



∃e [see(e) & EXPERIENCER(e)(John) & STIMULUS(the unique man that ran)(e)]

There is an event of *seeing* and the experiencer of that event is *John* and the stimulus of the event is *the unique man that ran*.

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(7) PR: *John saw the man running*

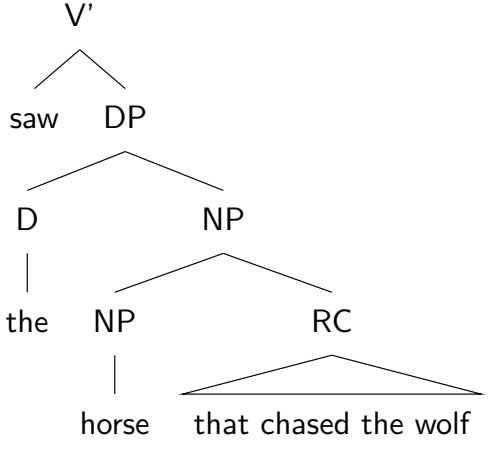
∃e∃e'[see(e) & EXPERIENCER(e)(John) & STIMULUS(e')(e) & run(e') & AGENT(e')(the man)]

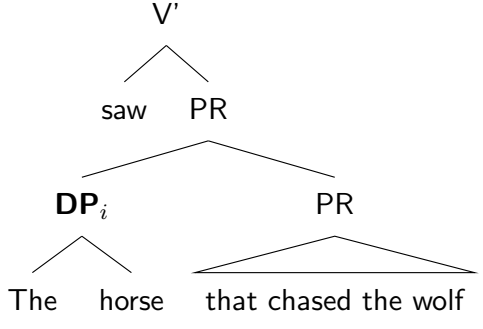
There is an event of *seeing* and the experiencer of that event is *John* and the stimulus of the event is *an event of running* and the agent of running is *the man*.

[1] Example from Pozniak et al. (2019)

PRs vs. RCs

- RCs are NP-modifiers and denote properties of entities
- PRs are complements of VPs and denote events/situations
  - **Only** compatible with a **HA** reading!





So What? PRs and Attachment Preferences

- The grandma of the girl that was screaming
  - RC: HA
  - RC: LA
  - PR: HA

The Pseudo-Relative First Hypothesis (Grillo & Costa 2014)

All else being equal:

- When available: PR **preferred over** RC parse (so: $\sim$ HA)
- Otherwise: LA RC **preferred over** HA RC parse

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(2) (Io) Ho visto **[la nonna della ragazza che gridava]**
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PRs vs. RCs Environments (Guasti 1999, Cinque 1992: a.o.)

- Verb type restrictions
- Tense/aspect restrictions

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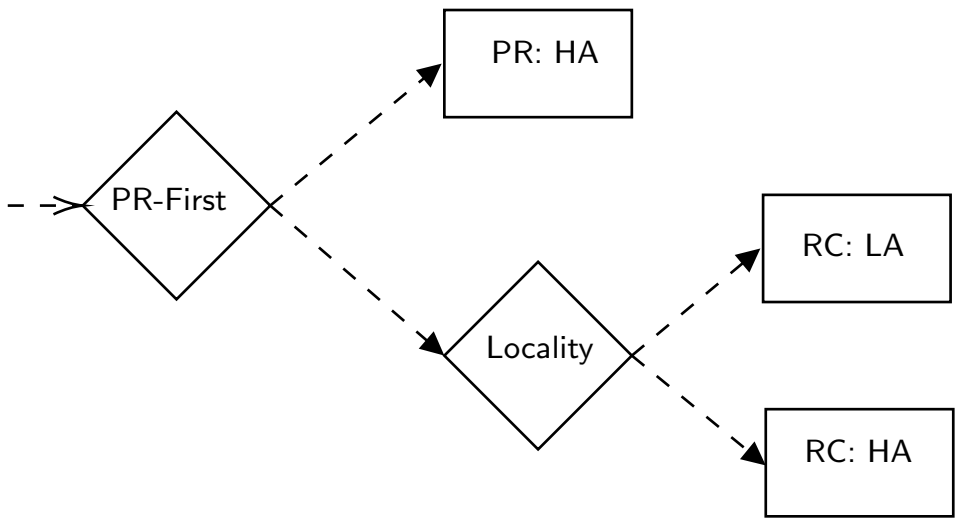

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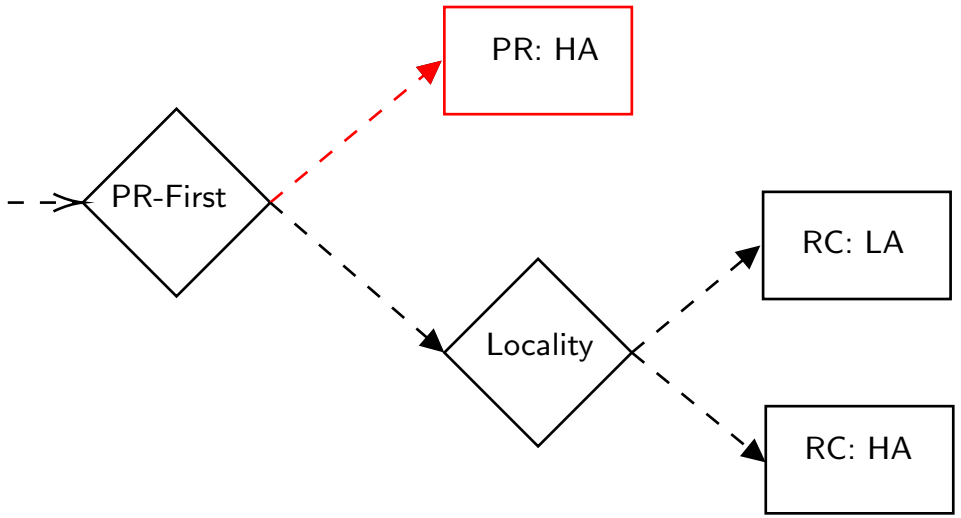

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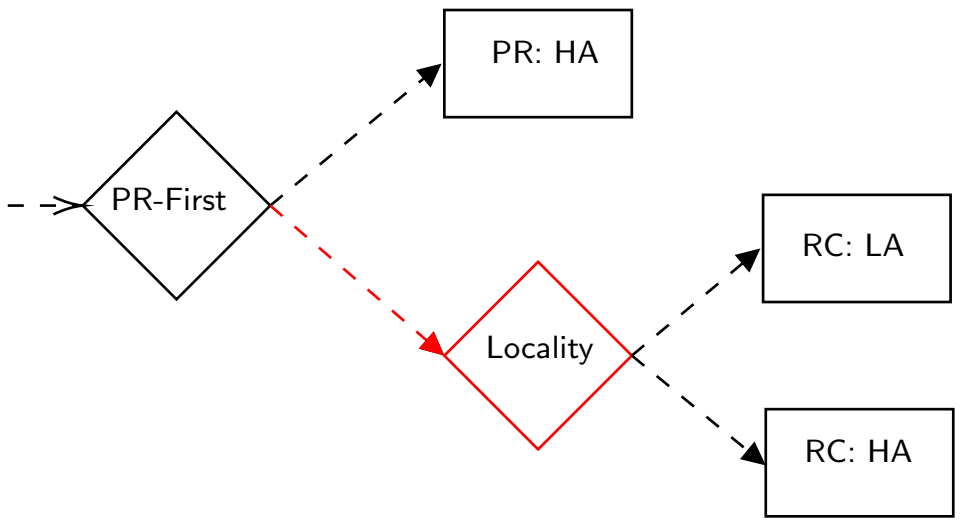

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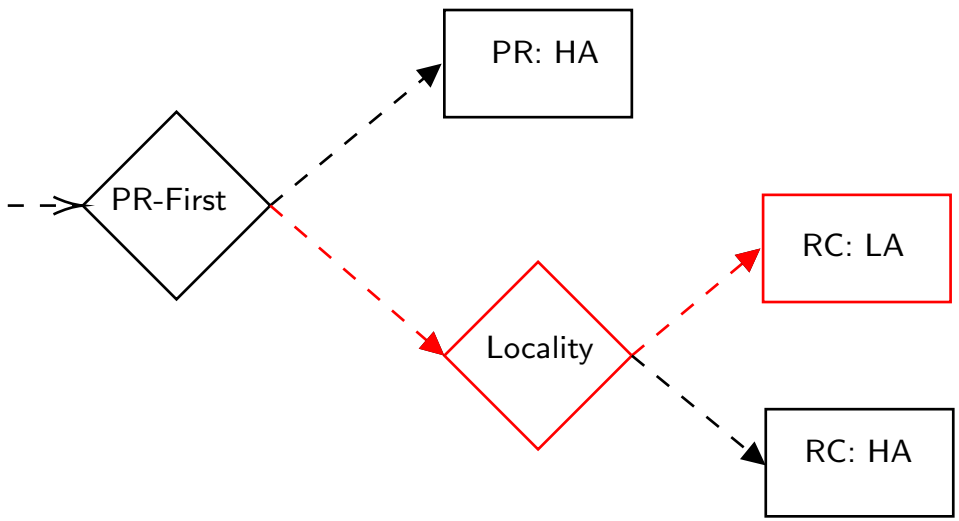

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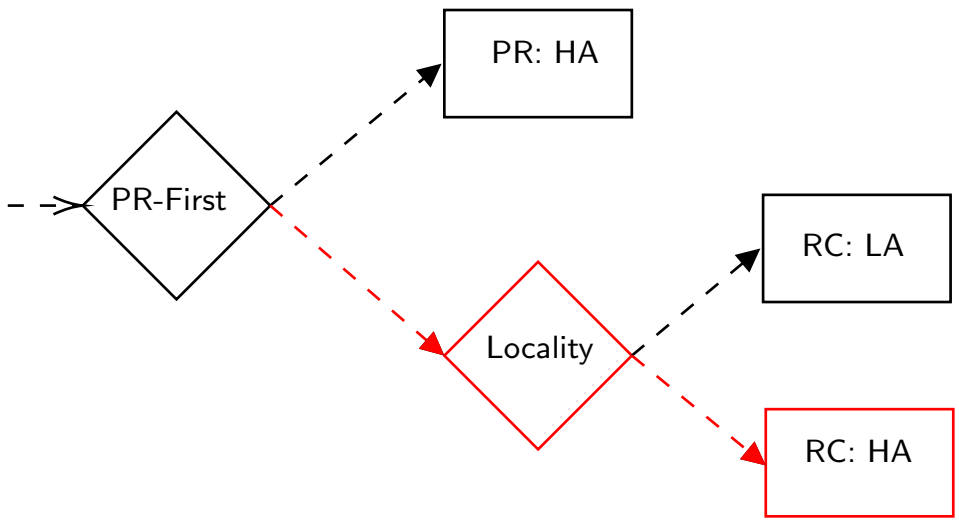

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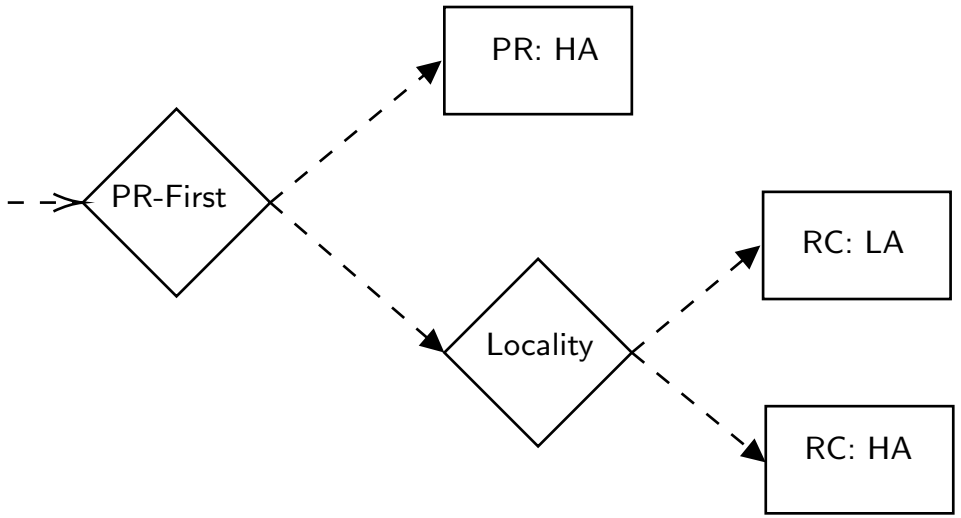

PRs vs. RCs Environments (Guasti 1999, Cinque 1992: a.o.)

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PRs vs RCs: Distributional Restrictions

Verb Type Restrictions

- PRs are eventive!
  1. Ho incontrato/ *Vivevo con Gianni che correva.
     'I met/ *lived with Gianni running.'

Tense Restrictions

- Tense within PR is dependent on the Tense specification of the matrix clause.

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Tense Restrictions

- Tense within PR is dependent on the Tense specification of the matrix clause.

(16) Ho visto il ragazzo/ *Gianni che correrà.
Have.I seen the boy/ *Gianni that run.FUT 'I saw the boy/*Gianni that will run.'

Grillo and Costa (2014)

- The daughter of the actress **[that was on the balcony]**
  - RC: HA
  - RC: LA
  - PR: (∼) HA

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(57) **Stimuli Experiment II**

a. PR/ RC CONDITION: PR-VERBS
Gianni ha visto il figlio del medico che correva.
G. saw the son of the doctor running.

b. RC ONLY CONDITION: STATIVE VERBS
Gianni vive con il figlio del medico che correva.
G. lives with the son of the doctor running.

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Table 6
Percentage of high attachment preferences.

Eventive	Stative
78.6%	24.2%

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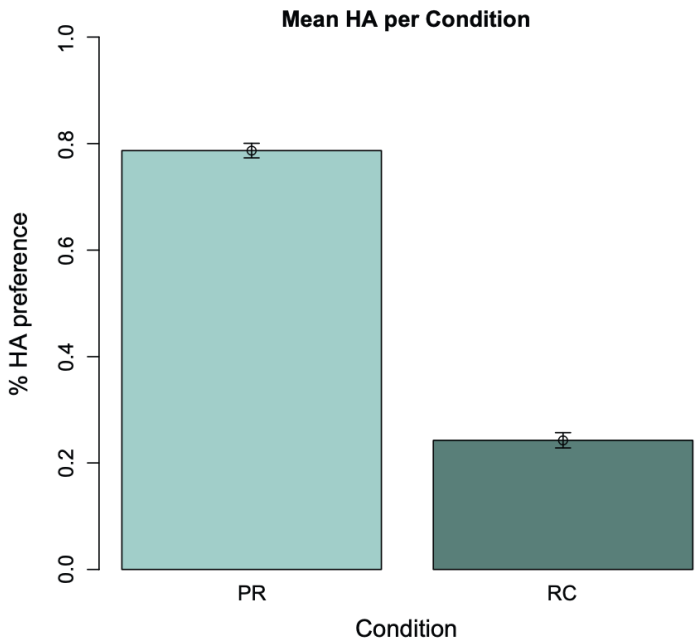

Fig. 2. Summary of attachment preference experiment 2.

Grillo and Costa (2014) [cont.]

