Should Psycholinguists (Still) Care about Symbolic Parsers?

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Let's Start with Some Data!

(1) The horse that has chased the lions **SRC**

(2) The horse that the lions have chased **ORC**

SRC > ORC

- Well-attested cross-linguistically (Lau & Tanaka 2021)
- ... with some possible exceptions (Mandarin?)

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A Cross-linguistic Trend

Asymmetries in Italian Relative Clauses

Italian conforms to the general cross-linguistic preference for SRC over ORC (Adani et al. 2010; Arosio et al. 2018)

(3) Il cavallo che ha inseguito i leoni
The horse that has chased the lions
"The horse that chased the lions" **SRC**

(4) Il cavallo che i leoni hanno inseguito
The horse that the lions have chased
"The horse that the lions chased" **ORC**

SRC > ORC

Postverbal Subjects and Ambiguity

Italian allows for postverbal subjects, making some sentences ambiguous (De Vincenzi 1991):

(5) Il cavallo che ha inseguito il leone
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a. "The horse that chased the lion" **SRC**

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Agreement can disambiguate:

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"The horse that chased the lions" **SRC**

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"The horse that the lions chased" **ORCp**

Processing Asymmetry (De Vincenzi 1991, Arosio et al. 2018, a.o.)

SRC > ORC > ORCp

One Big Question

(How much) does grammatical structure matter in sentence processing?

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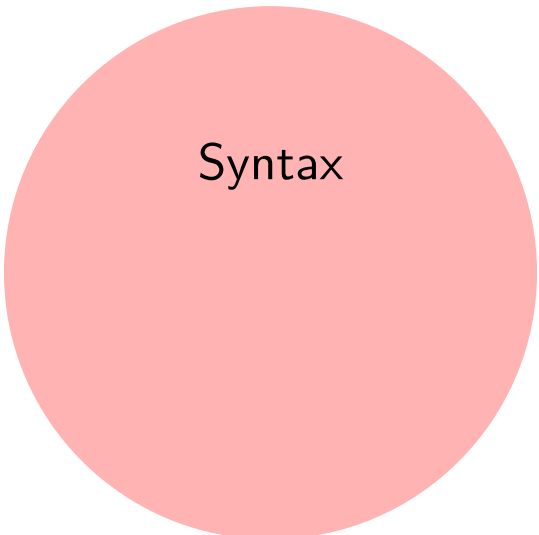

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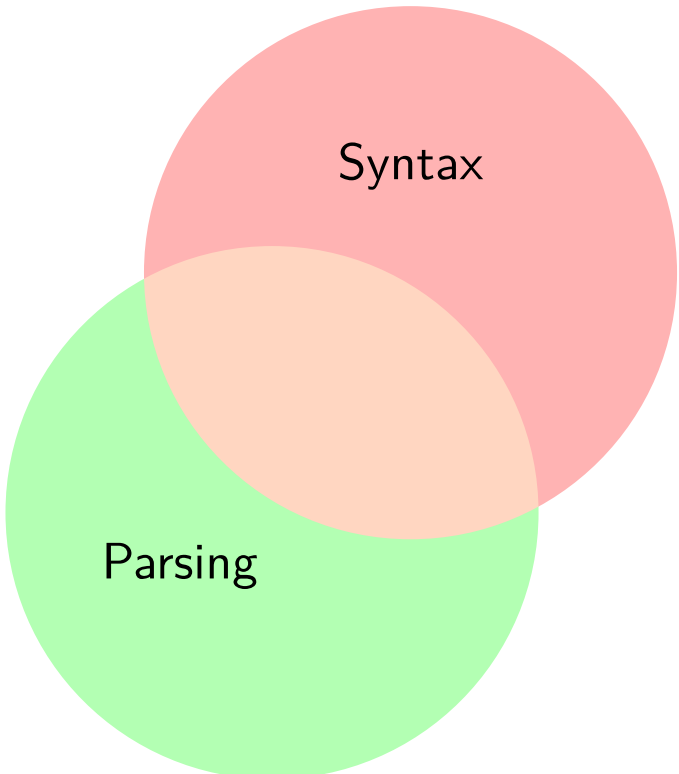

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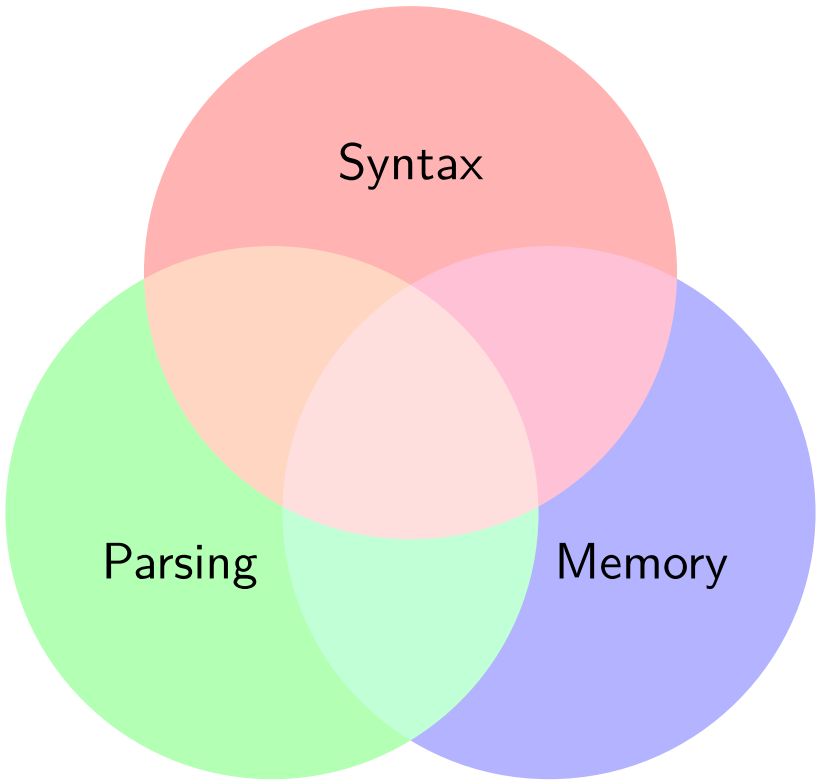

Forward to the Past

- What is the relation between grammatical operations and cognitive processes?

Derivational Theory of Complexity (Miller and Chomsky, 1963)

- Processing complexity $\sim$ length of a derivation (Fodor & Garrett 1967; Berwick & Weinberg 1983)
- Essentially: there is a **cost** to mental computations.

- What is the right notion of syntactic derivation?
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Computational Models and Theory Building

[...] this is a confusion of two quite separate issues, ***simulation and explanation****. [...] What we are* ***really*** *interested in [...] is explanation — in developing models that help us* ***understand how it is that people behave*** *that way, not merely demonstrating that we can build an artifact that behaves similarly.*

(Kaplan, 1995)

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Interpretability for the win!

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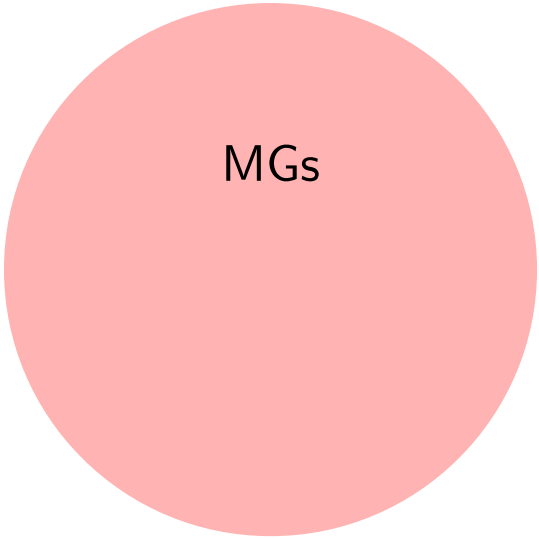

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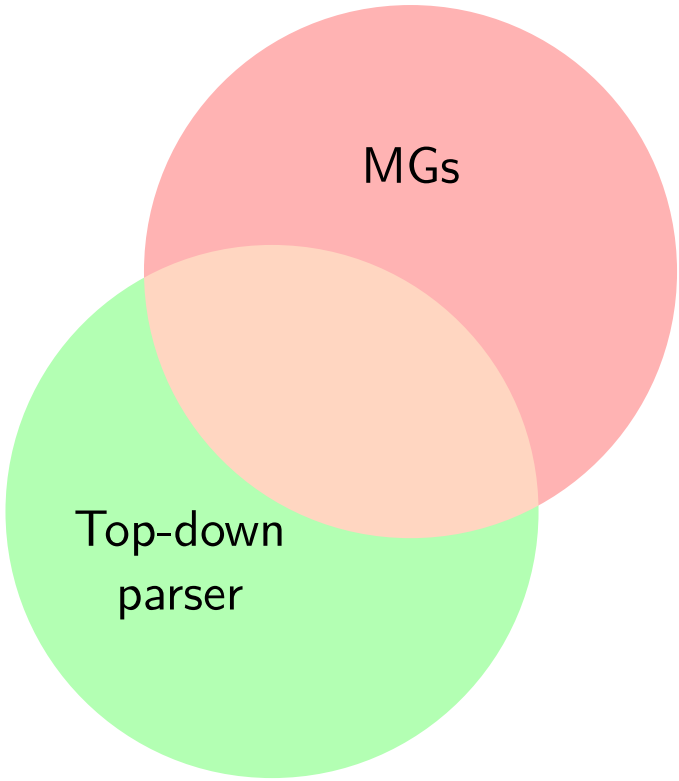

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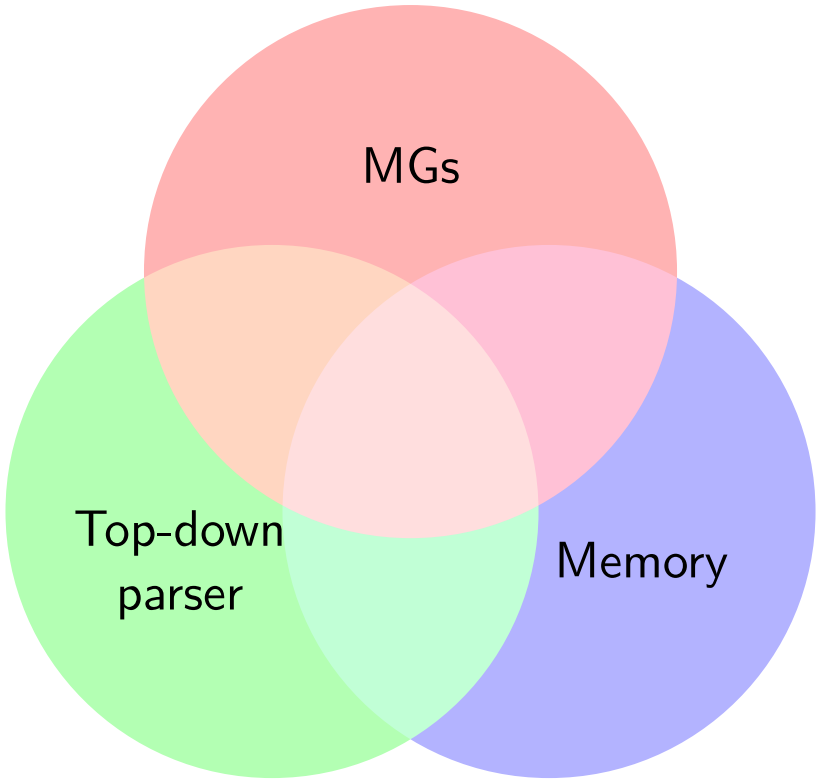

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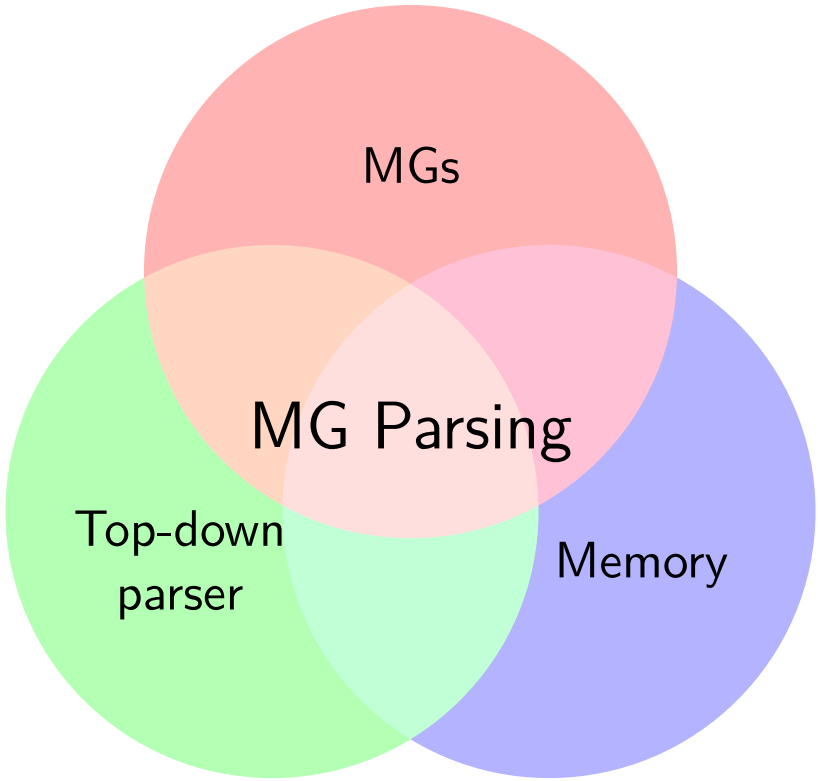

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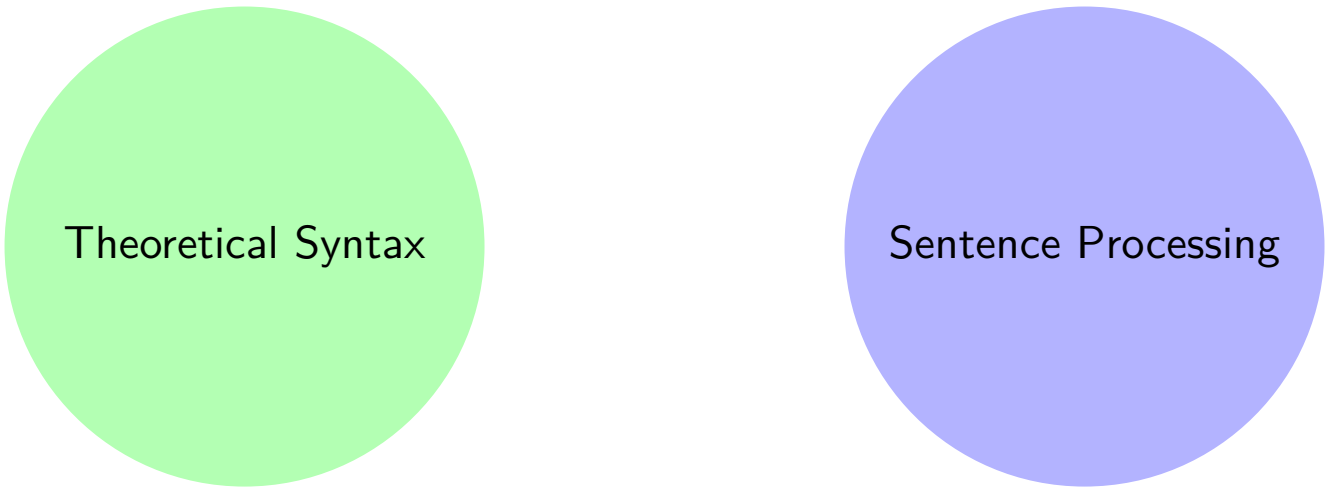

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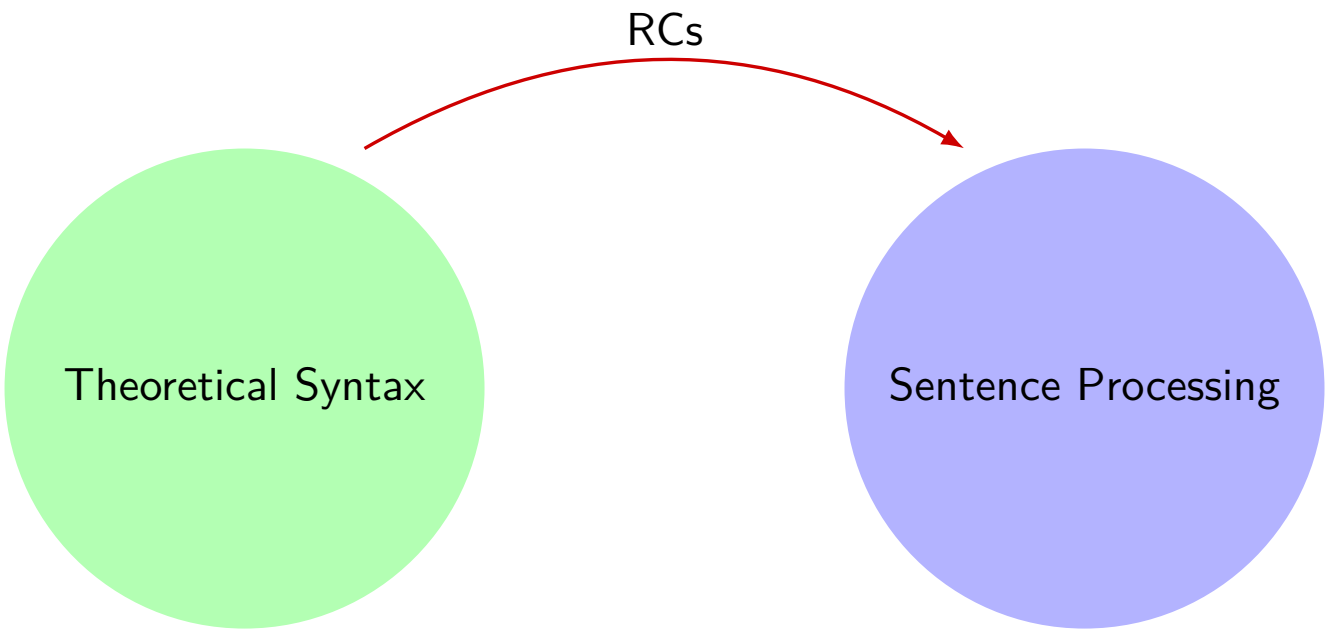

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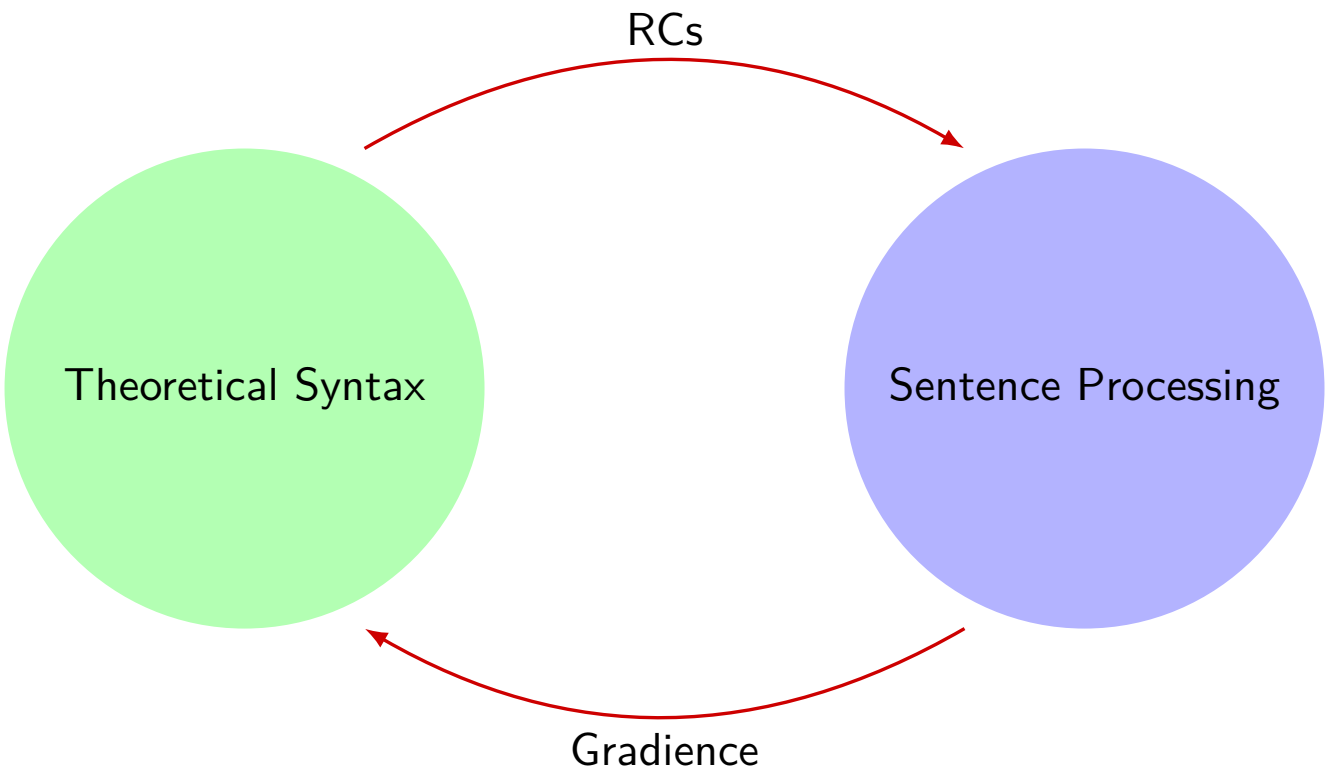
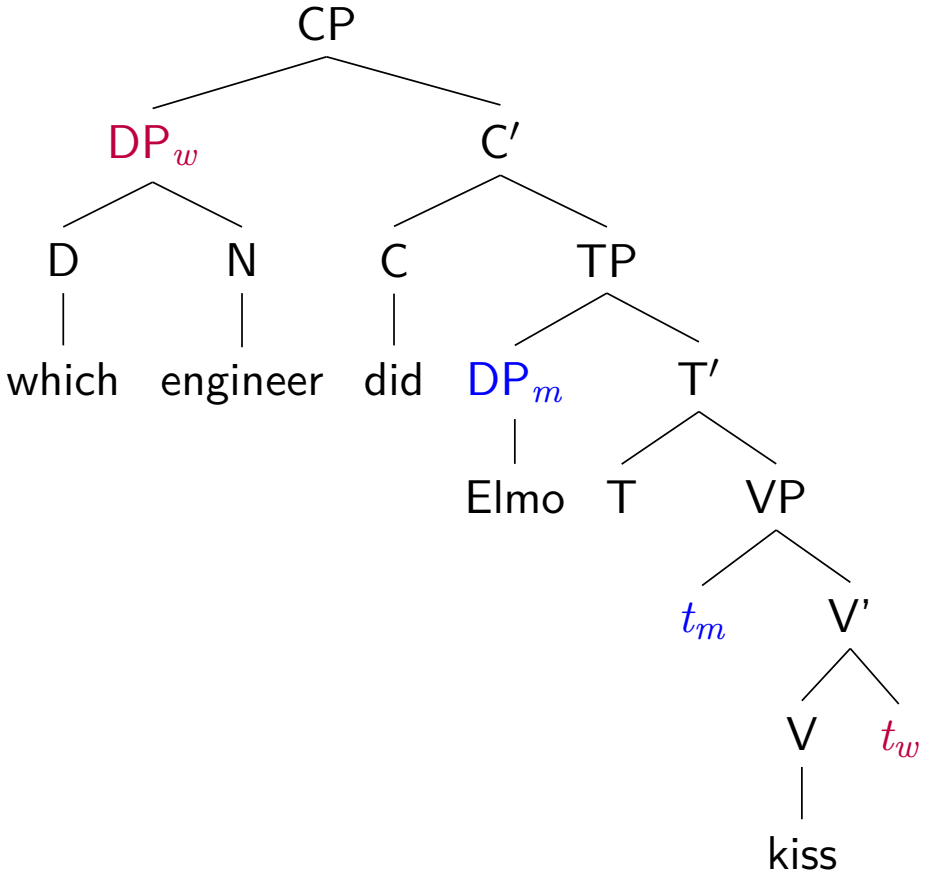


Outline

Minimalist Grammars (MGs) & Derivation Trees



Phrase Structure Tree

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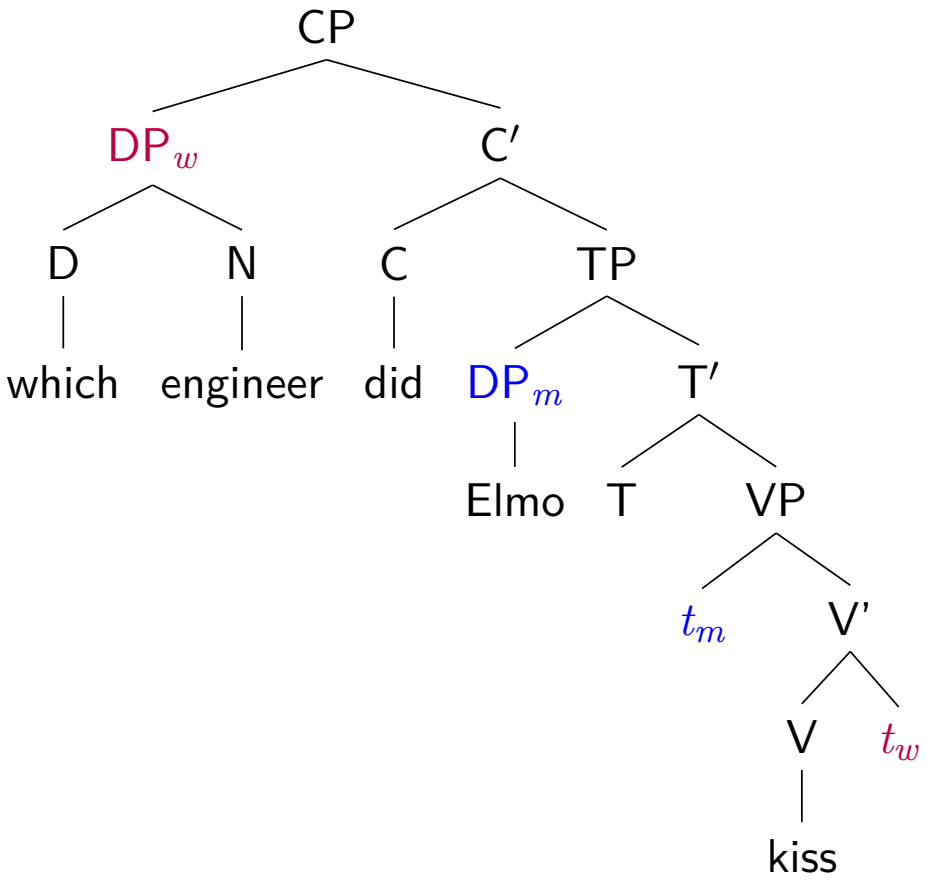