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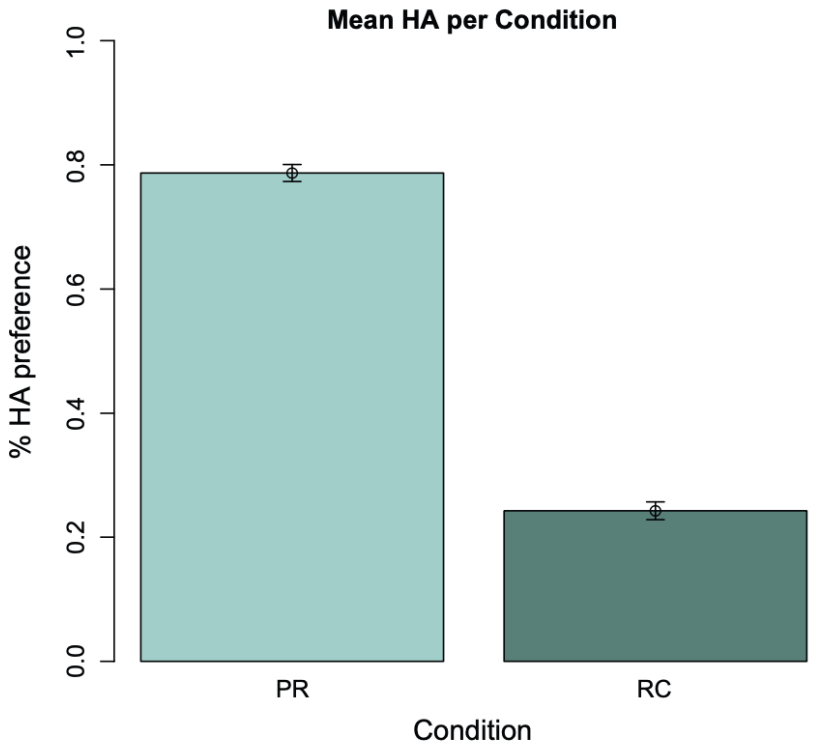
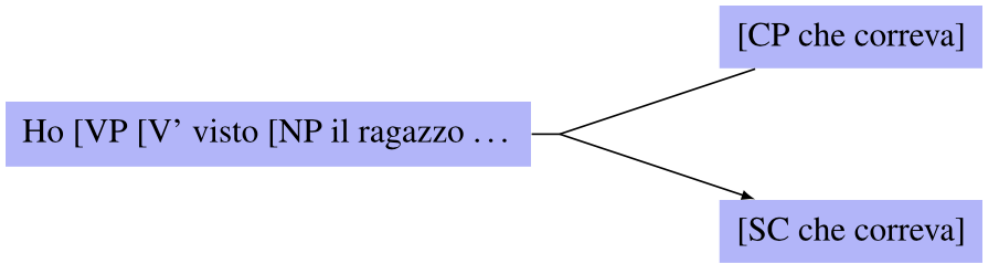


Fig. 2. Summary of attachment preference experiment 2.

- Similar offline effects found for Spanish, French, Greek, European Portuguese, a.o.

PR-First and Online Preferences



- Offline results in support of PR-first!
- PR-first makes predictions about the timing of ambiguity resolution (PR vs. RC)...
- ...and about the timing of locality principles in RC-only contexts
- **But** scarcity of online studies!

PR-First and Online Preferences

Pozniak et al. (2019): Eye-tracking in French/English

- verb type (perceptual/stative) and tense (match/mismatch).
- PR-advantage: shorter regression-path duration for the tense-matching condition at target in PR-contexts in French (but not in English!)
- Crucially: no LA/HA disambiguation in this study

Aguilar et al. (2021): Eye-tracking in Spanish

- verb type (perceptual/stative) and attachment type (by gender agreement), all tense matched
- PR-effect in total RT duration: HA preferred over LA in PR contexts
- no PR-effect in more fine-grained measures (i.e. regression path duration) at target
- early preference for LA in RC-only (but not later)

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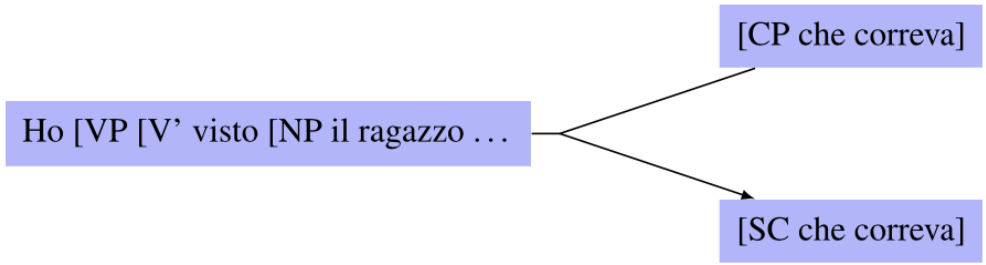
PRs Online



1. Online effects of PR availability on ambiguity resolution strategies?
2. Locality principles in RC disambiguation, when PR availability is controlled for?

Italian PRs Online [2]

Question: Online effects of PR availability?

- Modulating:
  - Type of Verb: Perceptual vs. Non-perceptual
  - Attachment: HA vs. LA
- Temporal ambiguity HA/LA until # agreement on the **verb**

	Verb (PR availability)	Attachment				Target	Spillover 1	Spillover 2
a.	Perceptual (PR/RC)	LA	*Gianni vide il figlio dei*	*medici*	*che*	*correvano*	*la*	*maratona*
			Gianni saw the son-SG of the	*doctors-PL*	*who*	*were running-PL*	*the*	*marathon*
b.	Perceptual (PR/RC)	HA	*Gianni vide il figlio dei*	*medici*	*che*	*correva*	*la*	*maratona*
			Gianni saw the son-SG of the	*doctors-PL*	*who*	*was running-SG*	*the*	*marathon*
c.	Non-Perceptual (RC only)	LA	*Gianni amò il figlio dei*	*medici*	*che*	*correvano*	*la*	*maratona*
			Gianni loved the son-SG of the	*doctors-PL*	*who*	*were running-PL*	*the*	*marathon*
d.	Non-Perceptual (RC only)	HA	*Gianni amò il figlio dei*	*medici*	*che*	*correva*	*la*	*maratona*
			Gianni loved the son-SG of the	*doctors-PL*	*who*	*was running-SG*	*the*	*marathon*

[2] De Santo & Lee (2022a), Lee & De Santo (u.r.)

Trial Example

- Self-paced, non-cumulative moving window
- Followed by a forced choice comprehension task (*Who run?*)

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Gianni

Trial Example

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saw

Trial Example

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actors

Trial Example

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that

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were

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running

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marathon.

Trial Example

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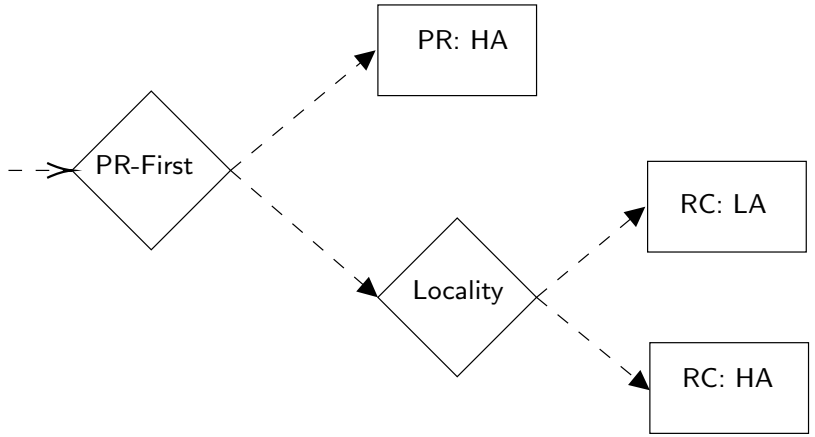
Who run?

the son the actors

Decomposing the Hypothesis: Perceptual Verbs



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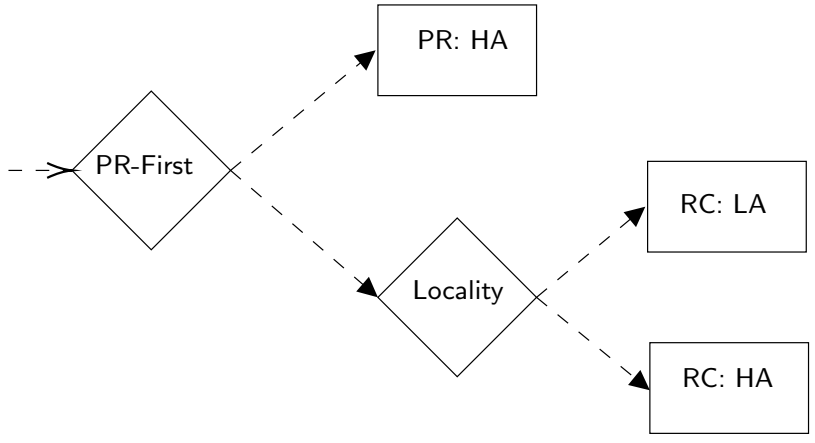
Perceptual Verbs

- PR vs RC
- PR-first: HA-like interpretation is preferred
- LA disambiguation (on verb) should be costly

Decomposing the Hypothesis: Non-Perceptual Verbs



	Verb (PR availability)	Attachment				Target	Spillover 1	Spillover 2
a.	Perceptual (PR/RC)	LA	*Gianni vide il figlio dei*	*medici*	*che*	*correvano*	*la*	*maratona*
			Gianni saw the son-SG of the	*doctors-PL*	*who*	*were running-PL*	*the*	*marathon*
b.	Perceptual (PR/RC)	HA	*Gianni vide il figlio dei*	*medici*	*che*	*correva*	*la*	*maratona*
			Gianni saw the son-SG of the	*doctors-PL*	*who*	*was running-SG*	*the*	*marathon*
c.	Non-Perceptual (RC only)	LA	*Gianni amò il figlio dei*	*medici*	*che*	*correvano*	*la*	*maratona*
			Gianni loved the son-SG of the	*doctors-PL*	*who*	*were running-PL*	*the*	*marathon*
d.	Non-Perceptual (RC only)	HA	*Gianni amò il figlio dei*	*medici*	*che*	*correva*	*la*	*maratona*
			Gianni loved the son-SG of the	*doctors-PL*	*who*	*was running-SG*	*the*	*marathon*

Non-Perceptual Verbs

- Just RC
- LA interpretation (more local) is preferred
- HA disambiguation (on verb) should be costly

Study Details: Sum Up

- Temporarily ambiguous sentences modulating:
  - Type of Verb: Perceptual vs. Non-perceptual
  - Attachment: HA vs. LA

Hypothesis

Perceptual Verbs

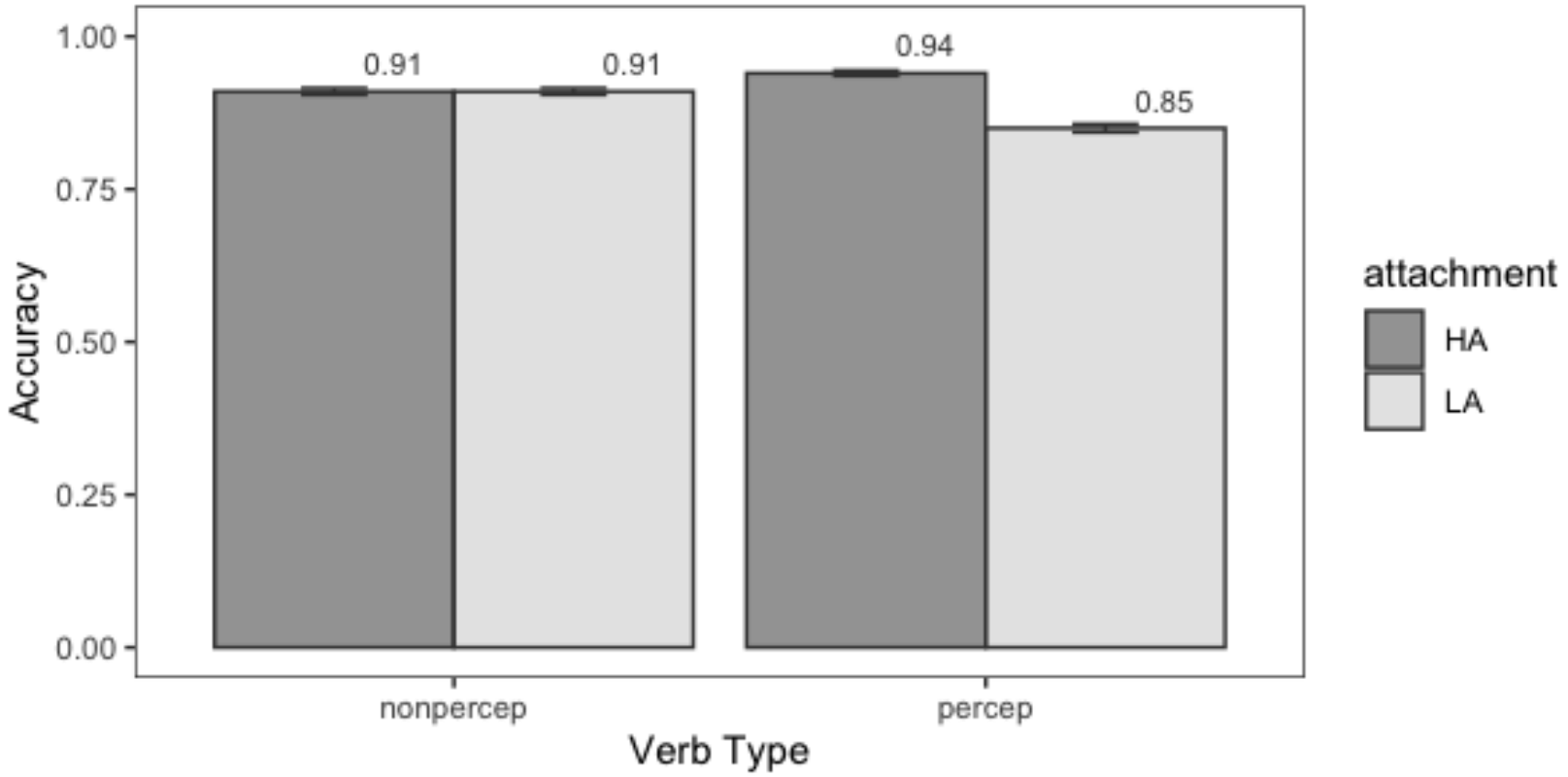
- LA disambiguation (on verb) should be costly

Non-Perceptual Verbs

- HA disambiguation (on verb) should be costly

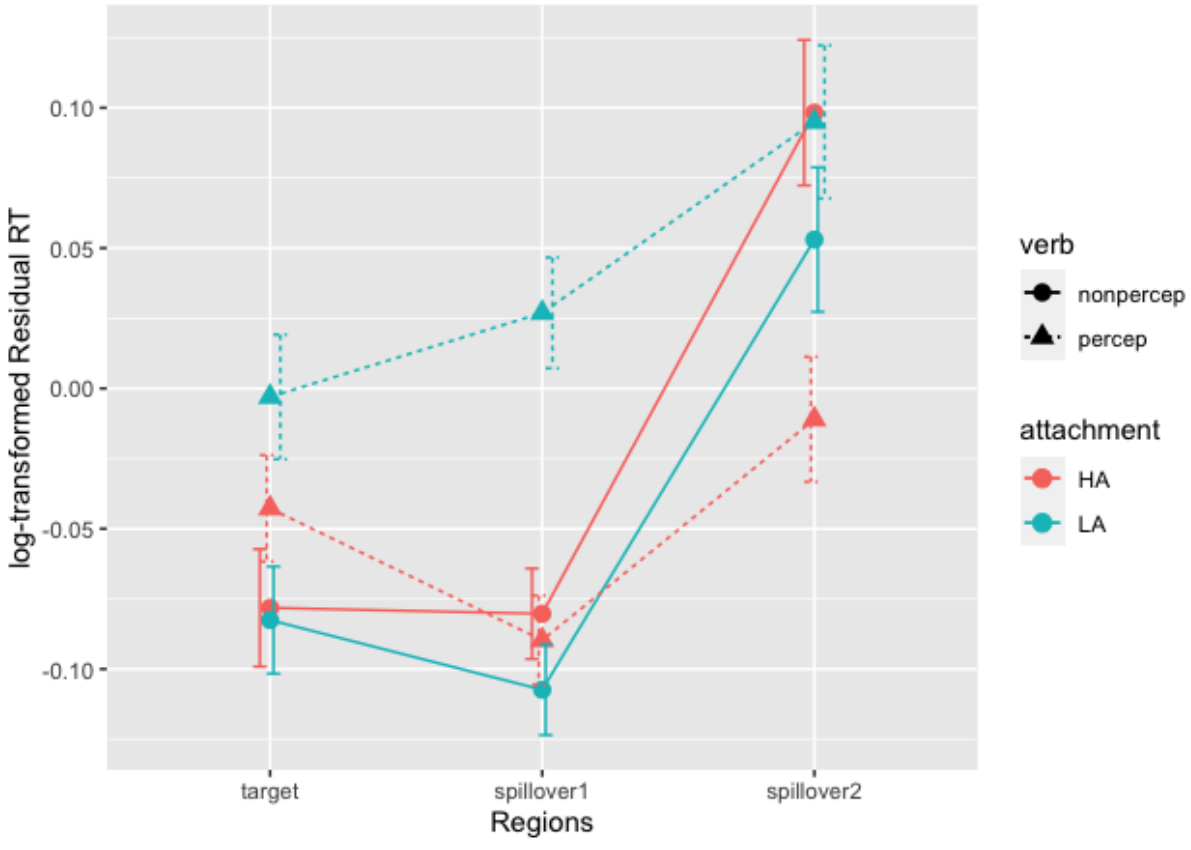
- Participants recruited through Prolific, run on Ibex Farm
- 93 participants analyzed (comprehension $> 80\%$)
- 24 item sets, 48 fillers

Results: Comprehension Accuracy



- Significant effect of Verb and Verb∗Attachment.
- PR effect with perceptual verbs!
- No LA preference with stative verbs!