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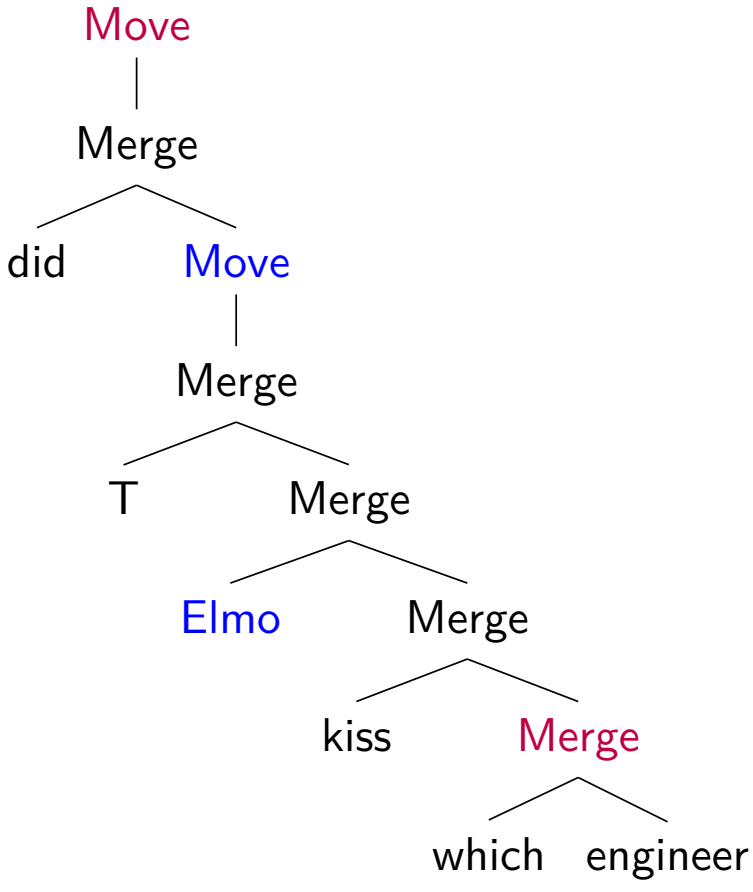
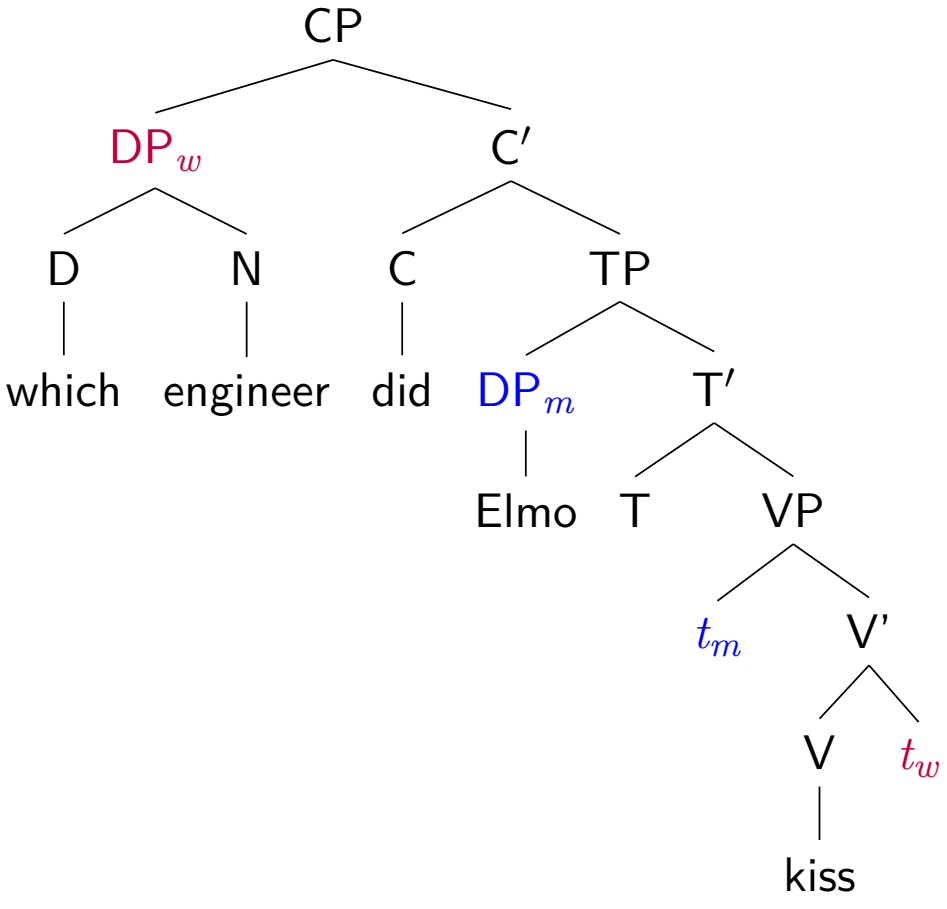


Derivation Tree

MG Syntax: Derivation Trees



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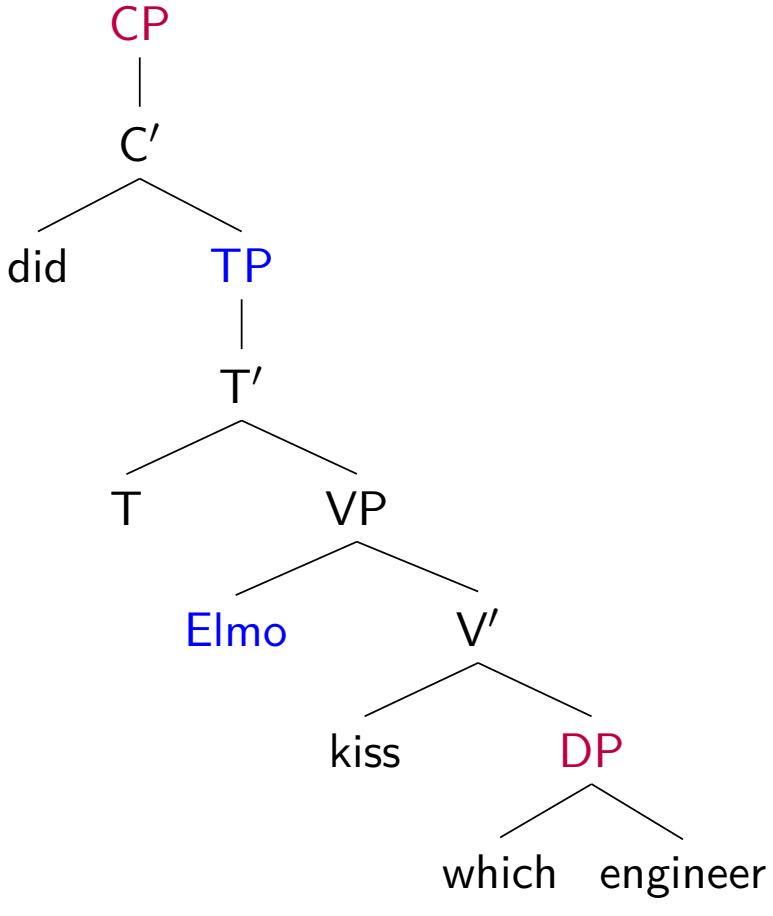

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The Intuition: Top-Down MG Parsing

Who does Salem mock?

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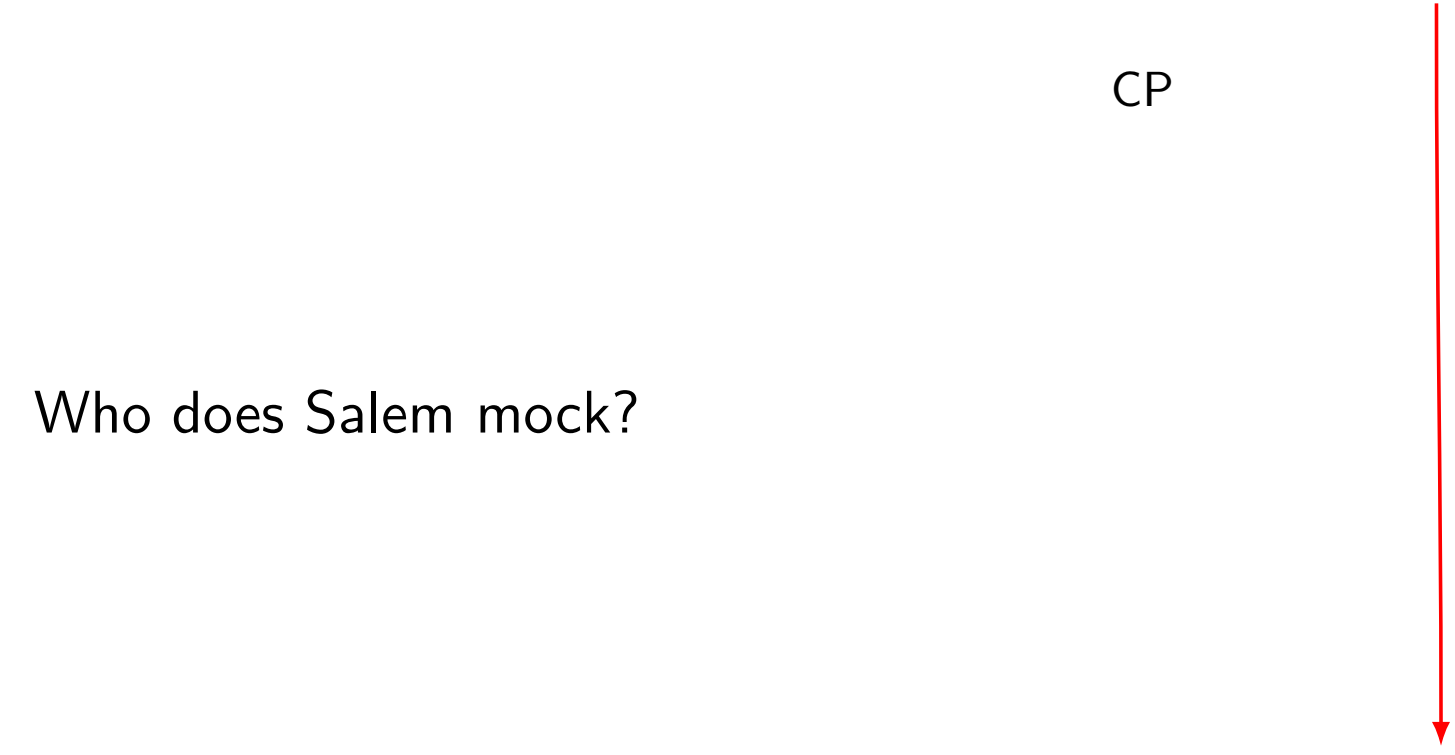

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- Takes elements in an out of memory
- Complexity of the structure $\approx$ how much memory is used!

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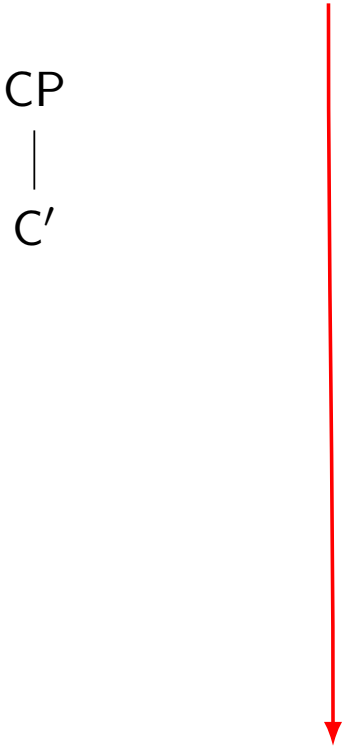

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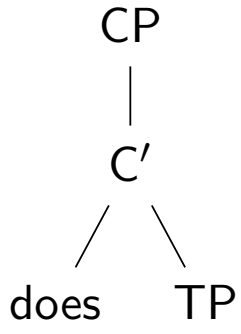

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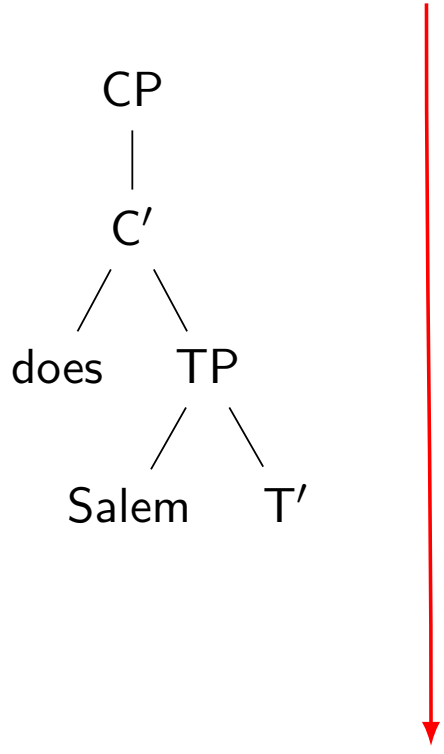

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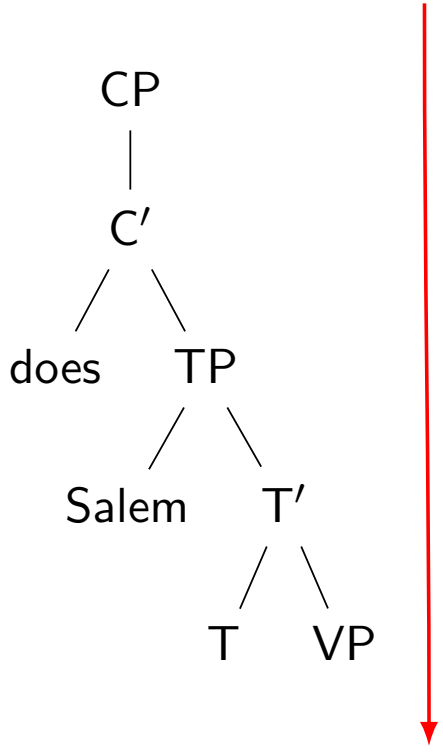

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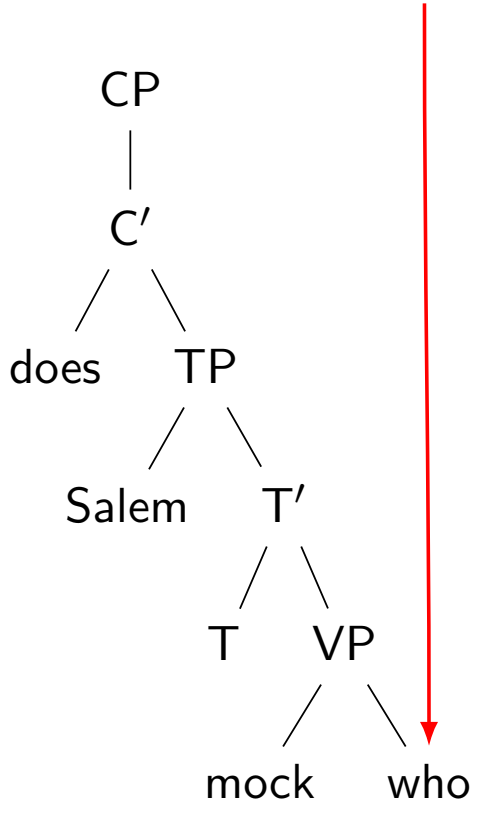

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Incremental Top-Down Parsing

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
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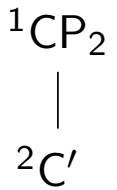

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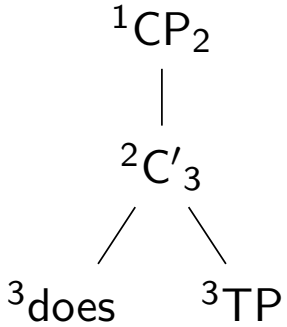

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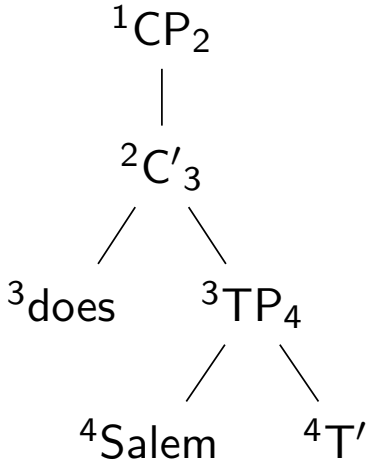

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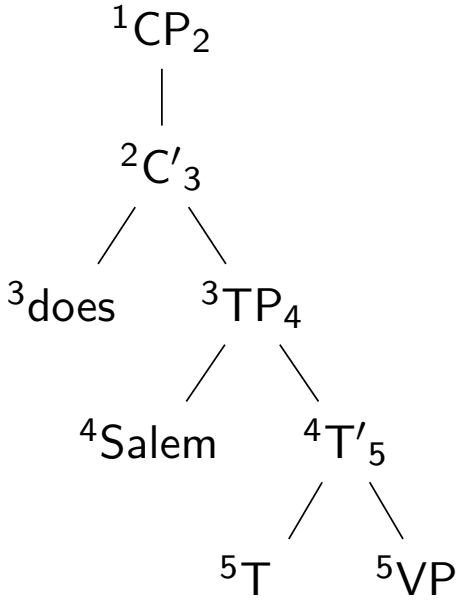