Results: RTs by ROI



Hypothesis

- **Percep**: LA costly
- **Non-Perc**: HA costly

- Target: No effect
- Spillover 1: Verb*Attachment ($p < 0.001$)
- Spillover 2: Verb ($p < 0.001$)

Interim Summary

The Question: Online effects of PR availability in Italian?

Hypothesis

Perceptual Verbs

- LA disambiguation (on verb) should be costly

Non-Perceptual Verbs

- HA disambiguation (on verb) should be costly

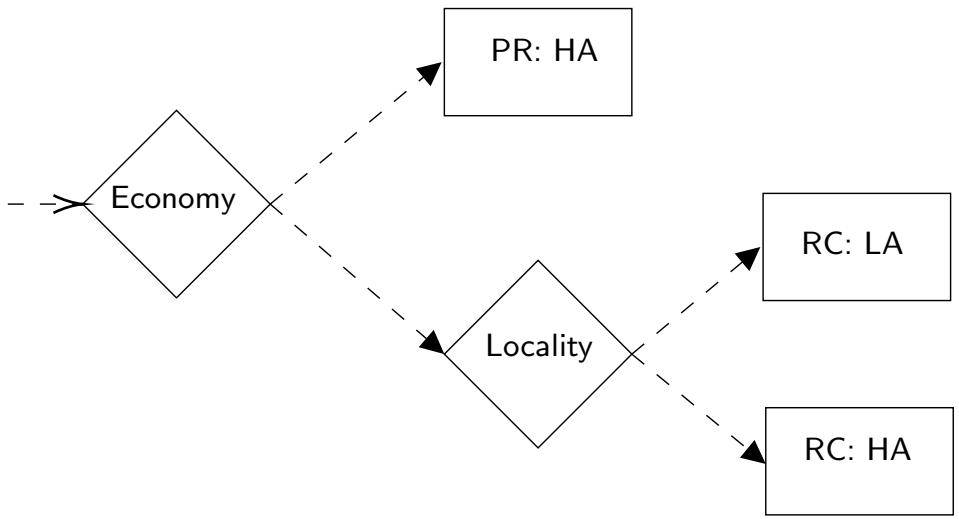
- Differences between PR-licensing and not PR-licensing verbs
- Significant slowdown in the LA condition with perceptual verbs
  - Online evidence to the PR-hypothesis (for Italian)
- No online evidence of locality principles with non-perceptual verbs

Outline

PR-First: Why?

Question

Why should PRs be preferred?



PR-First: Why?

Question

Why should PRs be easier/preferred?

Structural Economy

- PR structurally less complex than RC
- RCs: richer and more articulated functional domain

Pragmatic Economy

- Reference Theory (Altmann & Steedman, 1988; Crain & Steedman, 1985)
  the RC analysis requires building a context which contains more referents than the SC analysis.

Can we evaluate economy quantitatively?

PR-First: Why?

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The Role of Economy

- Economy considerations ubiquitous in Generative syntax
  (Chomsky 1995, Collins 2001, Boskovic and Messick 2017, a.o.)

But:

- What is the relevant notion of cost?
- What does simplicity mean in practice?
- Do fine-grained syntactic details matter?

What's to come

- Implemented economy principles might diverge from general intuitions
- **A Test Case**:
  → A Naive implementation of structural economy
  → MG parsing as a testing framework!

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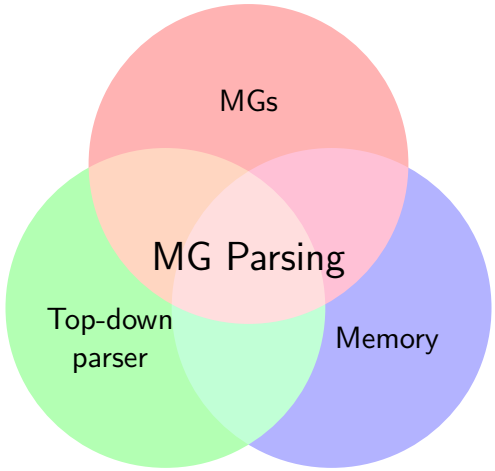
Transparent Computational Models



The MG model (Kobele et al. 2013; De Santo 2020; a.o.)

1. A formal model of syntax → Minimalist grammars (MGs)
2. A theory of how structures are built → MG parser
3. Complexity metrics: memory cost ⇒ processing complexity

- Successful on a variety of cross-linguistic constructions
- Tight connection with current generative syntax

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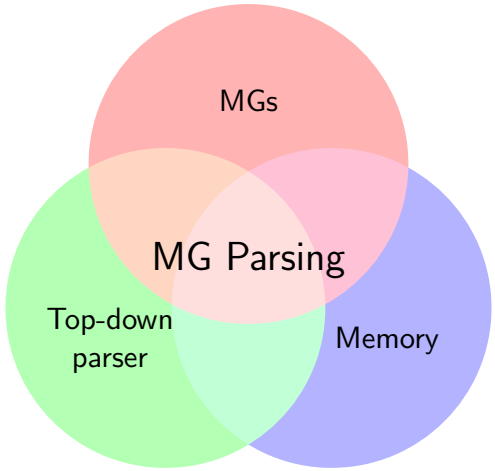

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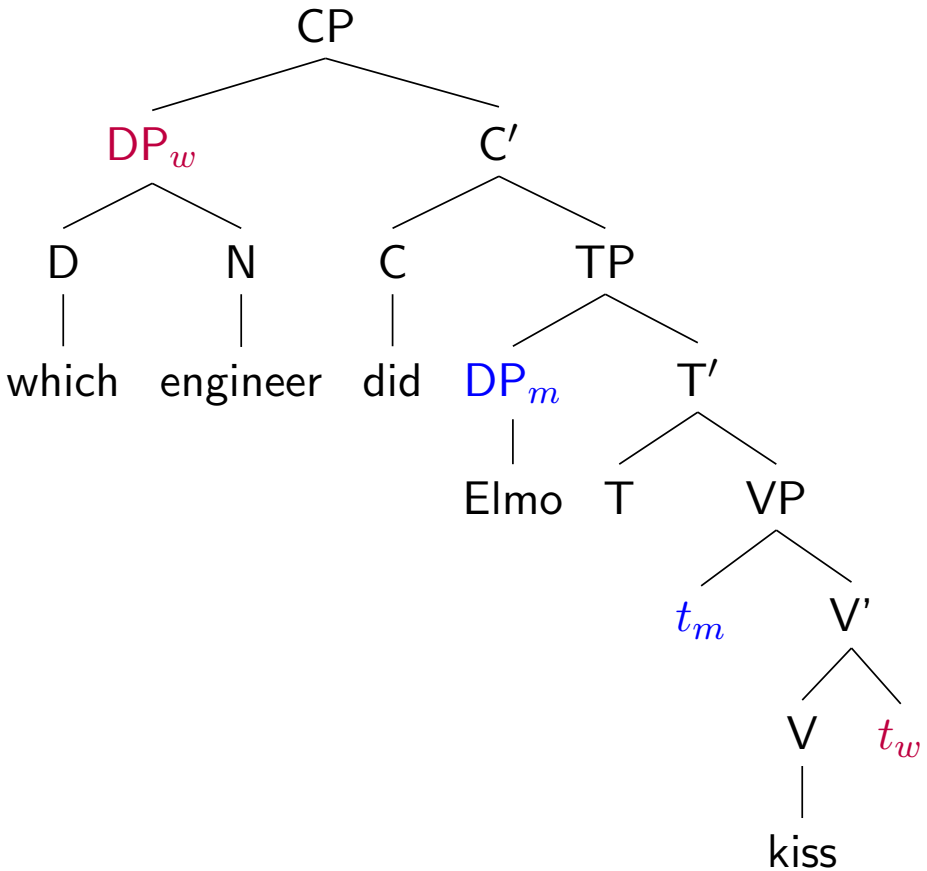
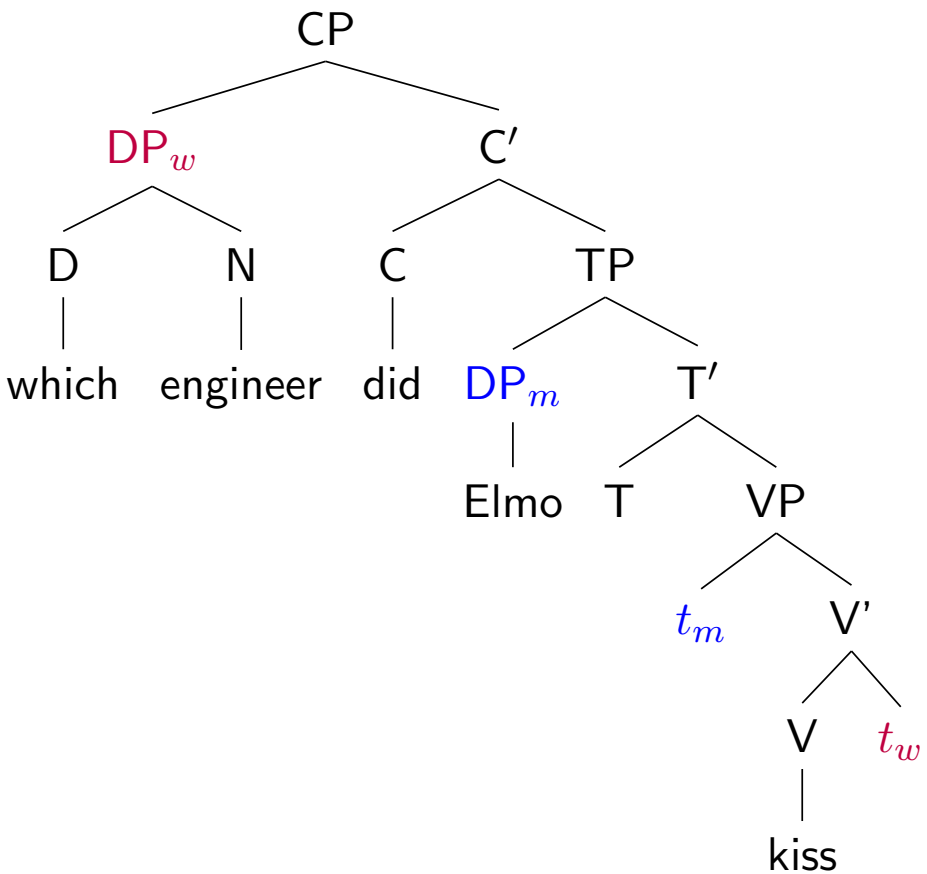
Minimalist Grammars (MGs) & Derivation Trees



Phrase Structure Tree

Minimalist Grammars (MGs) & Derivation Trees



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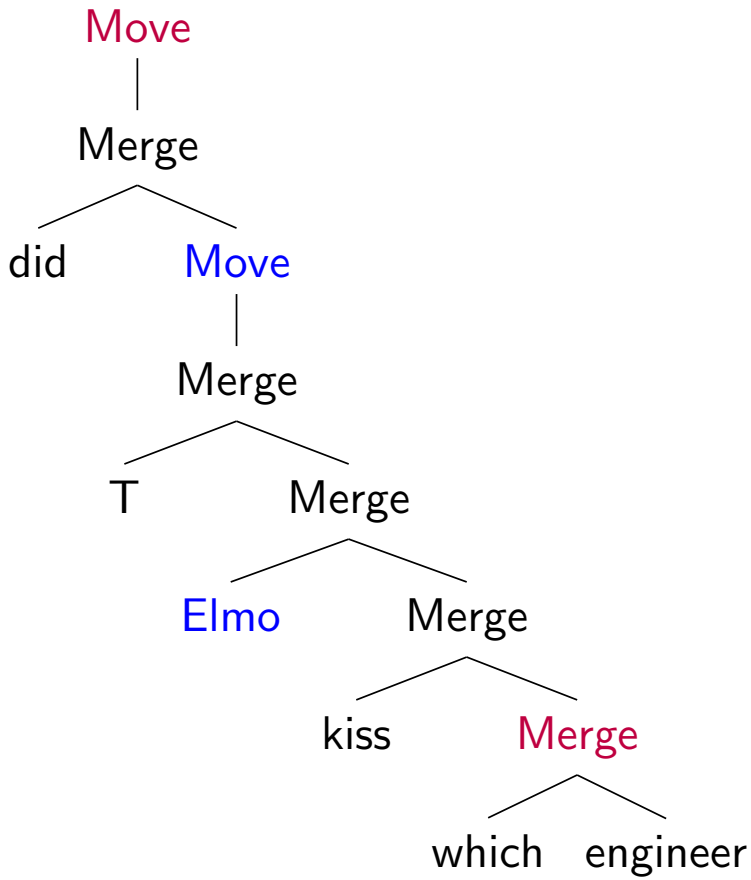
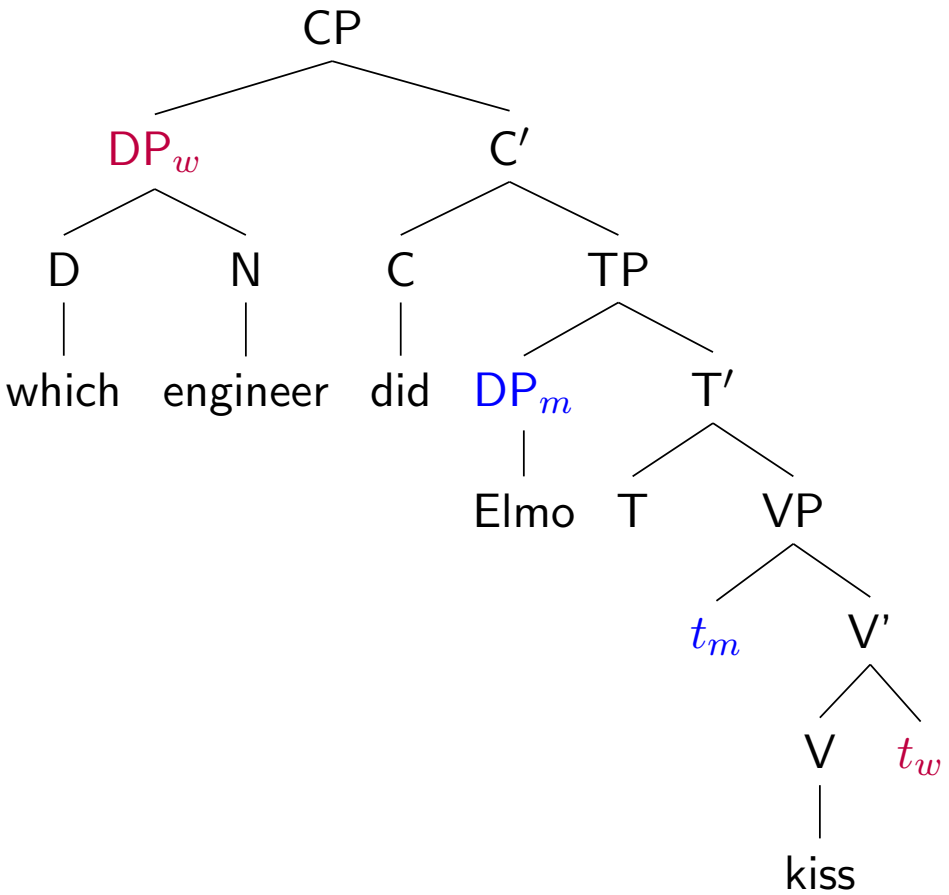