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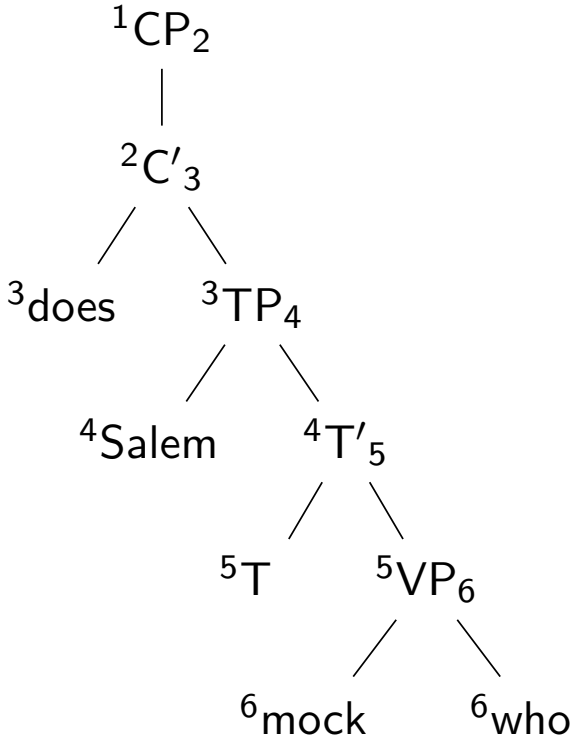

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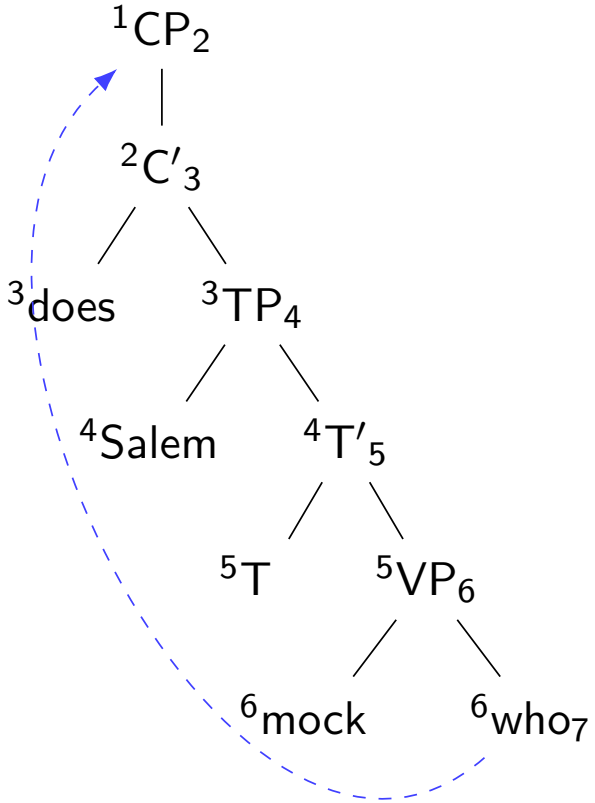

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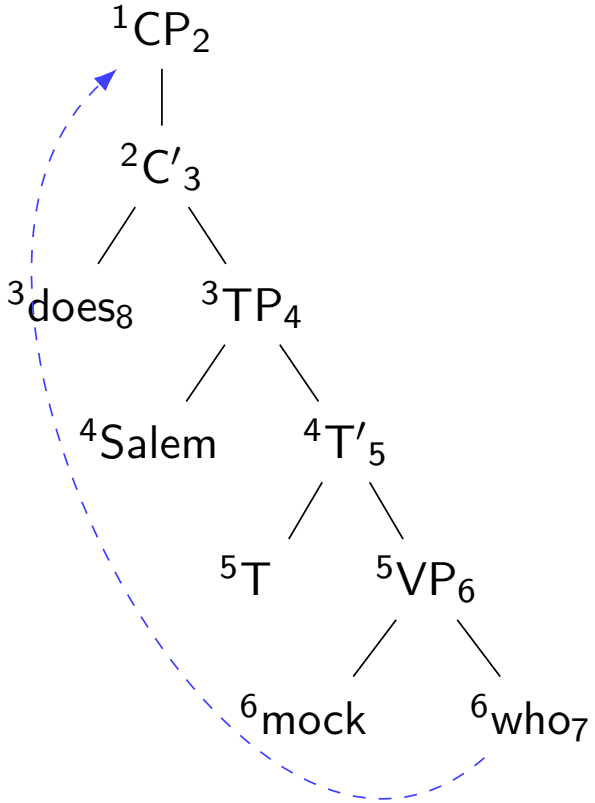

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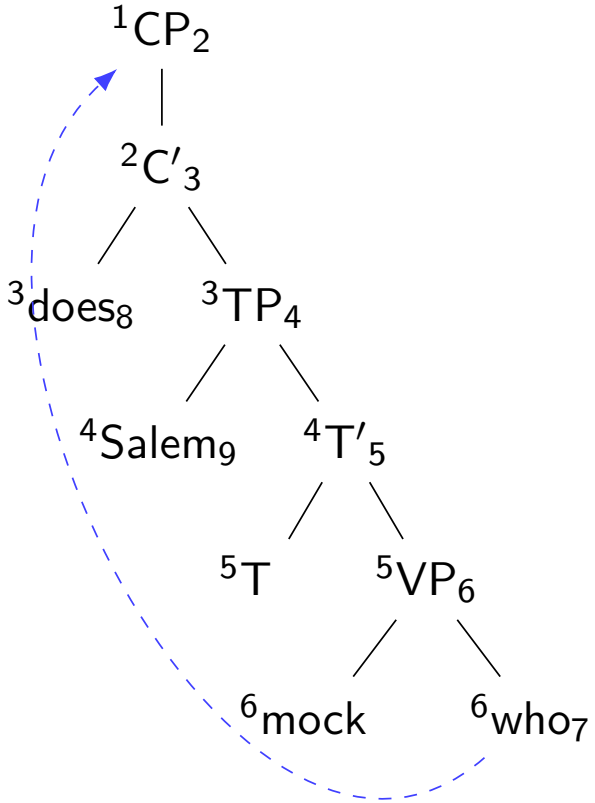

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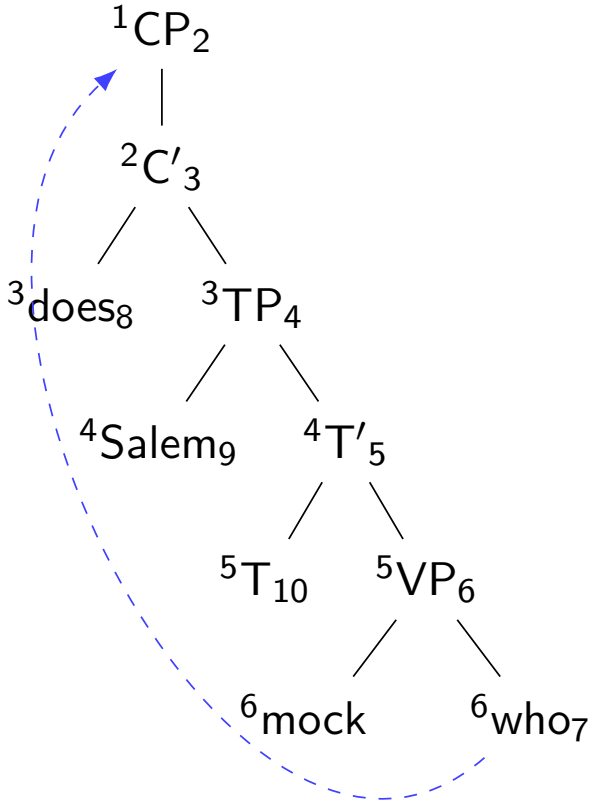

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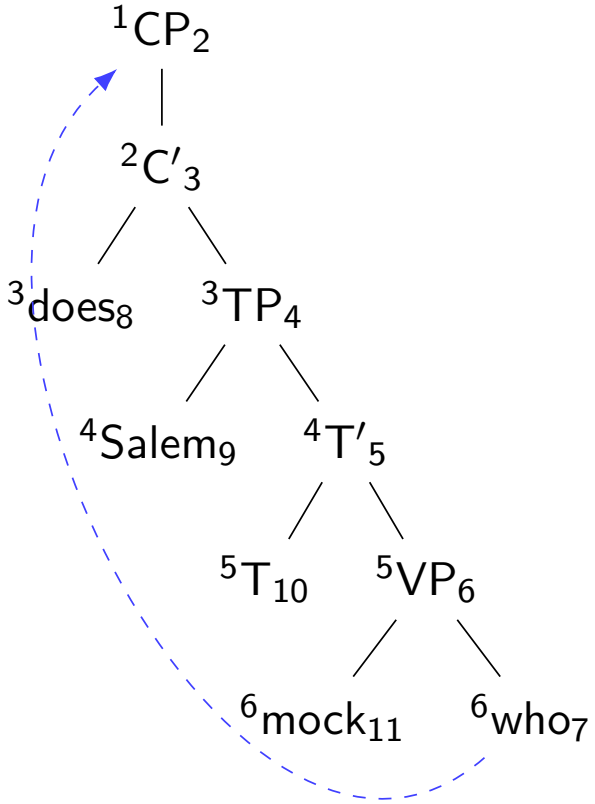
step 6	*VP* expands to *mock* and *who*
step 7	***who*** is found
step 8	***does*** is found
step 9	***Salem*** is found
step 10	***T*** is found
step 11	***mock*** is found



Incremental Top-Down Parsing

Technical details!

- String-driven recursive descent parser (Stabler 2013)

- • **Who** • **does** • **Salem** • **T** • **mock**

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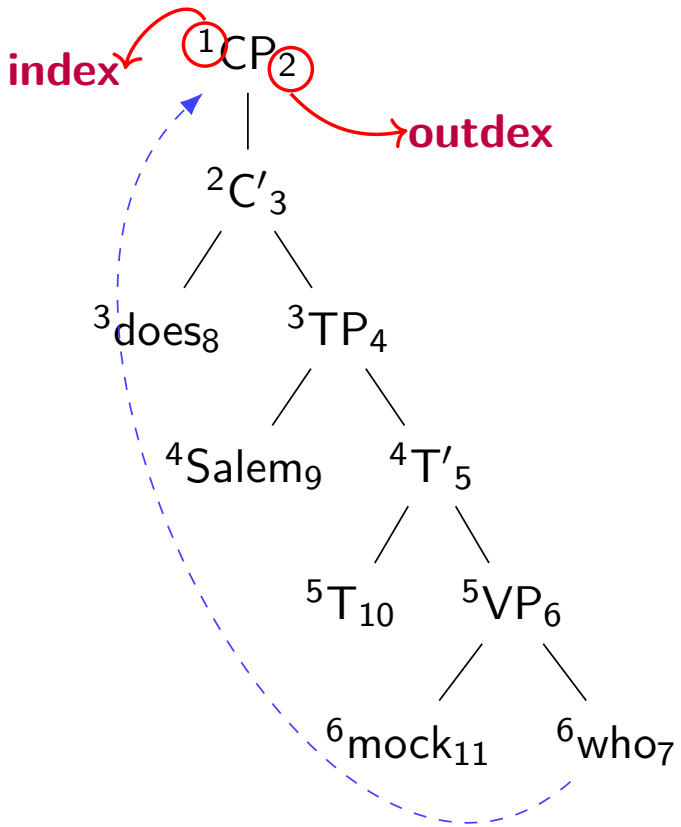

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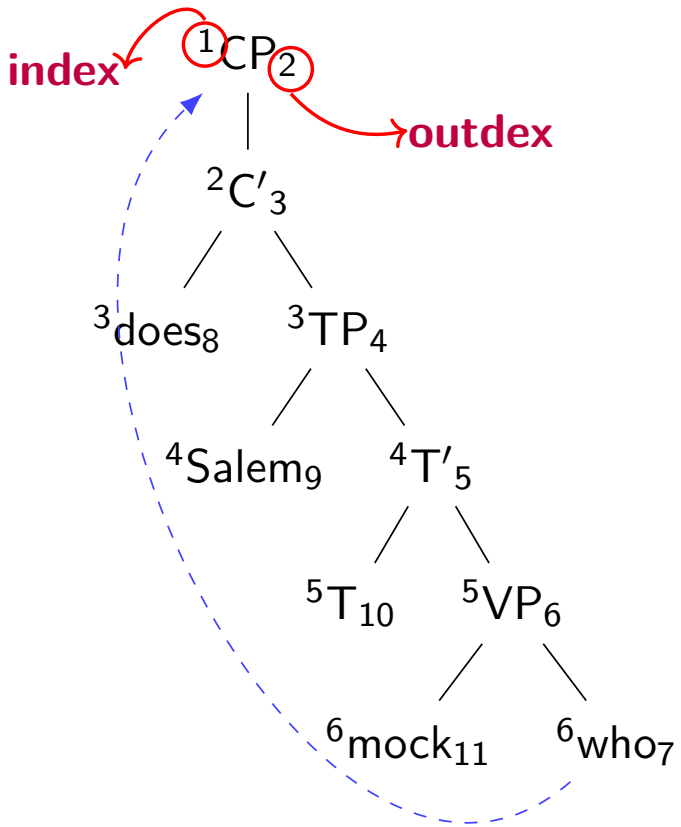


Index and Outdex are our connection to memory!

Measuring Memory Usage

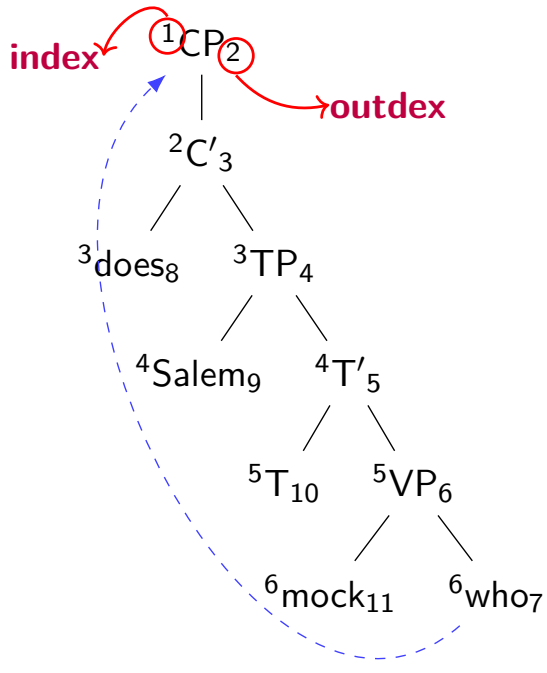
- **Memory usage**:
  (Kobele et al. 2012; Gibson, 1998)

Tenure How long a node is kept in memory
outdex(n) − index(n)

	Who	does	Salem	T	mock
Tenure	1	5	5	5	5

- Formalized into offline complexity metrics
  (Graf et a. 2017; De Santo 2020, 2021; a.o.)