Derivation Tree

MG Syntax: Derivation Trees



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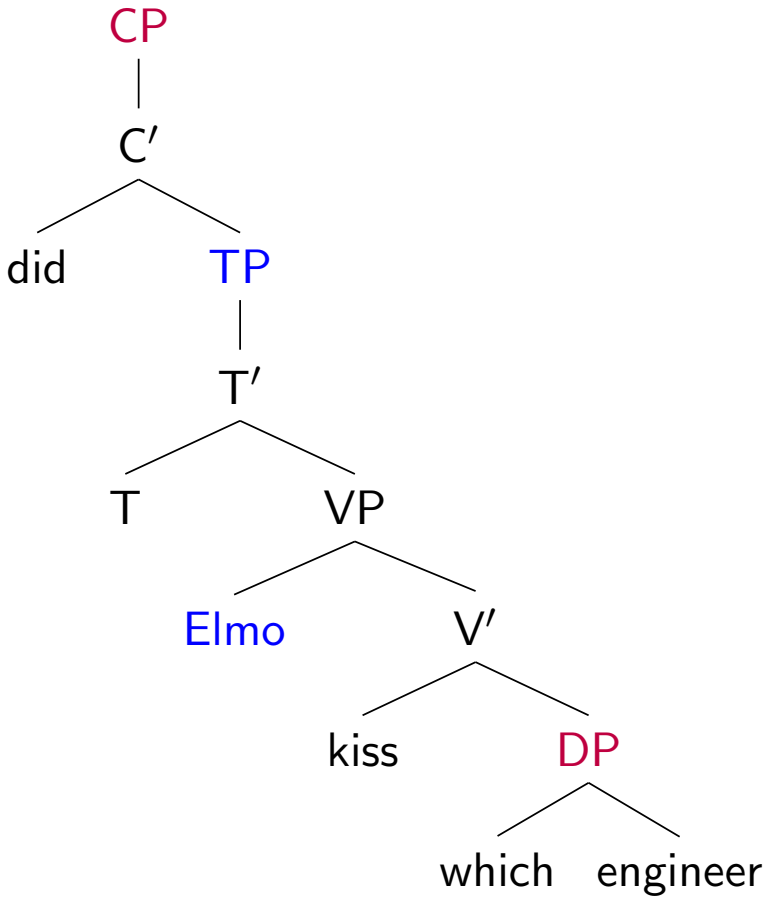
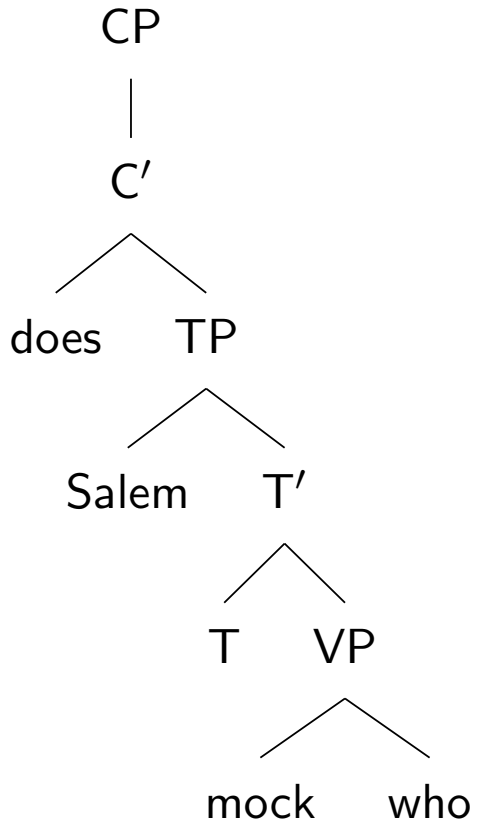


Derivation Tree

The Job of a Parser

Who does Salem mock?



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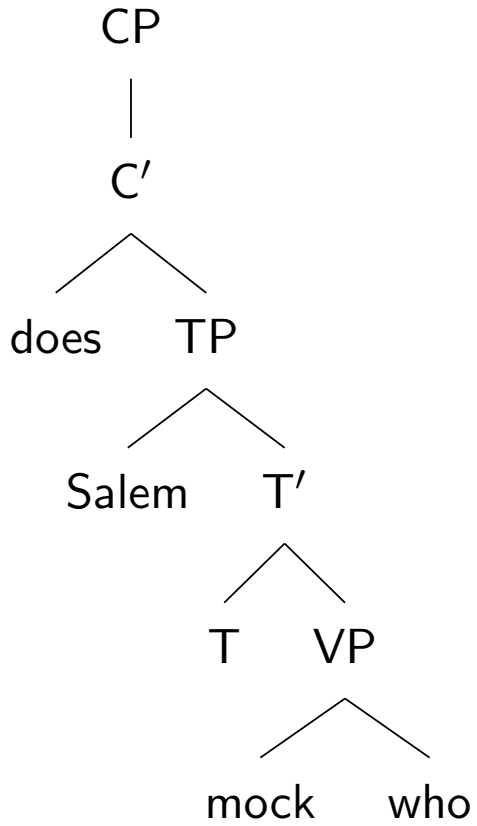

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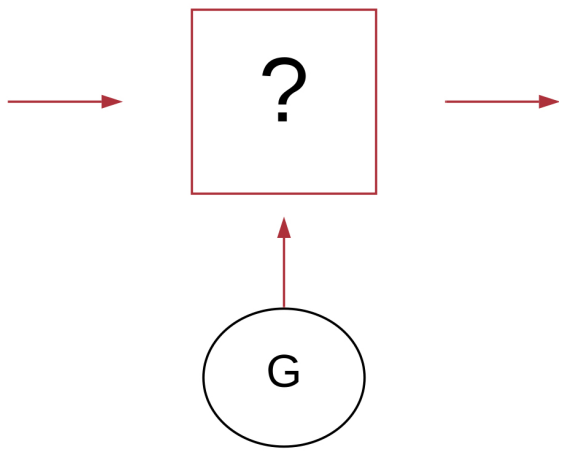

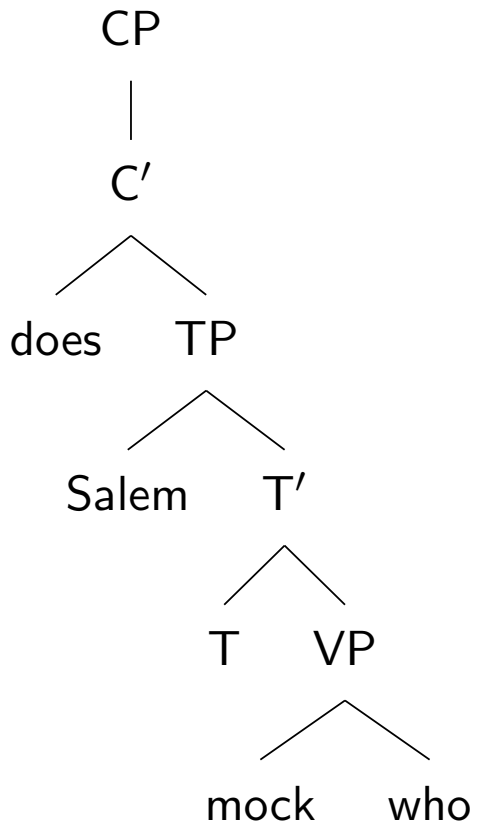

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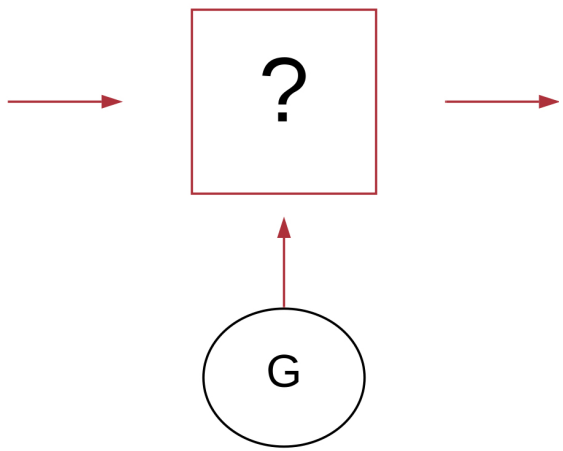

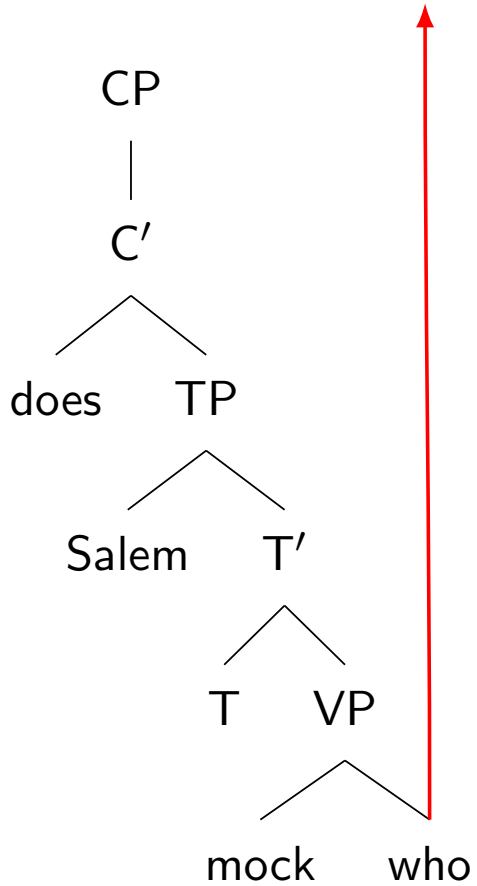

- Bottom-up

The Job of a Parser

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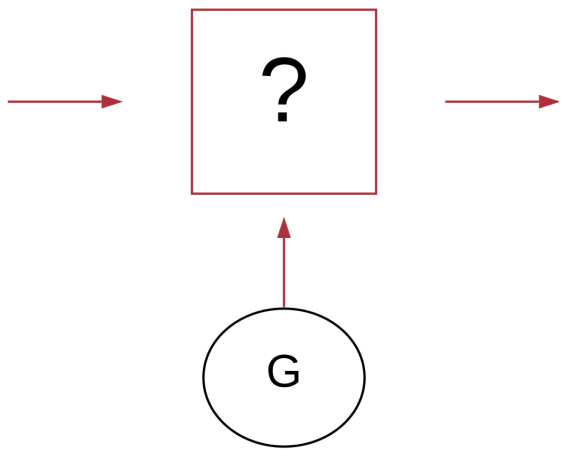
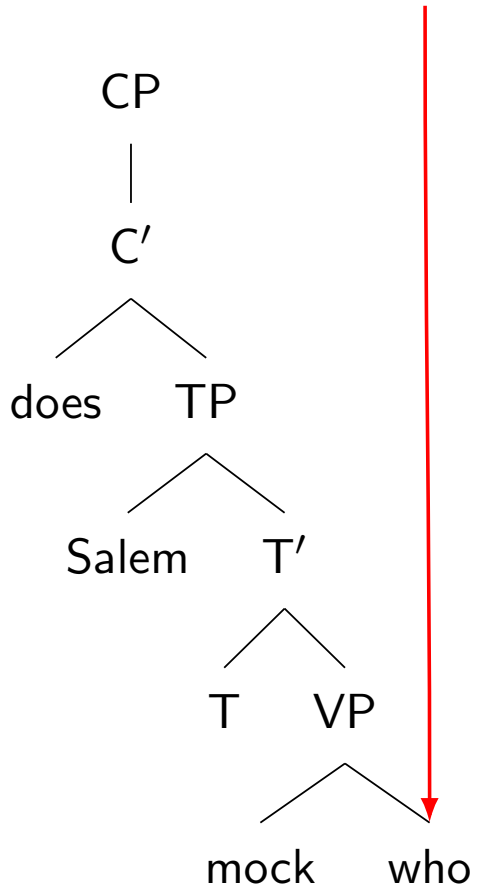
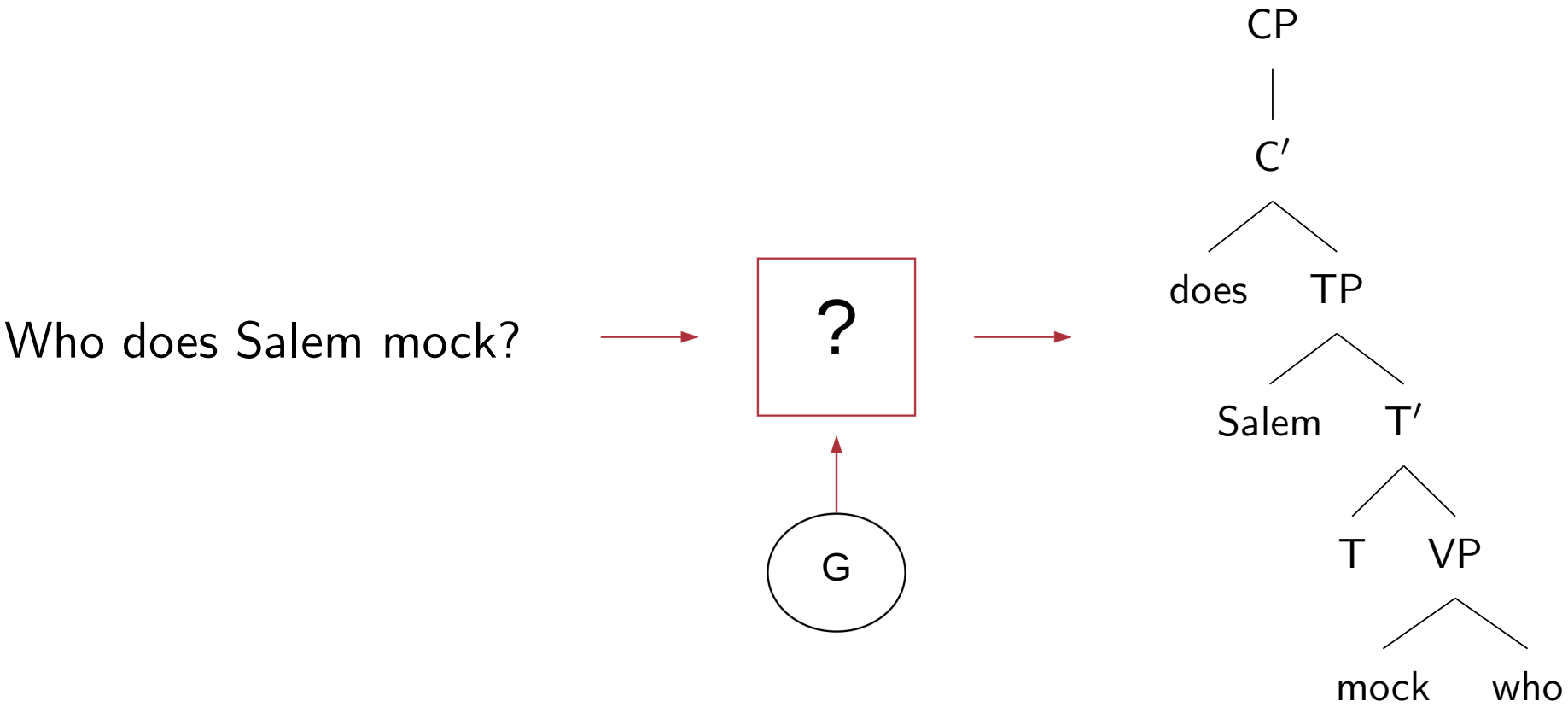




- Bottom-up
- Top-down

The Job of a Parser



- Bottom-up
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  - Psychologically plausible(-ish)

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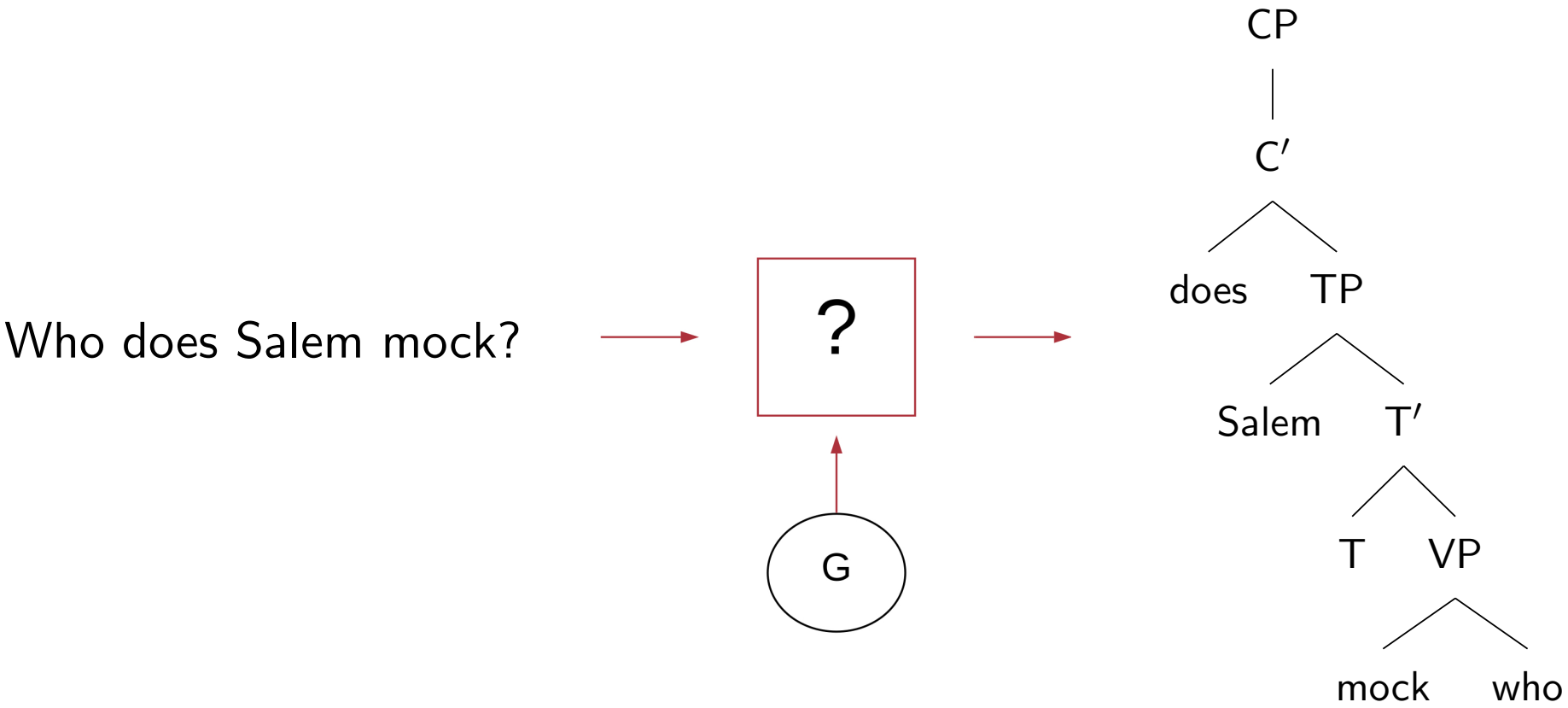

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- Top-down (Stabler, 2013)
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  - Assumption: Parser as an oracle!

Incremental Top-Down Parsing: The Intuition

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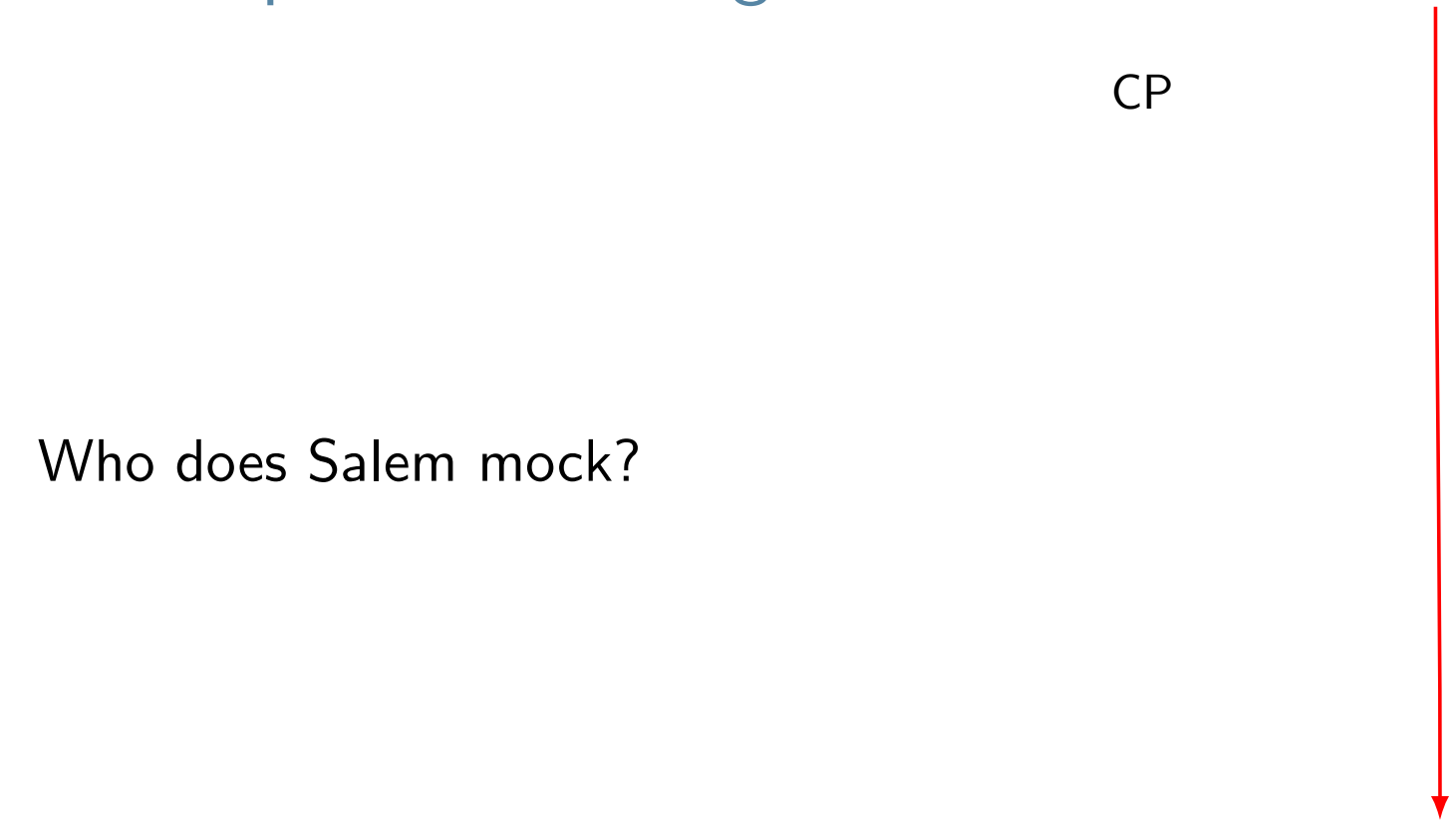

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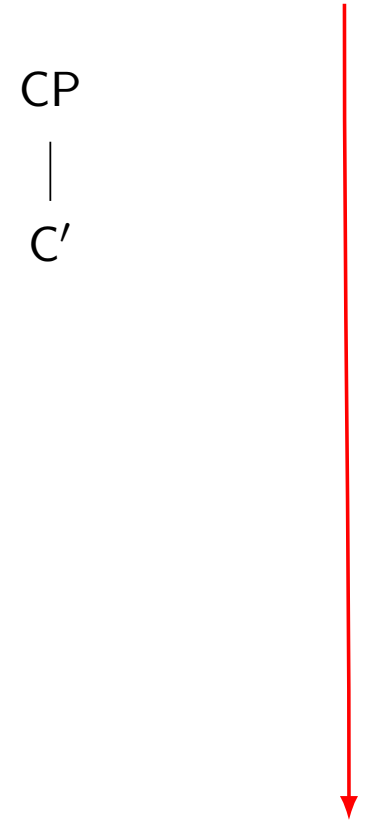

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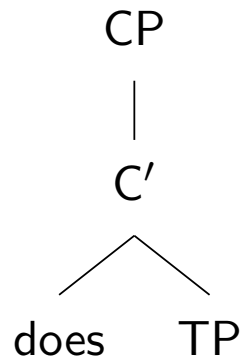

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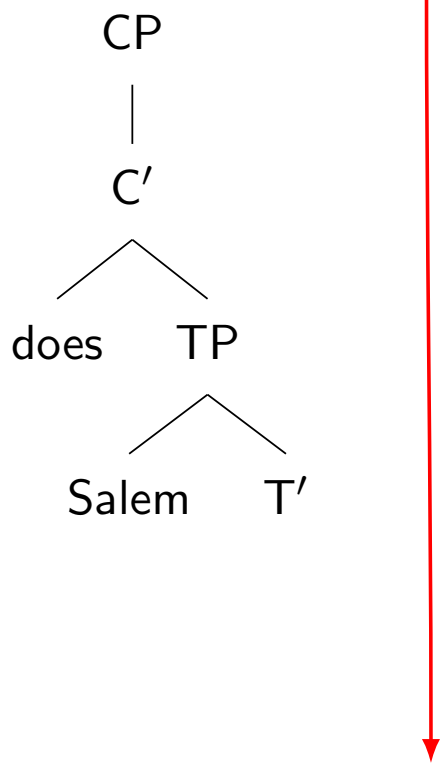

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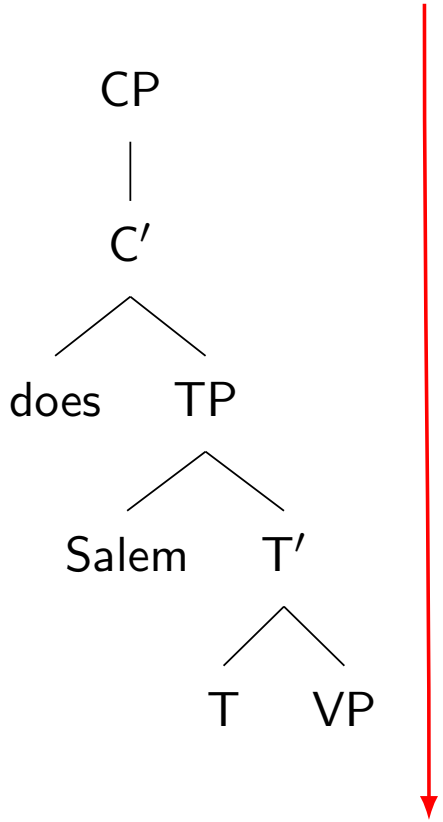

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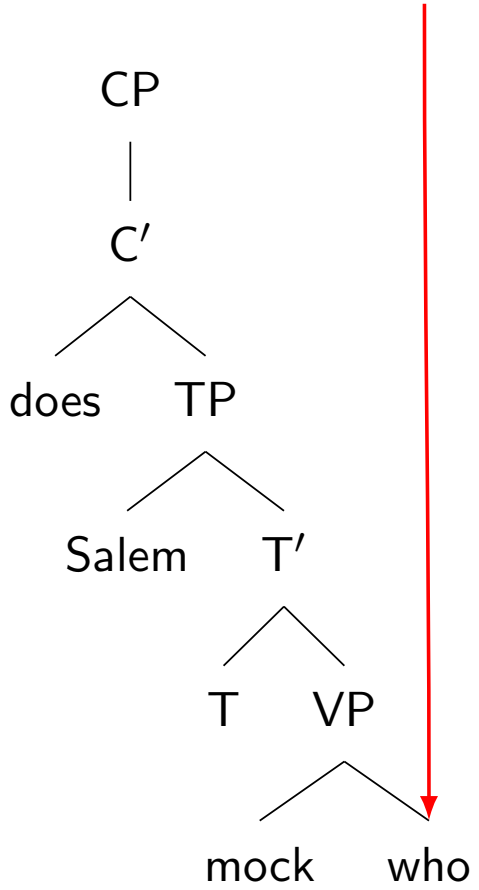

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Memory-Based Complexity Metrics

- **Memory usage**:
  (Kobele et al. 2012; Gibson, 1998)

Tenure How long a node is kept in memory

Size How much information is stored in a node

$\Rightarrow$ Intuitively, the length of its movement dependency!

- Formalized into offline **complexity metrics**

MaxTenure $max(\{\text{tenure-of}(n)|n \text{ a node of the tree}\})$

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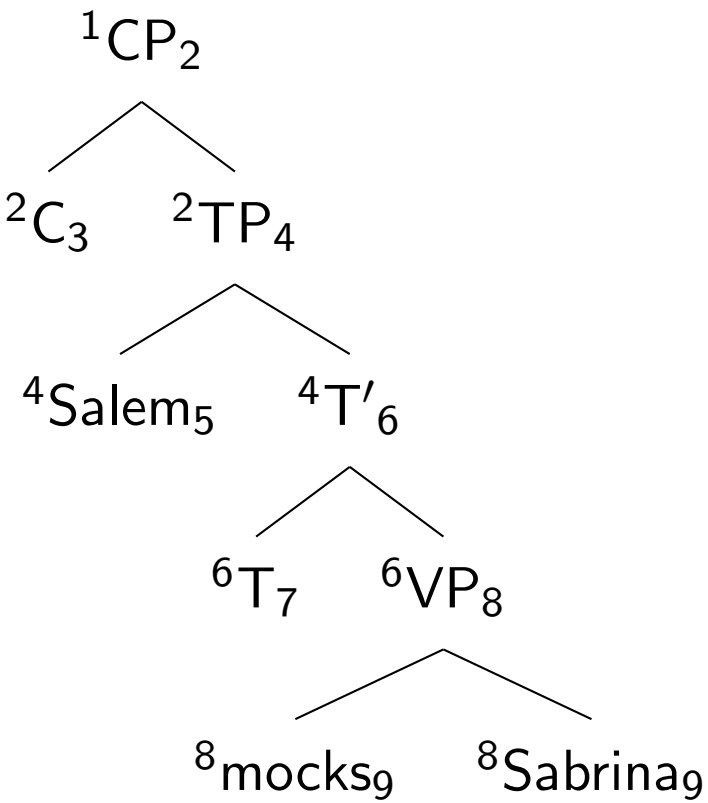
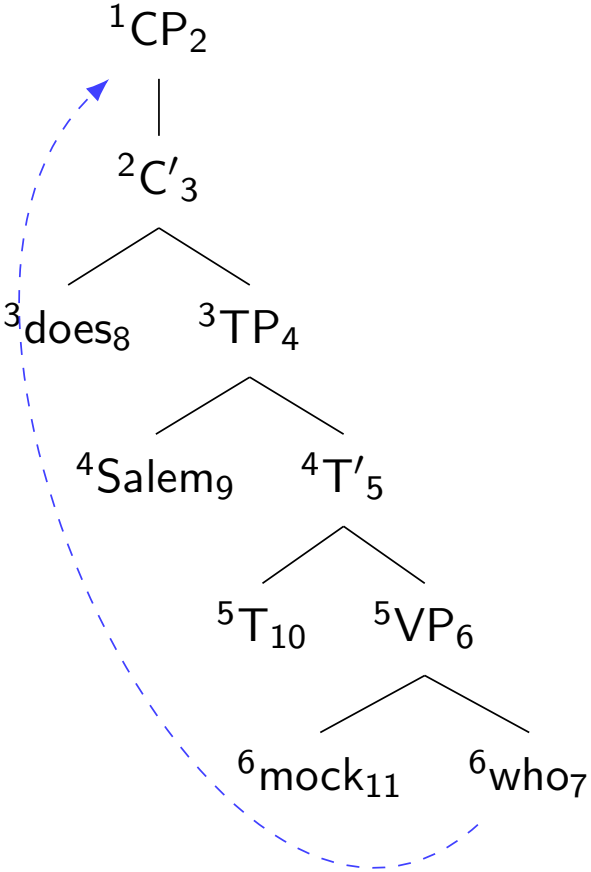
Contrasting Derivations

MaxTenure $= 2$



MaxTenure $= 5$



Summary of the Approach

A Computational Linking Hypothesis (De Santo & Lee 2022)

Grammar $\rightleftarrows$ MG Parser Effort $\rightleftarrows$ Economy

General Idea

(Kobele et al. 2012; Gerth 2015; Graf et al. 2017; De Santo 2020)

1. Pick two competing derivations
2. Evaluate metrics over each
   - Lowest score means easiest!
3. Compare parser's prediction to experimental data

Processing Asymmetries All the Way Down

A variety of processing insights!