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



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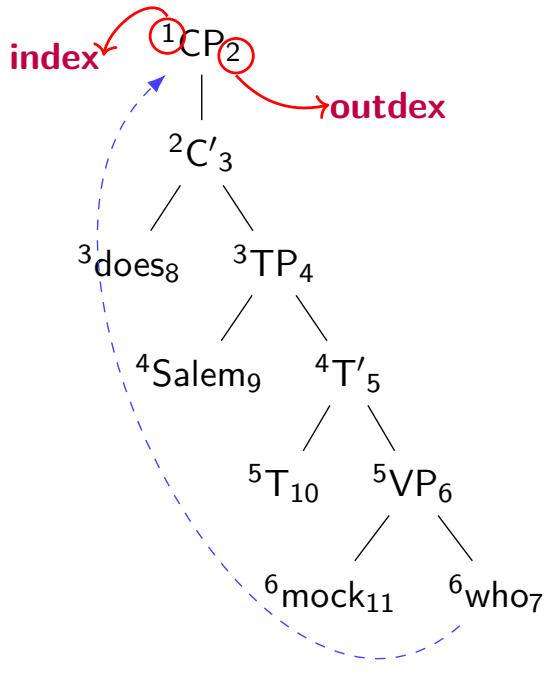

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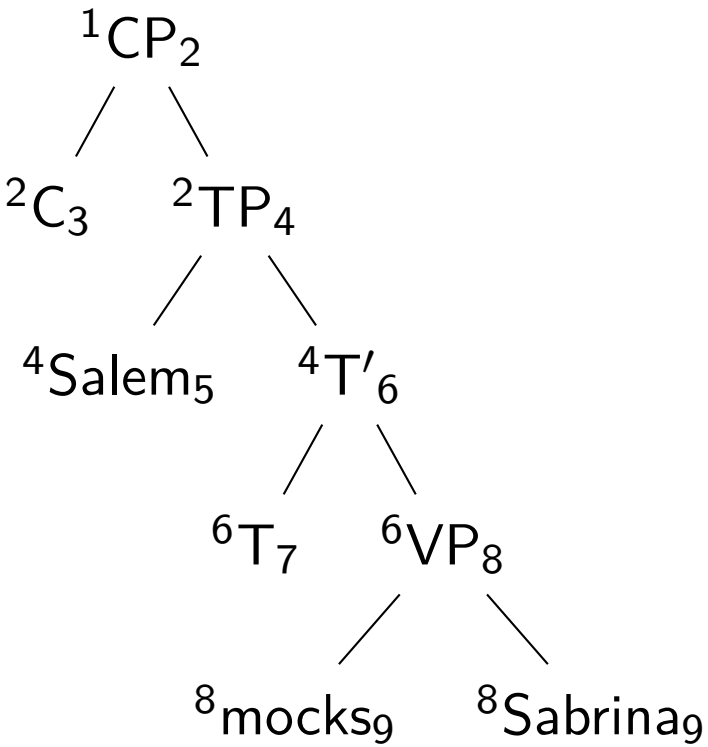
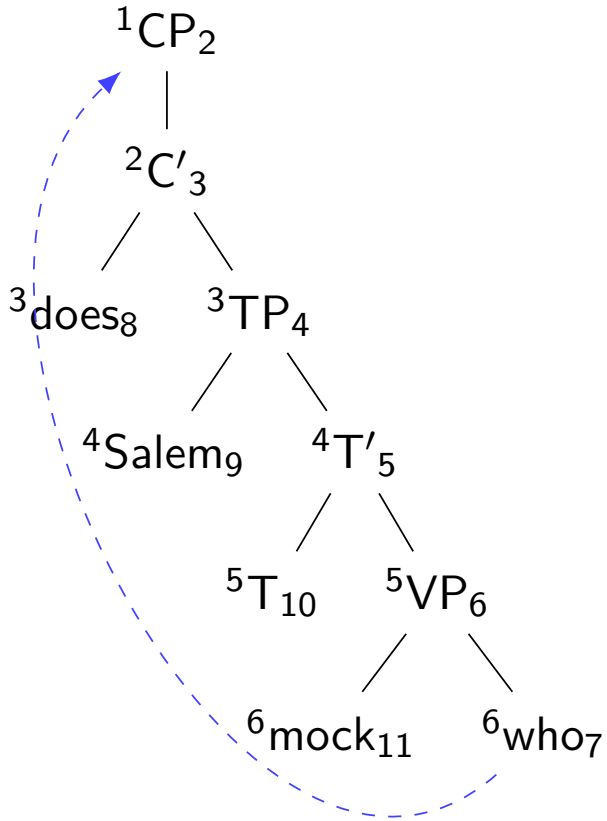
Contrasting Derivations Offline

Memory Usage $= 2$



Memory Usage $= 5$



Summary of the Approch

General Idea: Modeling Offline Asymmetries
(Kobele et al. 2012; Gerth 2015; Graf et al. 2017; De Santo 2020)

1. Pick two competing derivations for a processing contrast
2. Annotate derivation trees and compute memory usage
3. Evaluate effort over each
   - Lowest score means easiest!
4. Compare parser's prediction to reported offline contrasts

Reminder: Asymmetries in Italian Relative Clauses

(1) Il cavallo che ha inseguito i leoni
The horse that has chased the lions
"The horse that chased the lions" **SRC**

(2) Il cavallo che i leoni hanno inseguito
The horse that the lions have chased
"The horse that the lions chased" **ORC**

(4) Il cavallo che hanno inseguito i leoni
The horse that have chased the lions
"The horse that the lions chased" **ORCp**

Processing Asymmetry (De Vincenzi 1991, Arosio et al. 2018, a.o.)

SRC > ORC > ORCp

Modeling Assumptions

Reminder:

- Parsing strategy
  $\Rightarrow$ Top-down parser
- Complexity Metrics
  $\Rightarrow$ Memory Usage

Degrees of freedom: Syntactic analyses

1. RC constructions $\rightarrow$ Kayne (1994)
2. Postverbal subjects $\rightarrow$ Belletti & Leonini (2004)

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	SRC	>	ORC	>	ORCp
Memory	8/che		11/ha		16/Foc

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	SRC	>	ORC	>	ORCp	
Memory	8/che		11/ha		16/Foc	✓

[1] (De Santo 2019)

Results across Constructions [2]

Clause Type	<Memory>
obj. SRC > ORC	✓
obj. SRC > ORCp	✓
obj. ORC > ORCp	✓
subj. SRC > ORC	✓
subj. SRC > ORCp	✓
subj. ORC > ORCp	✓
matrix SVO > VOS	✓
VS unacc > VS unerg	✓

Table: Predictions of the MG parser by contrast.

[2] (De Santo 2019)

Results across Analyses [3]

		SRC < ORC	SRC < ORCp	ORC < ORCp
Postverbal	**RC Type**	MEMORY	MEMORY	MEMORY
Smuggling	Promotion	✓	✓	✓
	Wh-movement	✓	✓	✓
	Extraposition	✓	✓	✓
	DP analysis	✓	✓	✓
Scrambling	Promotion	✓	✓	✓
	Wh-movement	✓	✓	✓
	Extraposition	✓	tie	tie
	DP analysis	✓	tie	tie

Table: Predictions of the MG parser for the RC contrast by analysis.

[3] (De Santo 2021)

Processing Asymmetries All the Way Down

A variety of offline 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)
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- RC attachment preferences
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- English, German, Italian, French, Spanish
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Possible Accounts?

- Working-memory
  (Warren & Gibson 2008; Lewis & Vasishth, 2005; a.o.)
  ⇒ BUT: Nakamura & Miyamoto 2(013) Cf. Graf et al (2017)
- Expectation-based accounts
  (Hale 2001; Demberg Keller, 2008; Chen & Hale 2021)
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Can Tenure help us model word-by-word RTs?

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Modeling Assumptions [4]

Data

- SAP Benchmark (Huang et al. 2024)
  - self-paced reading
  - 2000 participants
  - English SRC/ORC RTs
  - 24 RC sets

Reminder: Model Details

- Parsing strategy
  ⇒ Top-down parser
- Linking Hypothesis
  ⇒ Processing Cost :: (word-by-word) Tenure

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Baseline Model (Huang et al. 2024)

$$RT \sim WordPosition(i) + logfreq(i) * length(i) + logfreq(i-1) * length(i-1) + logfreq(i-1) * length(i-2) + (1|participant) + (1|item)$$

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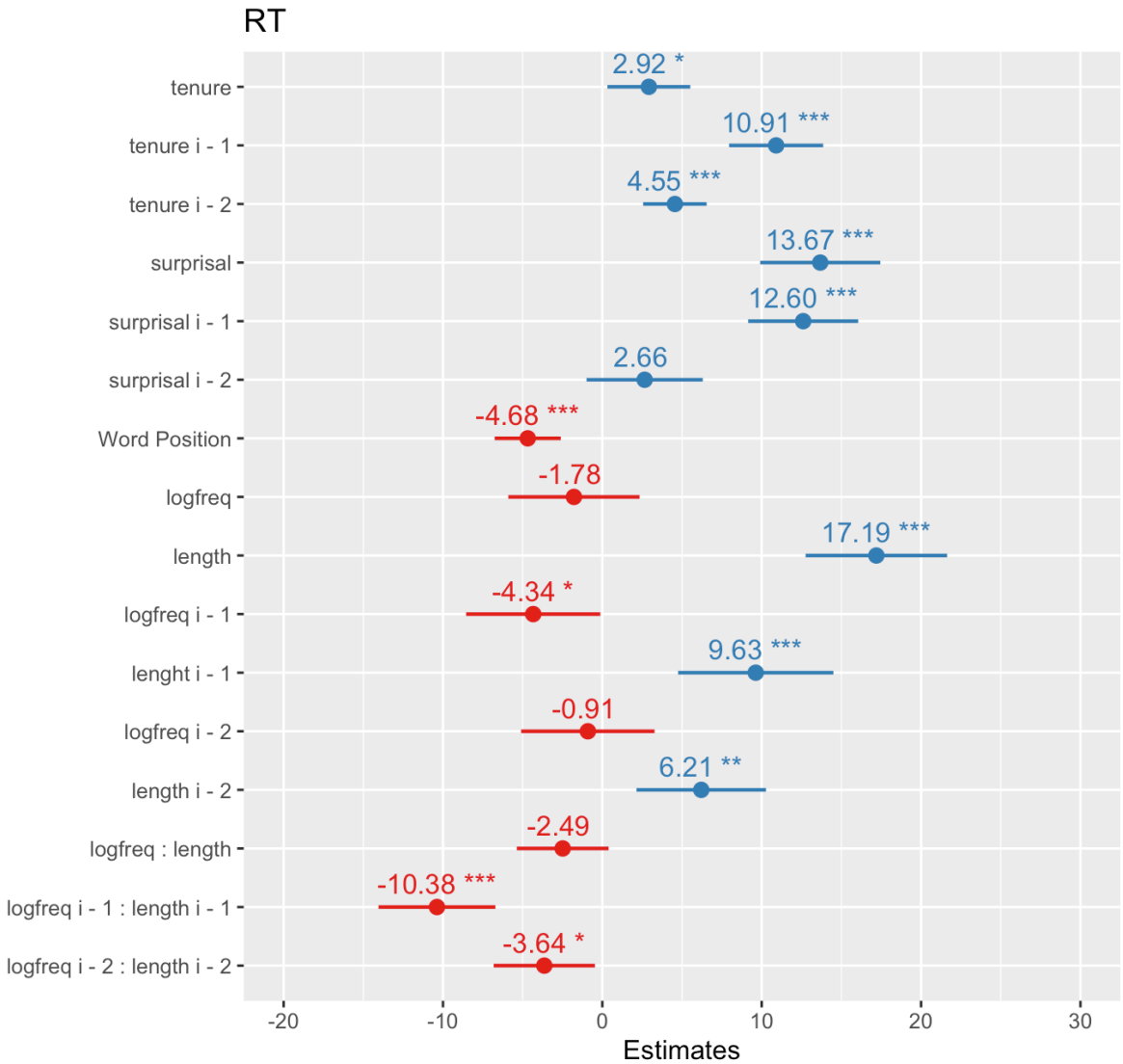

Figure: Estimates of coefficients for GTP Surprisal + Tenure.

Interim Summary

TL;DR

MG-based Tenure is a good predictor of RTs!

- Support for MGs + Tenure both for offline and online data!
- Bridge generative syntax/sentence processing!
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The tip of the iceberg!