Across Many Constructions

- Right > center embedding (Kobele et al. 2012)
- Crossing > nested dependencies (Kobele et al. 2012)
- SRC > ORC
  (Graf et al. 2017; De Santo 2020; Fiorini, Chang, De Santo 2023)
- Priming/Stacked RCs (De Santo 2020, 2022)
- Postverbal subjects
  (De Santo 2019, 2021; Del Valle & De Santo 2023)
- Persian attachment ambiguities (De Santo & Shafiei 2019)
- RC attachment preferences
  (De Santo & Lee 2022; Lee & De Santo 2023)

Across Languages

- English, German, Italian, French, Spanish
- Korean, Japanese, Mandarin Chinese
- Basque, Persian, ...

Back to Modeling PR-First

Why should PRs be easier/preferred?

- Can we evaluate structural economy quantitatively?
- Do different syntactic choices matter?

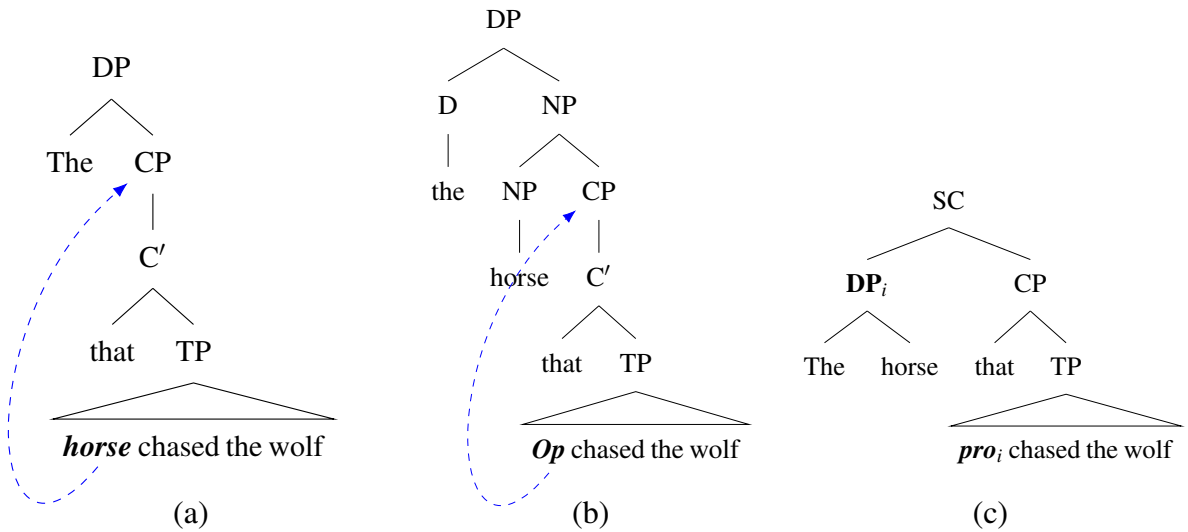


Figure 2: Sketches of the *(a)* RC with Promotion, *(b)* RC with Wh-movement, and *(c)* PR analyses for the sentence *The horse that the wolf chased*.

Modeling Results (De Santo & Lee, 2022b)

	MG Parser
Hypothesis	
PR > HA	
PR > LA	
LA > HA	

(3) (Io) Ho visto la nonna della ragazza che gridava
(I) have seen the grandma of the girl that screaming
'I saw the grandma of the girl that was screaming"

- The PR> HA RC depends on syntactic choices
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- In sum:
  No immediate support for a parsing economy explanation
- LA>HA arises without explicit locality constraints!

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Hypothesis	**Promotion**	**Wh-mov**
PR > HA	✓	Tie
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LA > HA	✓	✓

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From the Trees to the Forest

(4) (Io) Ho visto la nonna della ragazza che gridava
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Beyond these results

- Cross-linguistic and cross-analysis validation
- A variety of definitions for *cost* in parsing (Boston, 2012)
  - E.g., # bounding nodes/phases, discourse referents, retrieval
  - Pragmatic Economy?
    E.g. Reference Theory (Altmann & Steedman 1988)
- Investigating economy principles more broadly

From the Trees to the Forest

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Summing Up

PRs and Ambiguity Online

- Support for online impact of PR availability on disambiguation strategies.
- Complex pattern of interactions
  - task differences?
  - timing of cure-integration?

A fully specified model of syntactic cost:

- Allows evaluation of economy definitions
- Shows that syntactic choices affect "cost" in unexpected ways
- Suggest ways to narrow down the space of plausible accounts

Summing Up

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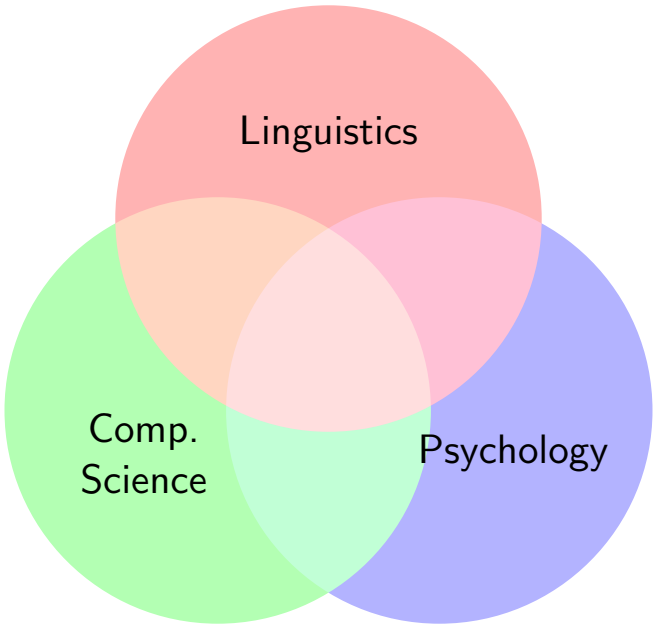
  - task differences?
  - timing of cure-integration?

A fully specified model of syntactic cost:

- Allows evaluation of economy definitions
- Shows that syntactic choices affect "cost" in unexpected ways
- Suggest ways to narrow down the space of plausible accounts

Embracing Multidisciplinarity



Within the program of research proposed here, joint work by linguists, computer scientists, and psychologists could lead to a deeper scientific understanding of the role of language in cognition.

(Bresnan 1978: pg. 59)

Appendix

Incremental Top-Down Parsing

Technical details!

- String-driven recursive descent parser (Stabler 2013)

- • Who • does • Salem • T • mock

step 1 CP is conjectured
step 2 CP expands to C′
step 3 C′ expands to does and TP
step 4 TP expands to Salem and T′
step 5 T′ expands to T and VP
step 6 VP expands to mock and who
step 7 who is found
step 8 does is found
step 9 Salem is found
step 10 T is found
step 11 mock is found

Incremental Top-Down Parsing

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- • Who • does • Salem • T • mock

[1]CP

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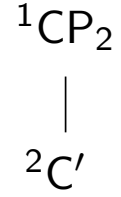

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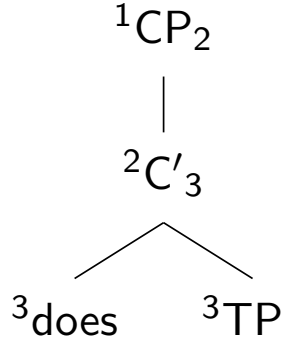

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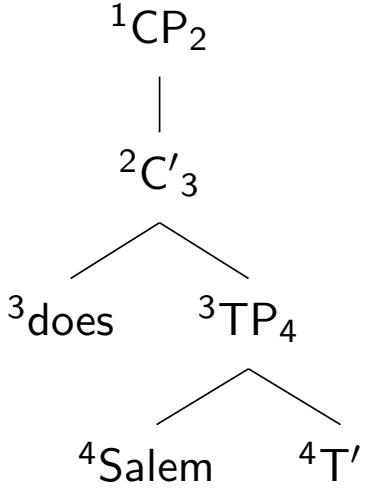

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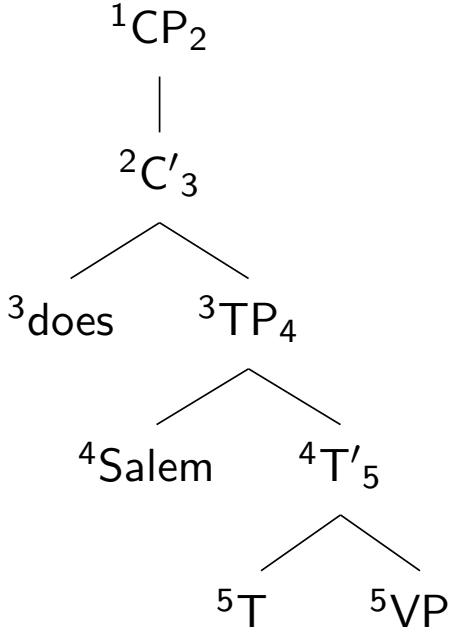

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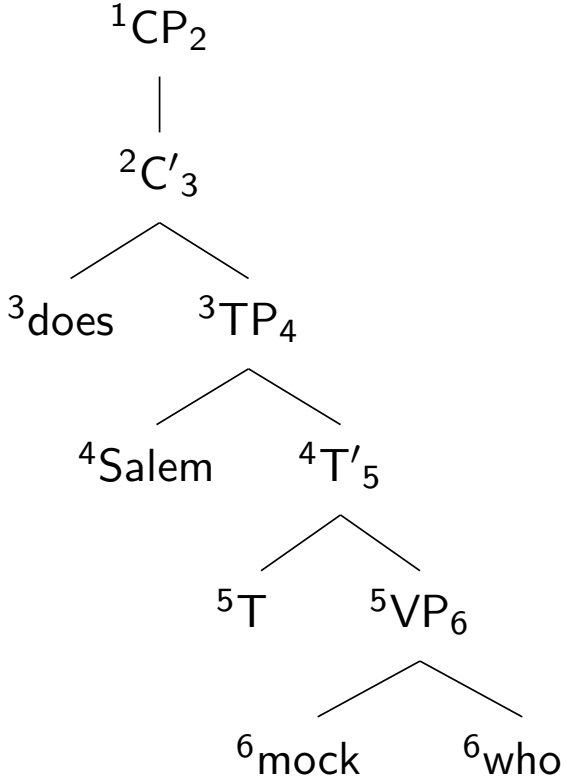

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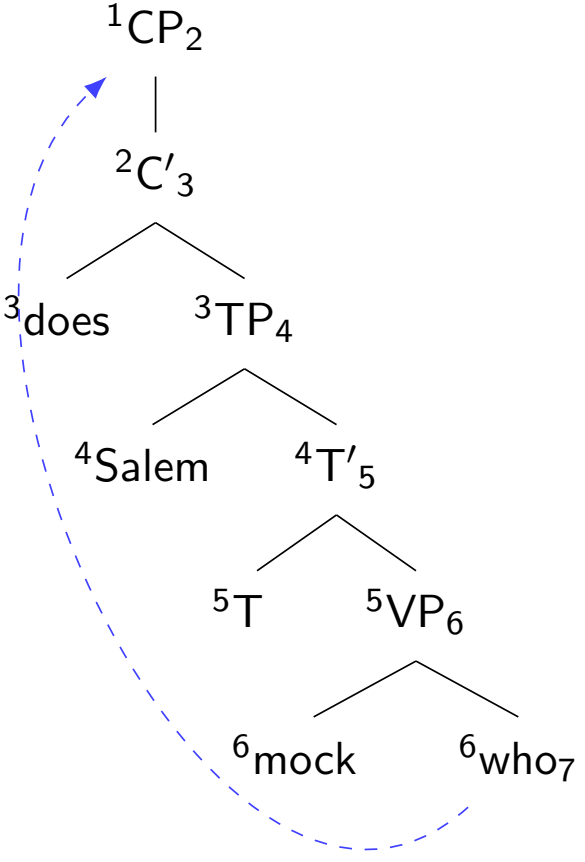

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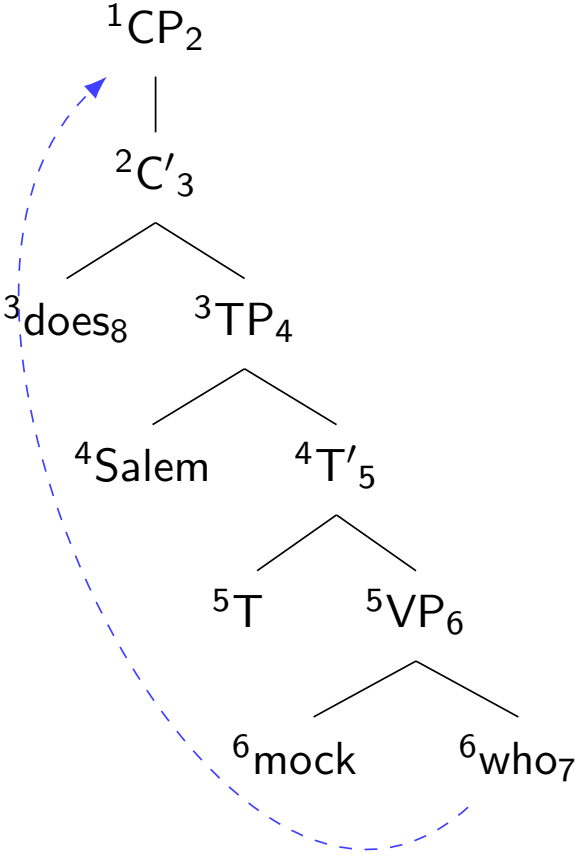

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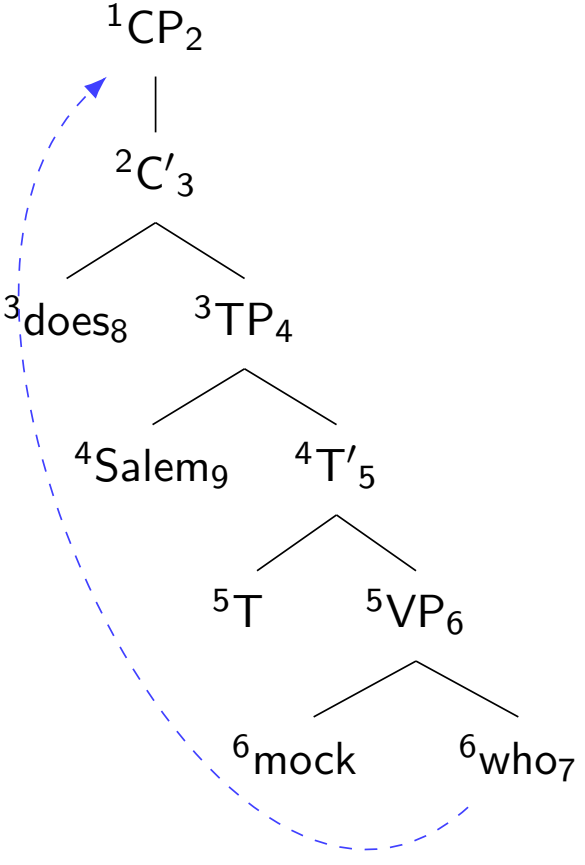

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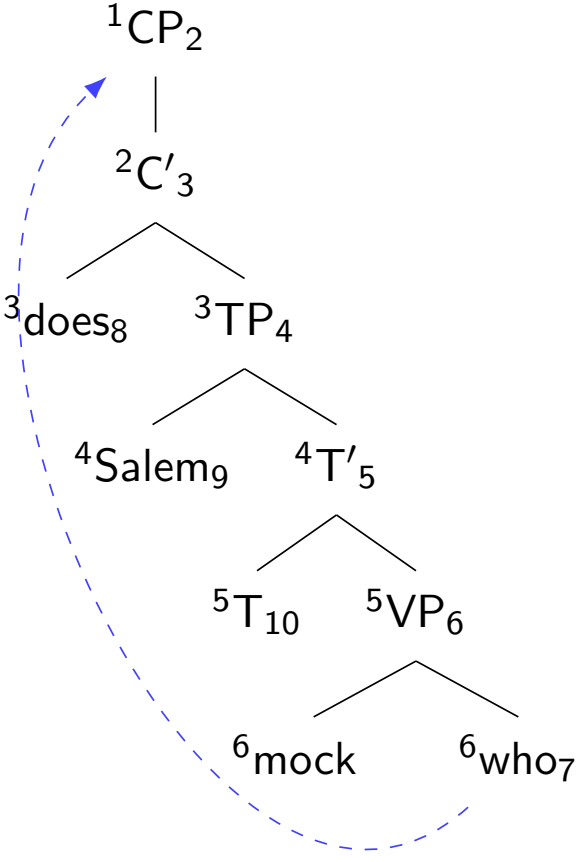

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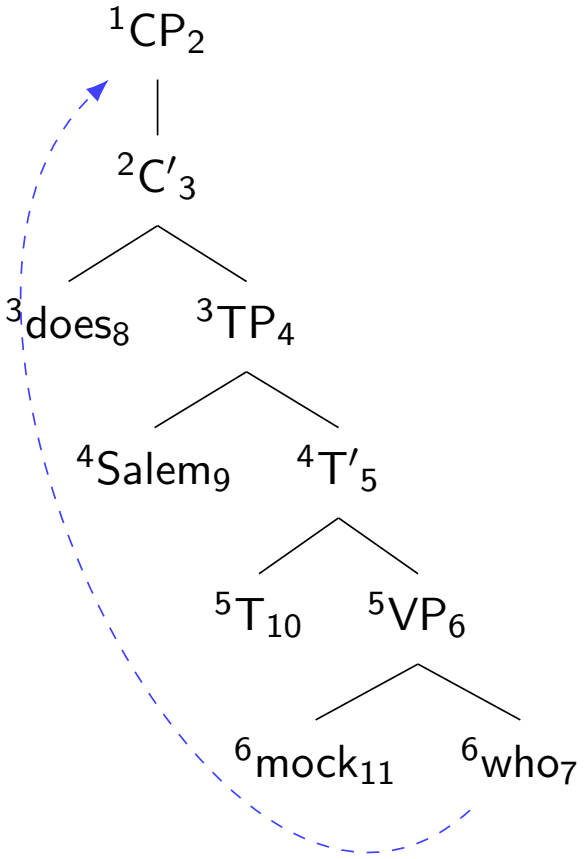

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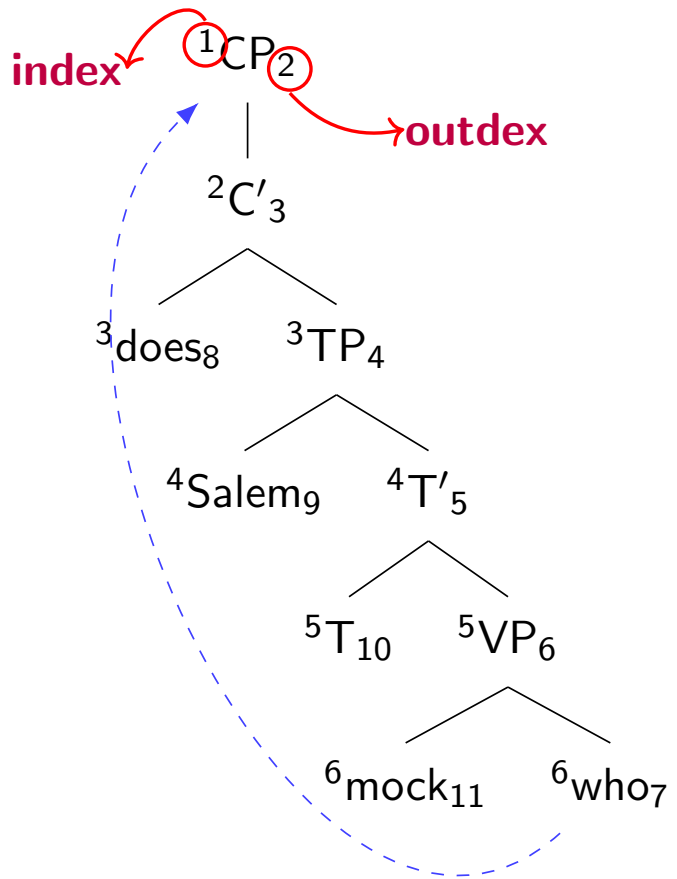

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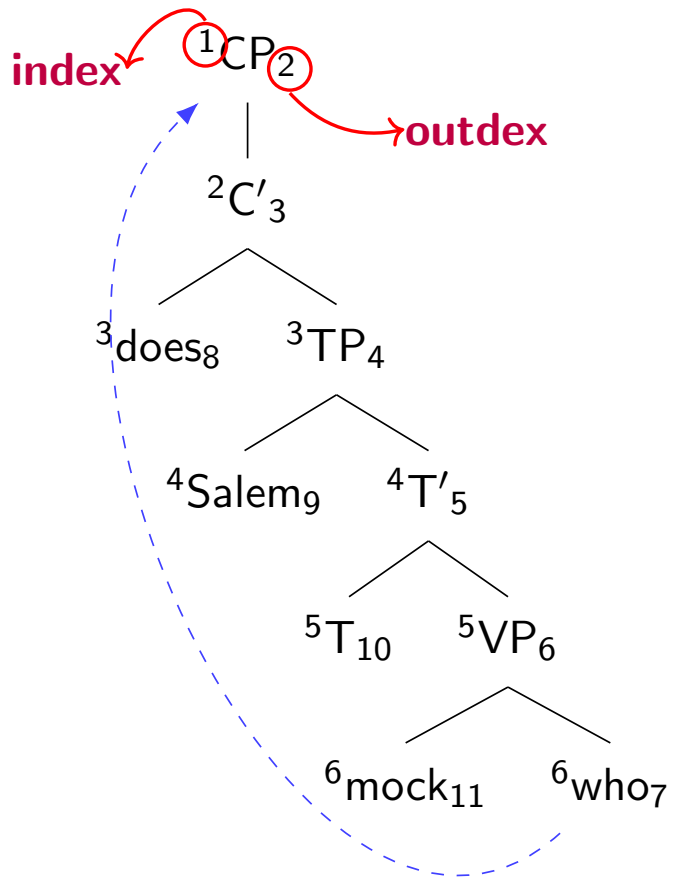
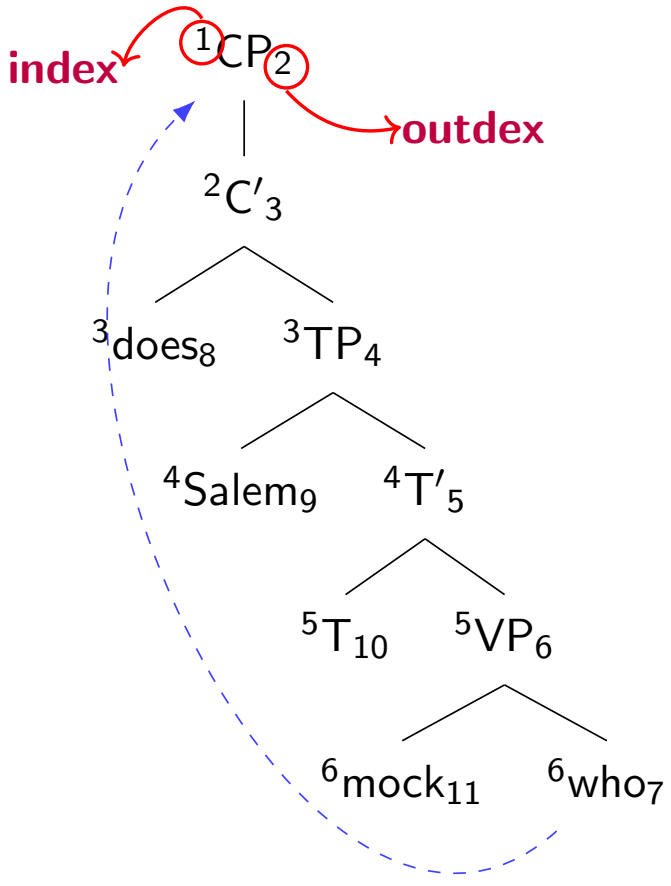


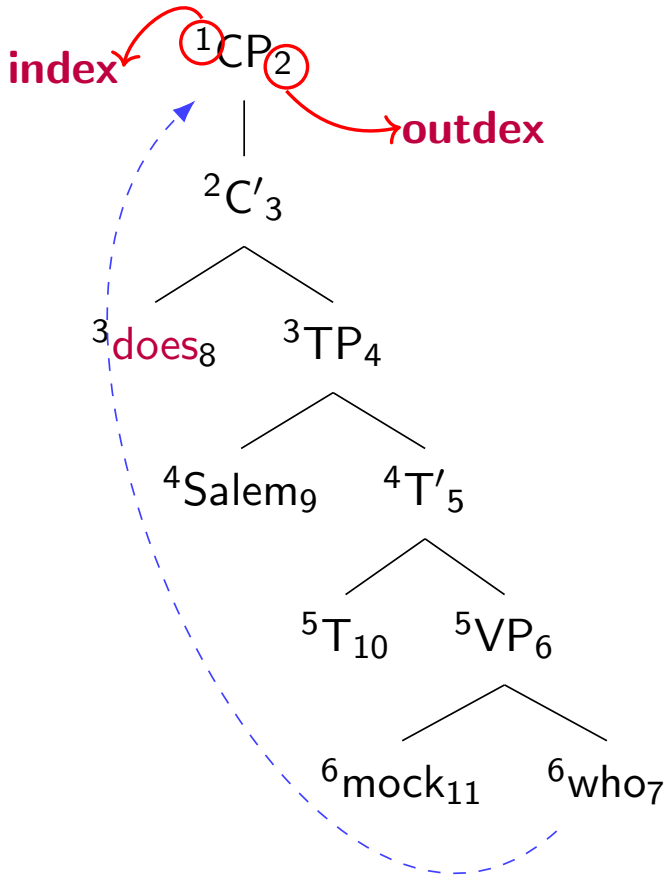
Index and Outdex are our connection to memory!

Computing Metrics: An Example



Tenure how long a node is kept in memory

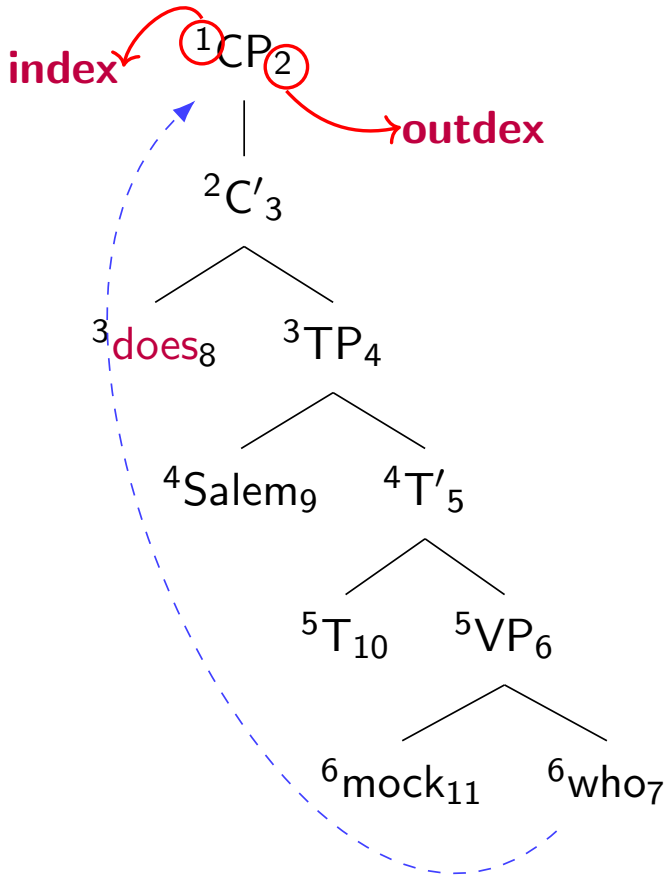
Computing Metrics: An Example



Tenure how long a node is kept in memory

Tenure($does$) $= 8 - 3 = 5$

Computing Metrics: An Example



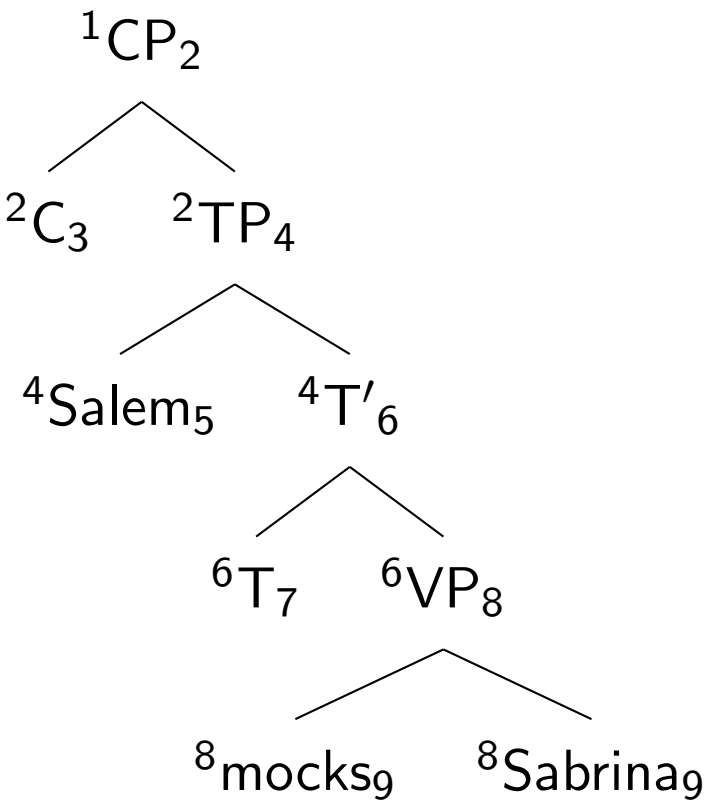
Tenure how long a node is kept in memory

Tenure$(does) = 8 - 3 = 5$

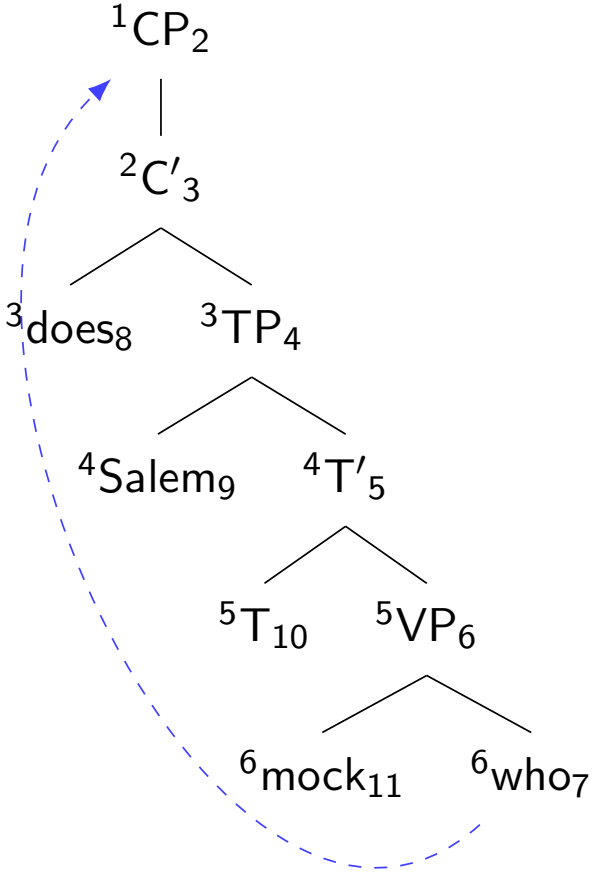
MaxTenure $= max\{$**Tenure**$(does)$, **Tenure**$(Salem), \dots\} = 5$

Contrasting Derivations

MaxTenure $= 2$



MaxTenure $= 5$



PRs vs RCs 1

i. PRs appear freely with proper names (13-a), contrary to RCs (13-b).[7]

(13) a. Ho visto Gianni che correva (Italian)
He visto a [$_{PR}$ Juan que corría] (Spanish)
J'ai vu [$_{PR}$ Jean qui courait] (French)
'I saw Gianni running.'
b. *I saw John that ran.
c. Ho visto Gianni, che correva. Appositive

ii. Relative pronouns are banned from PRs, but obviously not from RCs:

(14) *Ho visto Gianni il quale correva.
Have.I seen Gianni the which run.IMPF.
'I saw Gianni who was running.'

iii. Just like other types of Small Clauses (see ungrammatical translation), PRs are only available with embedded subjects and cannot be construed with embedded objects (15-a), this restriction obviously does not apply to RCs (15-b)[8]:

(15) a. *Luigi ha visto [$_{PR}$ Gianni$_i$ che Maria baciava EC$_i$].
Luigi saw Gianni that Maria kissed EC.
'Luigi saw John Mary kissing EC.'
b. Luigi ha visto il ragazzo che Maria ha baciato <ragazzo>.
'Luigi saw the boy that Mary kissed.'