- Structure- vs. expectation-based predictors!
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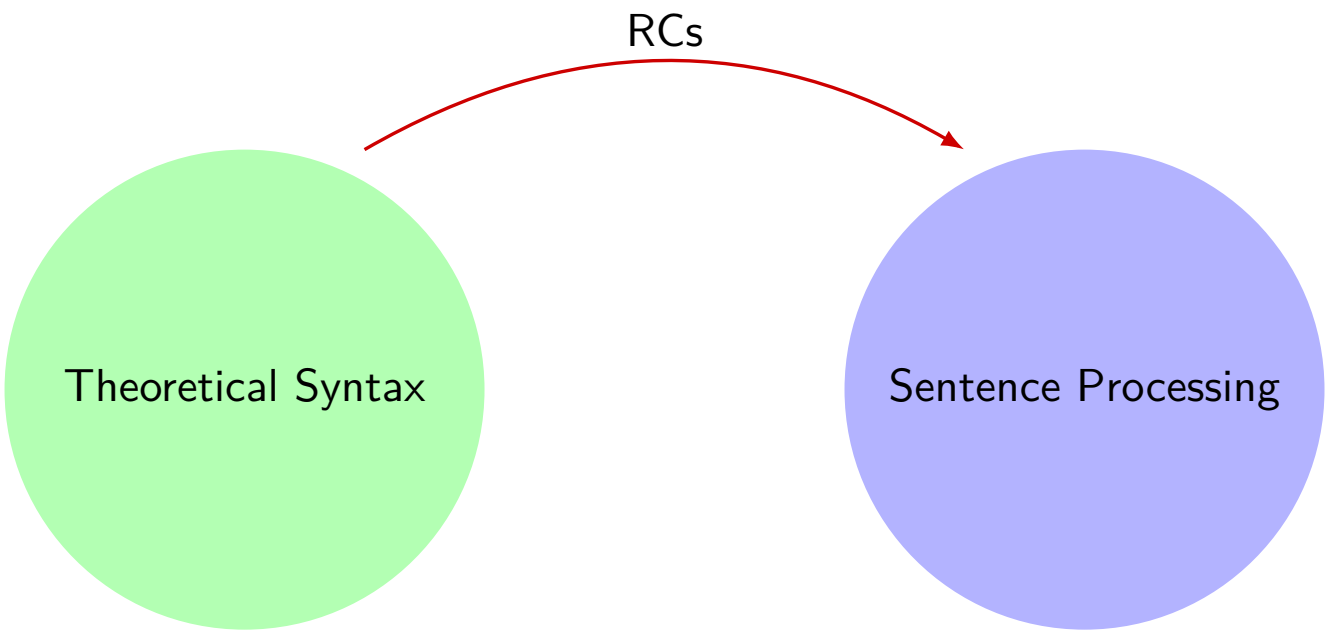

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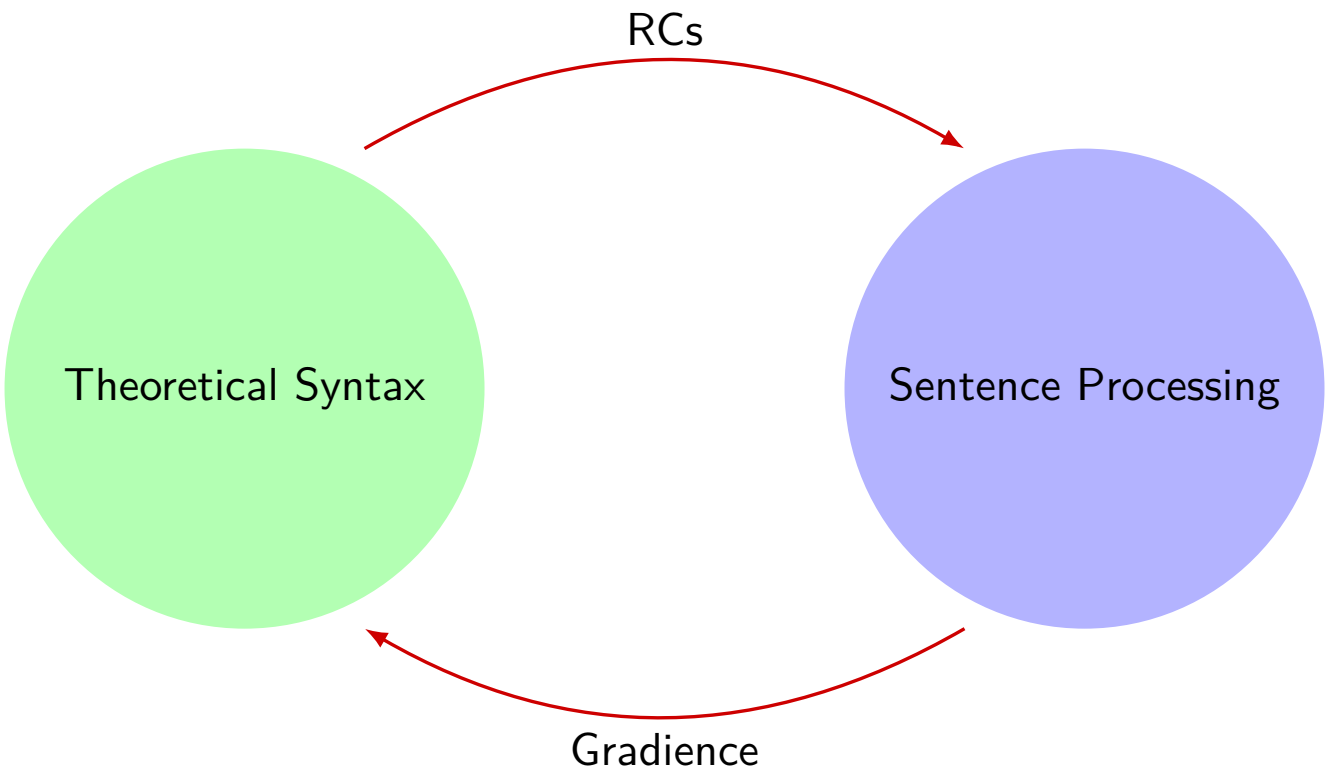

Acceptability and Grammaticality

1. What do you think that John bought *t*?
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Acceptability judgments ≈ Grammaticality judgments

Gradience in Acceptability Judgments

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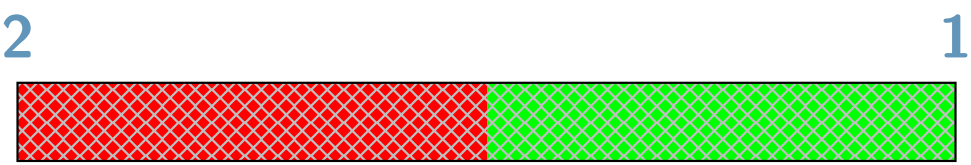

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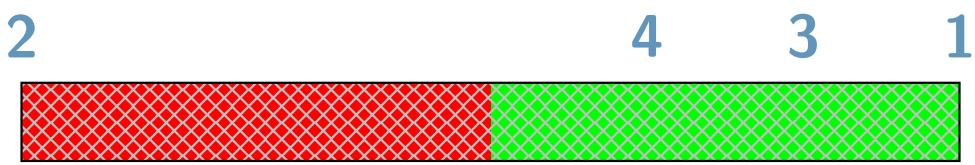

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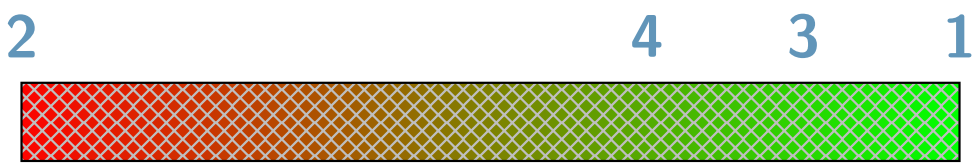

Gradient Acceptability and Categorical Grammars

Acceptability judgments are not binary but *gradient*:

> *An adequate linguistic theory will have to recognize degrees of grammaticalness [...] there is little doubt that speakers can fairly consistently order new utterances, never previously heard, with respect to their degree of belongingness to the language.*
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(Quantitative) Models of Gradience

Gradient Grammars (Keller 2000; Lau et al. 2014)

- OT-style constraint ranking
- Probabilistic grammars

Extra-grammatical Factors (Chomsky 1975; Schütze 1996)

- Processing effects
  - Plausibility
  - Working memory limitations
  - **But:** few models for quantitative predictions!

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A Proof of Concept: Island Effects

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Results in pairwise comparisons ideal for the MG parser

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A factorial design for islands effects:

1. Gap Position: Matrix vs. Embedded
2. Structure: Island vs. Non-Island
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A Proof of Concept: Island Effects

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2. What do you wonder whether John bought *t*? — Island | Embedded
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Sprouse at al. (2012)

Four island types

Subject islands

- What do you think the speech about *t* interrupted the show about global warming?

Adjunct islands

- What do you laugh if John leaves *t* at the office?

Complex NP islands

- What did you make the claim that John bought *t*?

Whether islands

- What do you wonder whether John bought *t*?

Gap Position × Structure

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Modeling Results [5]

Island Type	Sprouse et al. (2012)			MG Parser
Subj. Island 1	Subj. | Non Isl.	>	Obj. | Non Isl.	✓
	Subj. | Non Isl.	>	Obj. | Isl.	✓
	Subj. | Non Isl.	>	Subj. | Isl.	✓
	Obj. | Non Isl.	>	Obj. | Isl.	✓
	Obj. | Non Isl.	>	Subj. | Isl.	✓
	Obj. | Isl.	>	Subj. | Isl.	×
Subj. Island 2	Matrix | Non Isl.	>	Emb. | Non Isl.	✓
	Matrix | Non Isl.	>	Matrix | Isl.	✓
	Matrix | Non Isl.	>	Emb. | Isl.	✓
	Matrix | Isl.	>	Emb. | Isl.	✓
	Matrix | Isl.	>	Matrix | Isl.	✓
	Emb. | Non Isl.	>	Emb. | Isl.	✓
Adj. Island	Matrix | Non Isl.	>	Emb. | Non Isl.	✓
	Matrix | Non Isl.	>	Matrix | Isl.	✓
	Matrix | Non Isl.	>	Emb. | Isl.	✓
	Matrix | Isl.	>	Emb. | Isl.	✓
	Matrix | Isl.	>	Matrix | Isl.	✓
	Emb. | Non Isl.	>	Emb. | Isl.	✓
CNP Island	Matrix | Non Isl.	>	Emb. | Non Isl.	✓
	Matrix | Non Isl.	=	Matrix | Isl.	✓
	Matrix | Non Isl.	>	Emb. | Isl.	✓
	Matrix | Isl.	>	Emb. | Isl.	✓
	Matrix | Isl.	>	Matrix | Isl.	✓
	Emb. | Non Isl.	>	Emb. | Isl.	✓

[5] (De Santo 2020, in prep.)

Modeling Results [5]

Island Type	Sprouse et al. (2012)			MG Parser
Subj. Island 1	Subj. | Non Isl.	>	Obj. | Non Isl.	✓
	Subj. | Non Isl.	>	Obj. | Isl.	✓
	Subj. | Non Isl.	>	Subj. | Isl.	✓
	Obj. | Non Isl.	>	Obj. | Isl.	✓
	Obj. | Non Isl.	>	Subj. | Isl.	✓
	Obj. | Isl.	>	**Subj. | Isl.**	×
Subj. Island 2	Matrix | Non Isl.	>	Emb. | Non Isl.	✓
	Matrix | Non Isl.	>	Matrix | Isl.	✓
	Matrix | Non Isl.	>	Emb. | Isl.	✓
	Matrix | Isl.	>	Emb. | Isl.	✓
	Matrix | Isl.	>	Matrix | Isl.	✓
	Emb. | Non Isl.	>	Emb. | Isl.	✓
Adj. Island	Matrix | Non Isl.	>	Emb. | Non Isl.	✓
	Matrix | Non Isl.	>	Matrix | Isl.	✓
	Matrix | Non Isl.	>	Emb. | Isl.	✓
	Matrix | Isl.	>	Emb. | Isl.	✓
	Matrix | Isl.	>	Matrix | Isl.	✓
	Emb. | Non Isl.	>	Emb. | Isl.	✓
CNP Island	Matrix | Non Isl.	>	Emb. | Non Isl.	✓
	Matrix | Non Isl.	=	Matrix | Isl.	✓
	Matrix | Non Isl.	>	Emb. | Isl.	✓
	Matrix | Isl.	>	Emb. | Isl.	✓
	Matrix | Isl.	>	Matrix | Isl.	✓
	Emb. | Non Isl.	>	Emb. | Isl.	✓

[5] (De Santo 2020, in prep.)

TL;DR

Success in all cases but one!

Subject Island: Case 1

(3) a. What do you think the speech interrupted *t*? Obj | Non Island

b. What do you think *t* interrupted the show? Subj | Non Island

c. What do you think the speech about global warming interrupted the show about *t*? Obj | Island

d. What do you think the speech about *t* interrupted the show about global warming? Subj | Island

Sprouse et al. (2012)			MG Parser
Subj. | Non Isl.	>	Obj. | Non Isl.	✓
Subj. | Non Isl.	>	Obj. | Isl.	✓
Subj. | Non Isl.	>	Subj. | Isl.	✓
Obj. | Non Isl.	>	Obj. | Isl.	✓
Obj. | Non Isl.	>	Subj. | Isl.	✓
Obj. | Isl.	>	Subj. | Isl.	×

Clause Type	MaxT	SumS
Obj./Non Island	14/*do*	19
Subj./Non Island	11/*do*	14
Obj./Island	23/*T2*	22
Subj./Island	15/*do*	20

Subject Island: Case 1

(5) a. What do you think the speech interrupted *t*? Obj | Non Island

b. What do you think *t* interrupted the show? Subj | Non Island

c. What do you think the speech about global warming interrupted the show about *t*? Obj | Island

d. * What do you think the speech about *t* interrupted the show about global warming? Subj | Island

Sprouse et al. (2012)			MG Parser
Subj. | Non Isl.	>	Obj. | Non Isl.	✓
Subj. | Non Isl.	>	Obj. | Isl.	✓
Subj. | Non Isl.	>	Subj. | Isl.	✓
Obj. | Non Isl.	>	Obj. | Isl.	✓
Obj. | Non Isl.	>	Subj. | Isl.	✓
Obj. | Isl.	>	Subj. | Isl.	×

Clause Type	MaxT	SumS
Obj./Non Island	14/*do*	19
Subj./Non Island	11/*do*	14
Obj./Island	23/*T2*	22
Subj./Island	15/*do*	20

Subject Island: Case 2

(6) a. Who *t* thinks the speech interrupted the primetime TV show?
Matrix | Non Island

b. What do you think *t* interrupted the primetime TV show?
Emb. | Non Island

c. Who *t* thinks the speech about global warming interrupted the primetime TV show?
Matrix | Island

d. What do you think the speech about *t* interrupted the primetime TV show?
Emb. | Island

Sprouse et al. (2012)			MG Parser
Matrix | Non Isl.	>	Emb. | Non Isl.	✓
Matrix | Non Isl.	>	Matrix | Isl.	✓
Matrix | Non Isl.	>	Emb. | Isl.	✓
Matrix | Isl.	>	Emb. | Isl.	✓
Matrix | Isl.	>	Matrix | Isl.	✓
Emb. | Non Isl.	>	Emb. | Isl.	✓

Clause Type	MaxT	SumS
Matrix | Non Isl.	$5/C$	9
Emb. | Non Isl.	$11/do$	14
Matrix | Isl.	$11/T_{RC}$	9
Emb. | Isl.	$17/T_{RC}$	20

Summary

Gradience from a categorical MG grammar?

- The **first** (quantitative) model of this kind!
- Overall, a success! ⇒ **just** from structural differences!
- Outlier is expected assuming grammaticalized constraints.

The tip of the iceberg!

- Modulate range of dependencies (De Santo, in prep.)
- Cognitive vs. grammatical constraints? (Ferrara-Boston 2012)
- Syntactic constraints ∼ pruning the parsing space (Stabler 2013, Graf & De Santo 2020)
- Economy principles (De Santo & Lee 2022)
- Compatible with distributional semantics models (Paulson, De Santo, & Rawski u.r.)