PRs vs RCs 3

Additionally, PRs and SCs can be freely coordinated (20-a,b), while neither of them can be coordinated with RCs (which is further evidence against a RC analysis of PRs or other types of clausal complements (20-c,d).

(20) a. SC & PR:
Ho visto [Gianni depresso] e [Piero che cercava di risollevarlo].
'I saw G. depressed and P. that was trying to cheer him up.'

b. SC & PR:
Ho visto [Gianni [depresso] e [che piangeva]].
'I saw G. depressed and that was crying.'

c. *RC & PR/SC:
*Ho visto [Gianni, [che vive con Maria], e [depresso/ che piangeva]].
'I saw G., who lives with M. and depressed/ that was crying.'

d. *PR/SC & FINITE CP:
*Ho visto [Gianni [che piangeva/ depresso] e [che P. cercava di risollevarlo]].
'I saw G. crying/ depressed and that P. tried to cheer him up.'

PRs vs RCs 4

iii. Just like other types of Small Clauses (see ungrammatical translation), PRs are only available with embedded subjects and cannot be construed with embedded objects (15-a), this restriction obviously does not apply to RCs (15-b)[8]:

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Aguilar et al. (2021): Spanish Online

- Temporarily ambiguous sentences
- Eye-tracking

(15) a. **Perceptual, High Attachment**
Juan vio al entrenador$_{\text{MASC}}$ de la tenista$_{\text{FEM}}$ que lloraba amargado$_{\text{MASC}}$ por la derrota.
'Juan saw the coach of the tennis player that wept bitterly for the defeat.'

b. **Perceptual, Low Attachment**
Juan vio al entrenador$_{\text{MASC}}$ de la tenista$_{\text{FEM}}$ que lloraba amargada$_{\text{FEM}}$ por la derrota.
'Juan saw the coach of the tennis player that wept bitterly for the defeat.'

c. **Non-Perceptual, High Attachment**
Juan conoció al entrenador$_{\text{MASC}}$ de la tenista$_{\text{FEM}}$ que lloraba amargado$_{\text{MASC}}$ por la derrota.
'Juan has met the coach of the tennis player that wept bitterly for the defeat.'

d. **Non-Perceptual, Low Attachment**
Juan conoció al entrenador$_{\text{MASC}}$ de la tenista$_{\text{FEM}}$ que lloraba amargada$_{\text{FEM}}$ por la derrota.
'Juan has met the coach of the tennis player that wept bitterly for the defeat.'

Aguila et al. (2021): Results (Target Region)

- Significant interaction: Verb type/Attachment
- Selective effect of Attachment with non-perceptual verbs
- Regression Path Duration times longer with non perceptual verbs (main effect of Verb type)

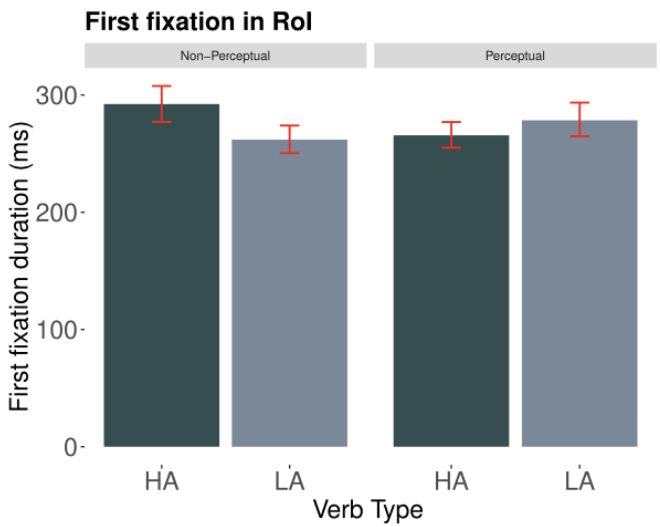
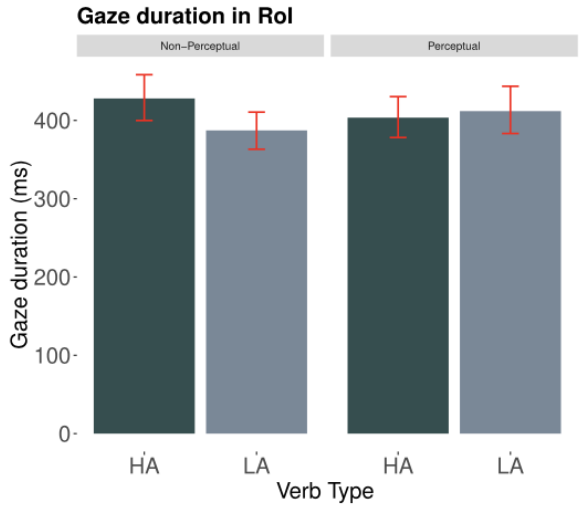


Fig. 1. First fixation duration in the disambiguating word (error bars represent SE).



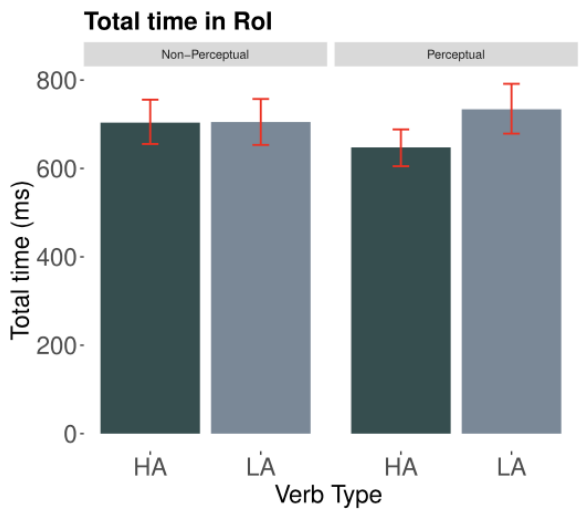


Fig. 3. Total Reading times in the disambiguating word (error bars represent SE).

Effect of Number

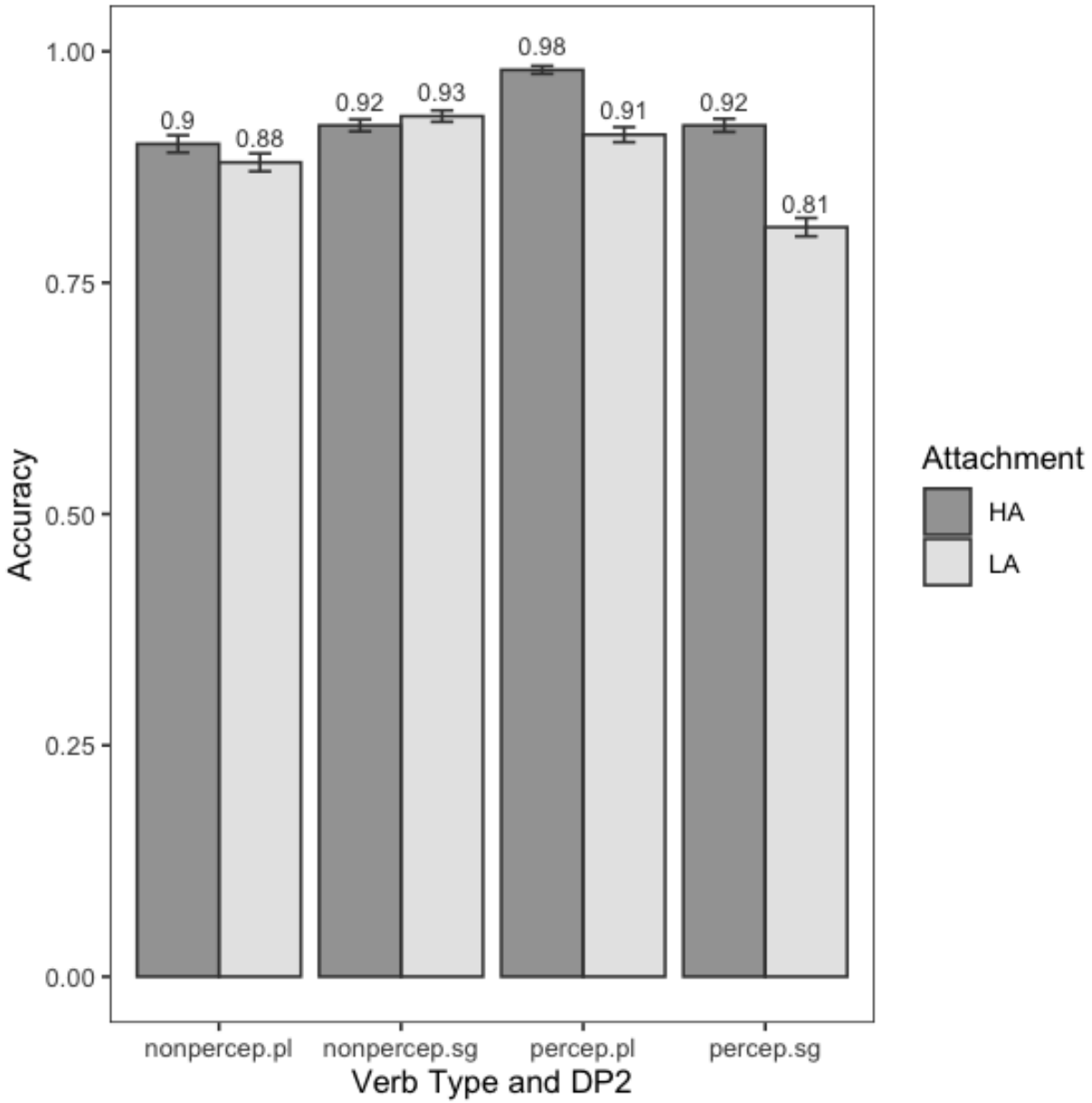
Table 5.: Summary of Logistic Mixed Effect analysis of the comprehension task.

Term	Estimate	Std. Error	z value	$\Pr(>\|z\|)$
(Intercept)	2.8266	0.5304	5.330	9.84e-08 ***
Perceptual(P) verb	1.6330	0.2426	6.731	1.68e-11 ***
LA	-0.1690	0.1704	-0.992	0.321325
DP2_sg	0.9012	0.6938	1.299	0.193938
P verb:LA	-1.0136	0.2927	-3.463	0.000534 ***
P verb:DP2_sg	-2.0441	0.2996	-6.823	8.89e-12 ***
LA:DP2_sg	0.5447	0.2336	2.331	0.019732 *
P verb:LA:DP2_sg	-0.0550	0.3708	-0.148	0.882087

Table 6.: Summary of pairwise comparison of the comprehension task.

Comparison	**Estimate**	**SE**	**z.ratio**	**p.value**
a. nonpercep HA pl - percep HA pl	-1.6330	0.243	-6.731	$< .0001$
b. nonpercep LA pl - percep LA pl	-0.6194	0.164	-3.772	0.0040
c. nonpercep HA sg - percep LA sg	1.1039	0.137	8.031	$< .0001$
d. nonpercep LA sg - percep LA sg	1.4797	0.148	9.993	$< .0001$
e. percep HA pl - percep LA pl	1.1826	0.232	5.099	$< .0001$
f. percep HA sg - percep LA sg	0.6929	0.154	4.490	0.0002
g. percep HA pl - nonpercep LA pl	1.8020	0.228	7.895	$< .0001$
h. percep HA sg - nonpercep LA sg	-0.7868	0.177	-4.453	0.0002

Effect of Number



Effect of Number

Table 8.: Summary of linear mixed effects models fitted to reading times at the regions of interest.

	Estimate	SE	t	pr(>|t|)	Slope
target					
(Intercept)	-0.0423719023	0.03669050	-1.154846812	0.24815316	(p,i)
P verb	-0.0003755636	0.04248111	-0.008840719	0.99294622	
LA	-0.0621587633	0.04384113	-1.417818506	0.15624376	
DP2_sg	-0.0560295743	0.04142054	-1.352700256	0.17615141	
P verb:LA	0.1166263683	0.05985569	1.948459108	0.05136005	
P verb:DP2_sg	0.0559747040	0.05571450	1.004670320	0.31505562	
LA:DP2_sg	0.0896532684	0.05592909	1.602980958	0.10893886	
P verb:LA:DP2_sg	-0.1210944201	0.07890096	-1.534764930	0.12484158	
spillover1					
(Intercept)	-0.081500164	0.03233380	-2.5205872	0.011715919*	(p,i)
P verb	-0.025545633	0.03565600	-0.7164470	0.473715384	
LA	-0.012000233	0.04111983	-0.2918356	0.770412302	
DP2_sg	-0.001521141	0.03567653	-0.0426370	0.965990897	
P verb:LA	0.162413270	0.05005553	3.2446621	0.001175901**	
P verb:DP2_sg	0.040395080	0.04685603	0.8621105	0.388626694	
LA:DP2_sg	-0.016477695	0.05254365	-0.3136001	0.753824776	
P verb:LA:DP2_sg	-0.052206169	0.06590356	-0.7921601	0.428267328	
spillover2					
(Intercept)	0.16603196	0.04700930	3.5318962	0.0004125913**	(p,i)
P verb	-0.14905292	0.05412496	-2.7538664	0.0058895807**	
LA	-0.07812655	0.06161563	-1.2679664	0.2048099322	
DP2_sg	-0.09442706	0.05341896	-1.7676696	0.0771161616	
P verb:LA	0.07110749	0.07648244	0.9297230	0.3525145053	
P verb:DP2_sg	0.04993822	0.07042307	0.7091173	0.4782516714	
LA:DP2_sg	0.06014768	0.07587526	0.7927179	0.4279421918	
P verb:LA:DP2_sg	0.13296595	0.09989631	1.3310396	0.1831759805	

Modeling Results

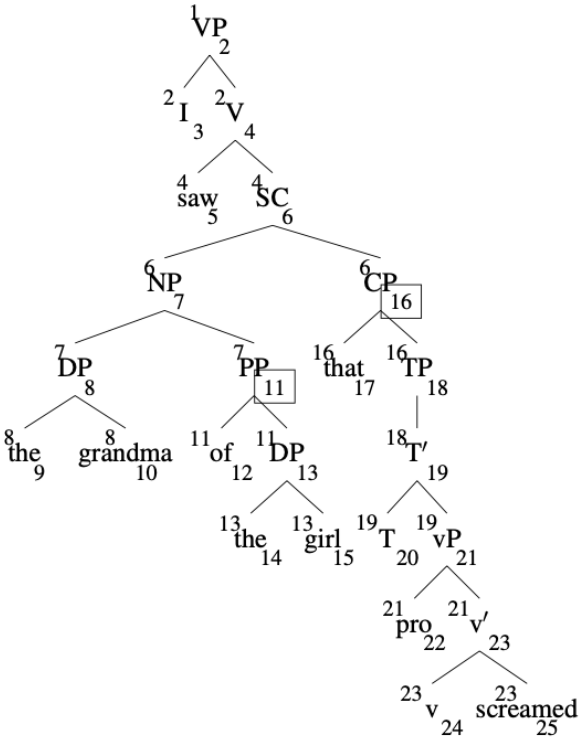


Figure 3: Annotated derivation trees for the Italian sentence *I saw the grandma of the girl that screamed*, according to a pseudo-relaive clause analysis. The tree is treated as a VP since additional structure in the matrix clause would be identical across comparisons.

	MG Parser	
Hypothesis	**Promotion**	**Wh-mov**
PR < HA	✓	Tie
PR < LA	×	×
LA < HA	✓	✓

Table 1: Summary of the predictions made by a *pseudo-relative first* account, and corresponding parser's predictions based on MAXTENURE, as pairwise comparisons (x < y: x is preferred over y).

	MAXT	
	Promotion	**Wh-mov**
PR	10/CP	
HA	11/that	10/CP
LA	5/that	7/that

Table 2: MAXT values (*value/node*) by construction, with RCs modulated across a promotion and wh-movement analysis.