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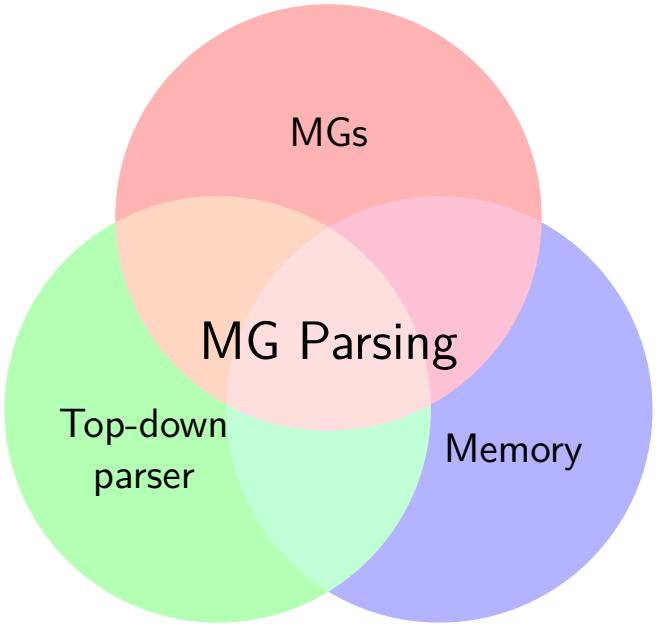
From the Trees (back) to the Forest



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)

Looking Ahead: A Collaborative Enterprise

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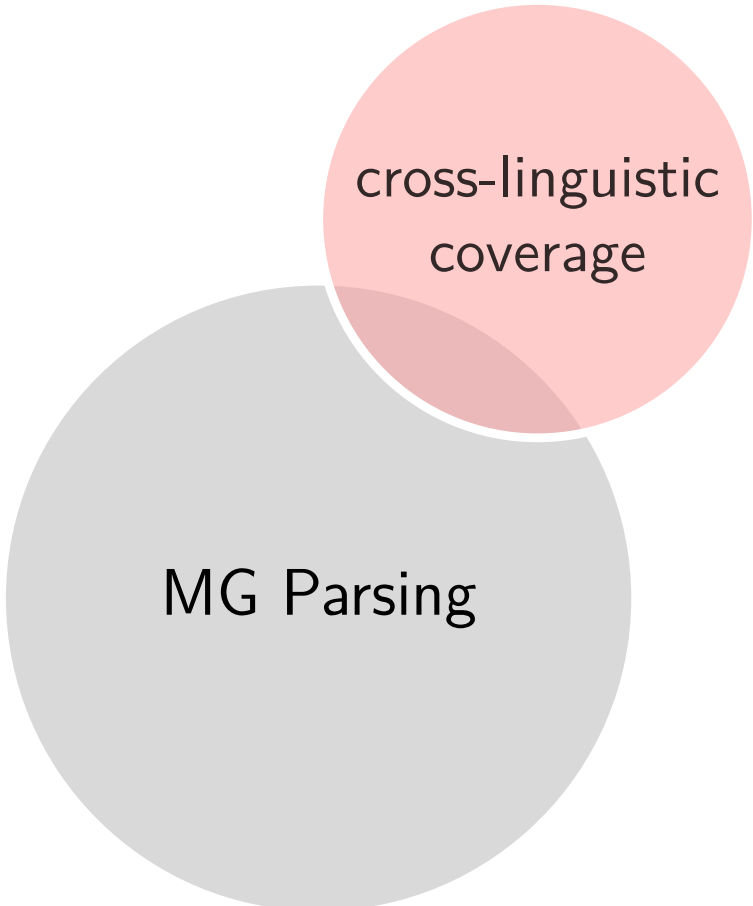

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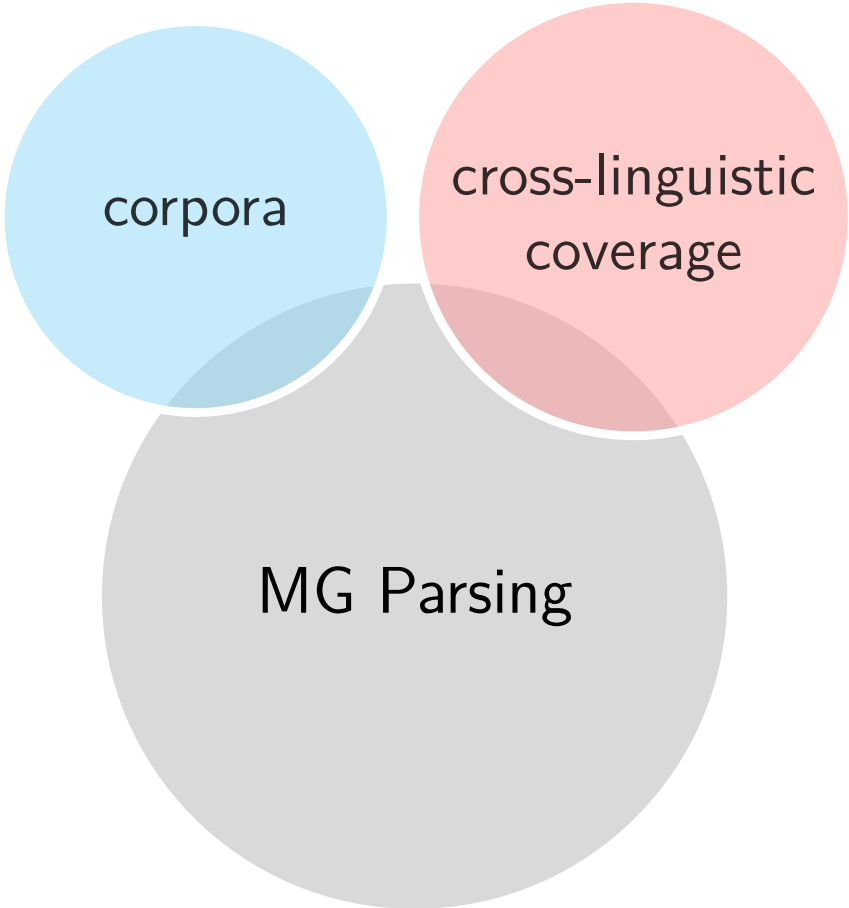

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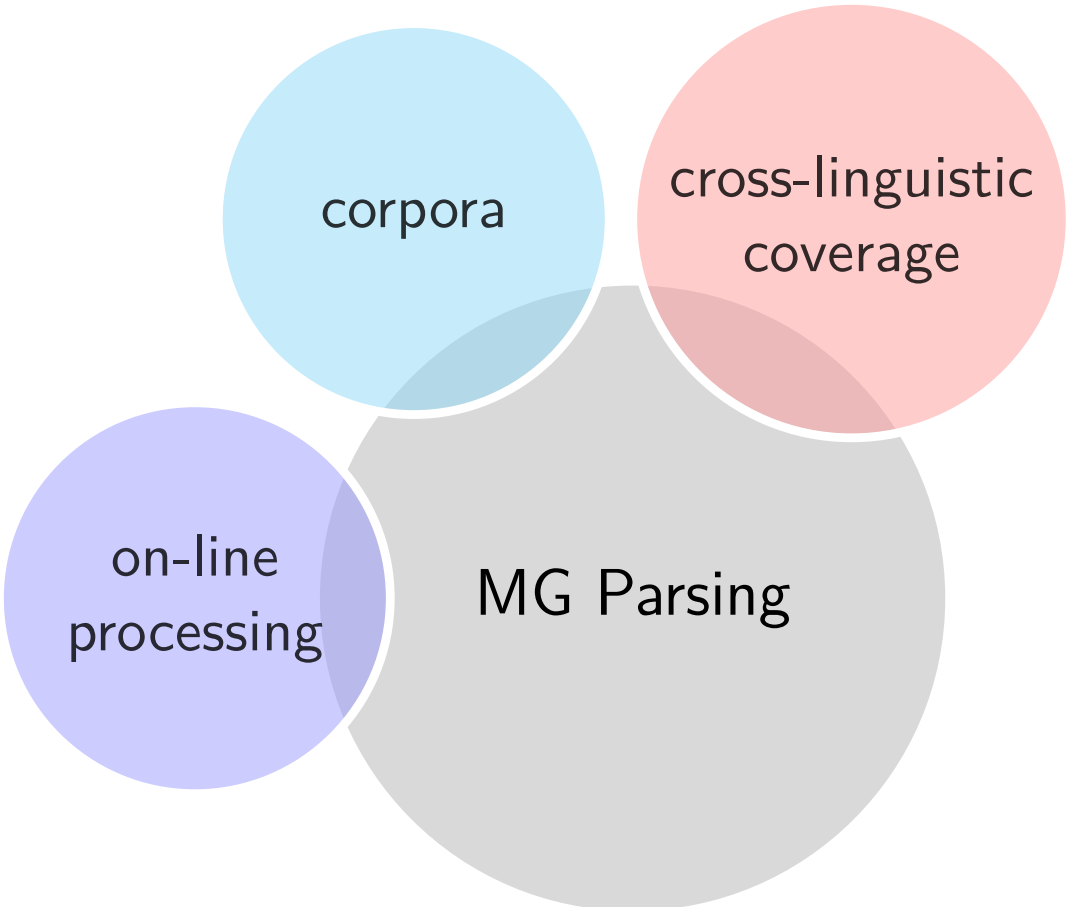

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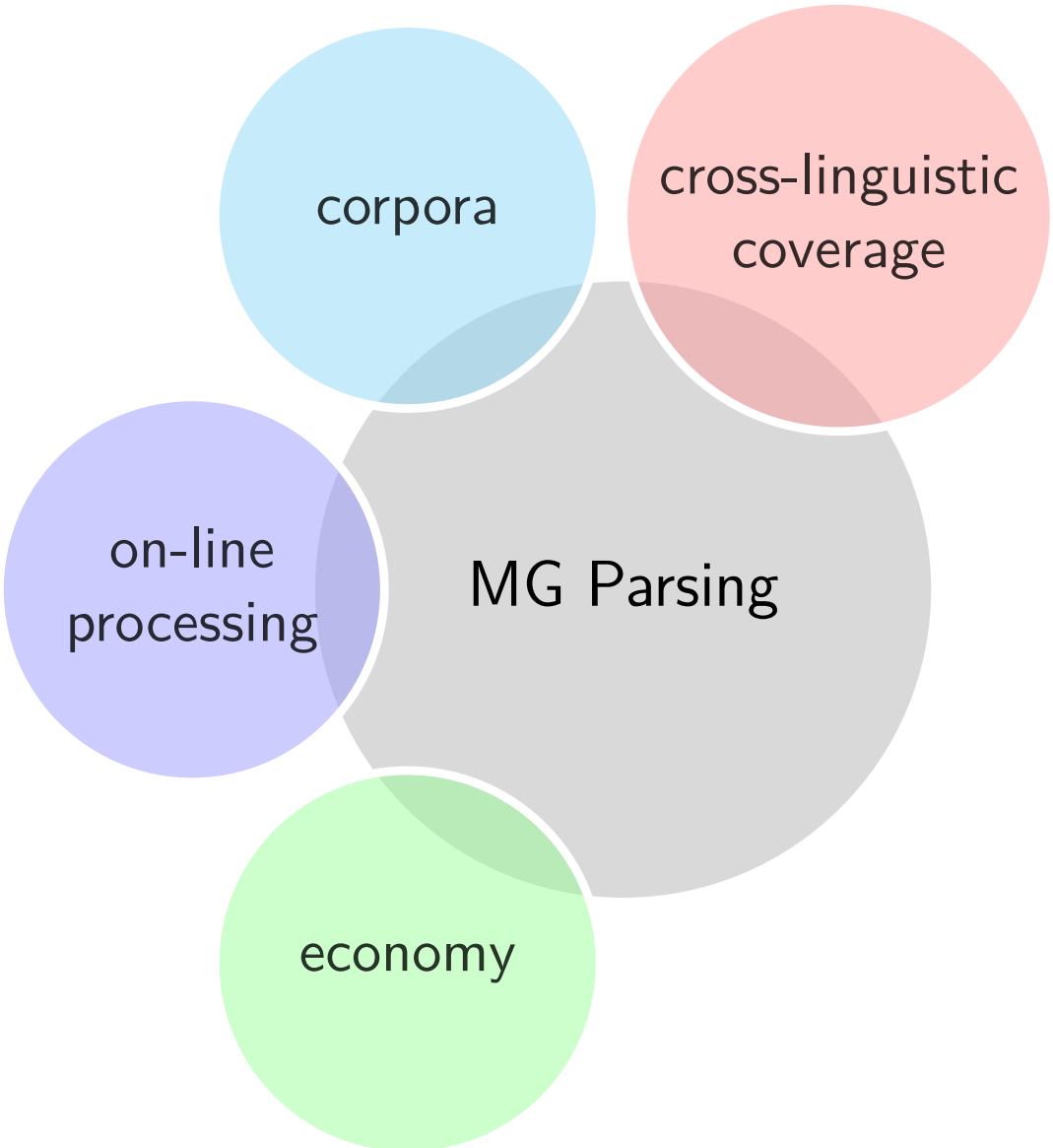

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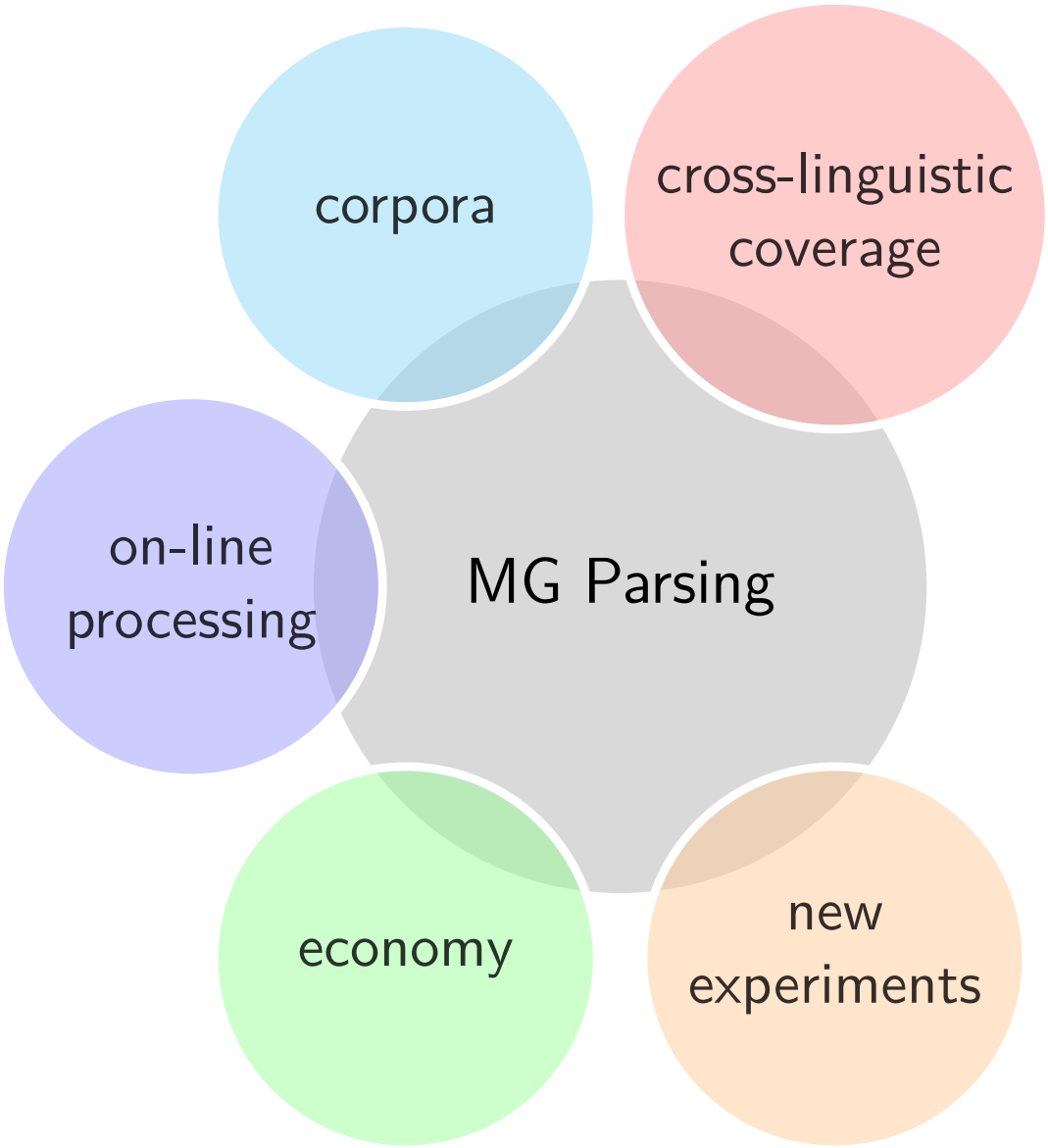

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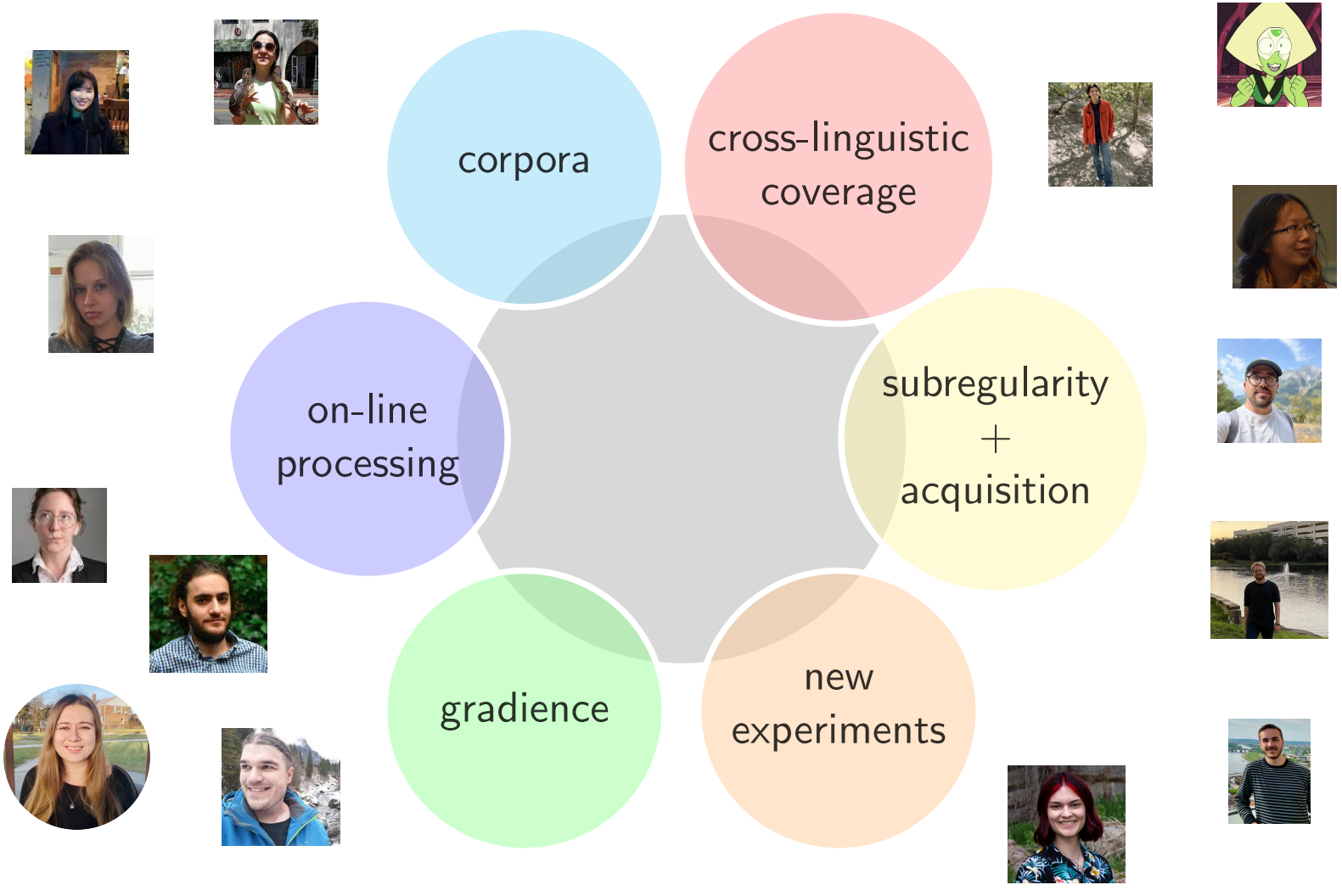

Looking Ahead: A Collaborative Enterprise

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Appendix

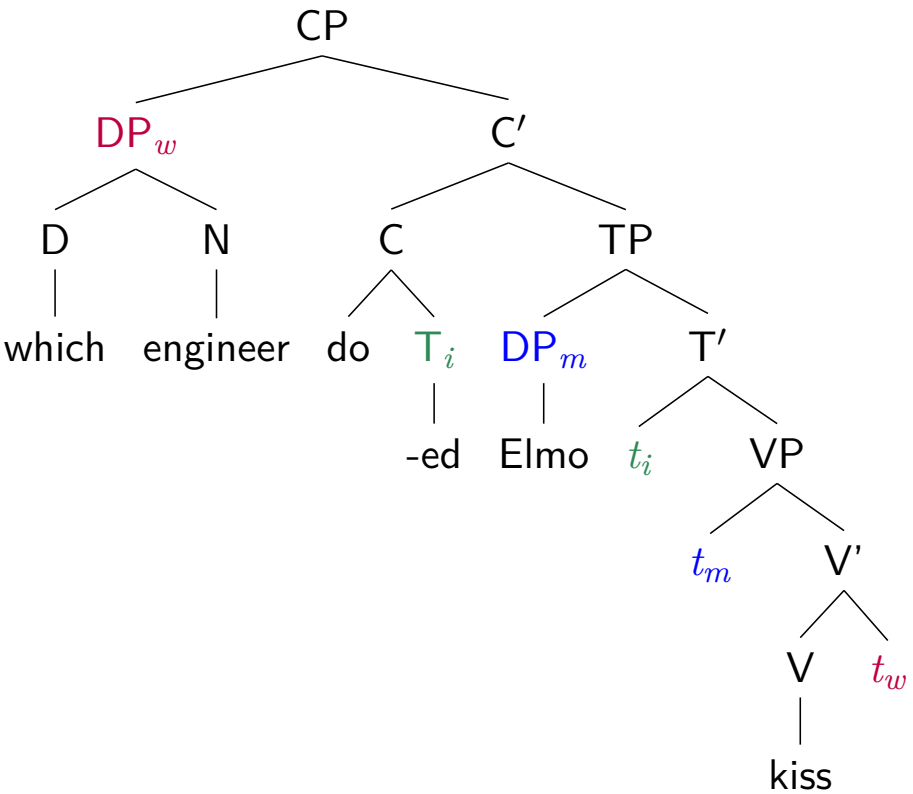
Why MGs?

1. Vast analytical coverage
   - MGs handle virtually all analyses in the generative literature
2. Centrality of derivation trees
   - MGs can be viewed as CFGs with a more complicated mapping from trees to strings
3. Simple parsing algorithms
   - Variant of a recursive descent parser for CFGs
     $\Rightarrow$ cf. TAG (Rambow & Joshi, 1995; Demberg, 2008)

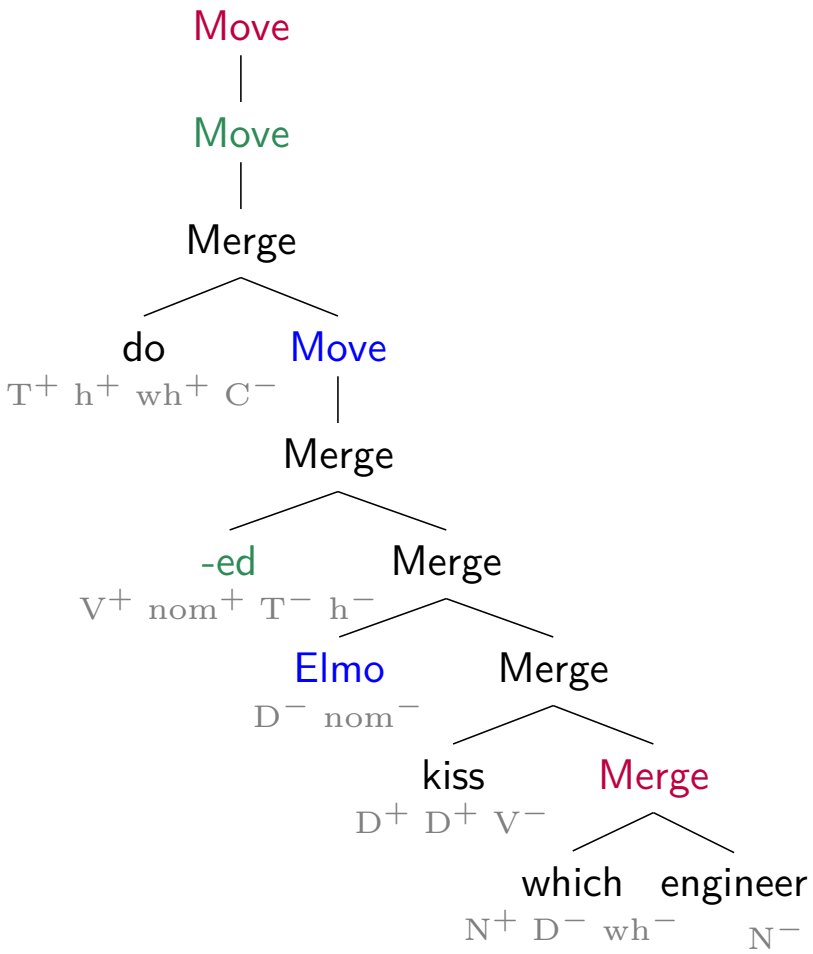
Some Important Properties of MGs

- MGs are weakly equivalent to MCFGs and thus mildly context-sensitive. (Harkema 2001, Michaelis 2001)
- But we can decompose them into two finite-state components: (Michaelis et al. 2001, Kobele et al. 2007, Monnich 2006)
  - a regular language of well-formed derivation trees
  - an MSO-definable mapping from derivations to phrase structure trees
- **Remember:** Every regular tree language can be re-encoded as a CFG (with more fine-grained non-terminal labels). (Thatcher 1967)

Fully Specified Derivation Trees



Phrase Structure Tree



Derivation Tree

Technical Fertility of MGs

MGs can accommodate the full syntactic toolbox:

- sidewards movement (Stabler, 2006; Graf 2013)
- affix hopping (Graf 2012; Graf2013)
- clustering movement (Gartner & Michaelis 2010)
- tucking in (Graf 2013)
- ATB movement (Kobele 2008)
- copy movement (Kobele 2006)
- extraposition (Hunter &Frank 2014)
- Late Merge (Kobele 2010; Graf 2014)
- Agree (Kobele 2011; Graf 2011)
- adjunction (Fowlie 2013; Hunter 2015)
- TAG-style adjunction (Graf 2012)

Why These Metrics?

- These complexity metrics are all related to **storage cost** (cf. Gibson, 1998)
- We could implement alternative ones (cf. Ferrara-Boston, 2012)
  - number of bounding nodes / phases
  - surprisal
  - feature intervention
  - status of discourse referents
  - integration, retrieval, ...
- We want to keep the model **simple** (but not **trivial**):
  - Tenure and Size only refer to the geometry of the derivation
  - they are sensitive the specifics of tree-traversal (cf. node-count; Hale, 2001)

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Memory-Based Complexity Metrics

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

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!

- These can be formalized into **complexity metrics**

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

SumSize $\sum_{m \in M} size(m)$

Ranked $\langle MaxTenure, SumSize \rangle$

Greg Kobele

Sabrina Gerth

John Hale

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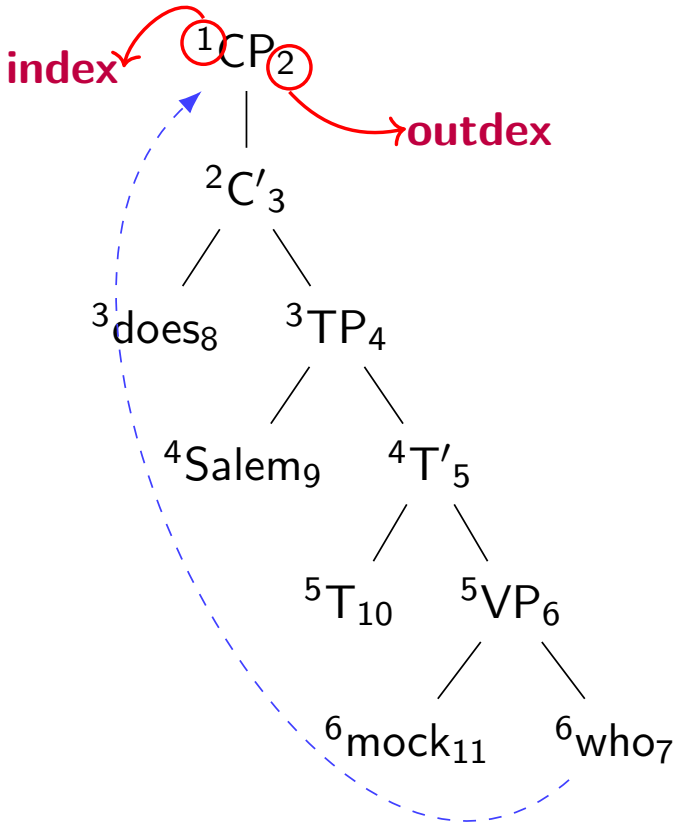
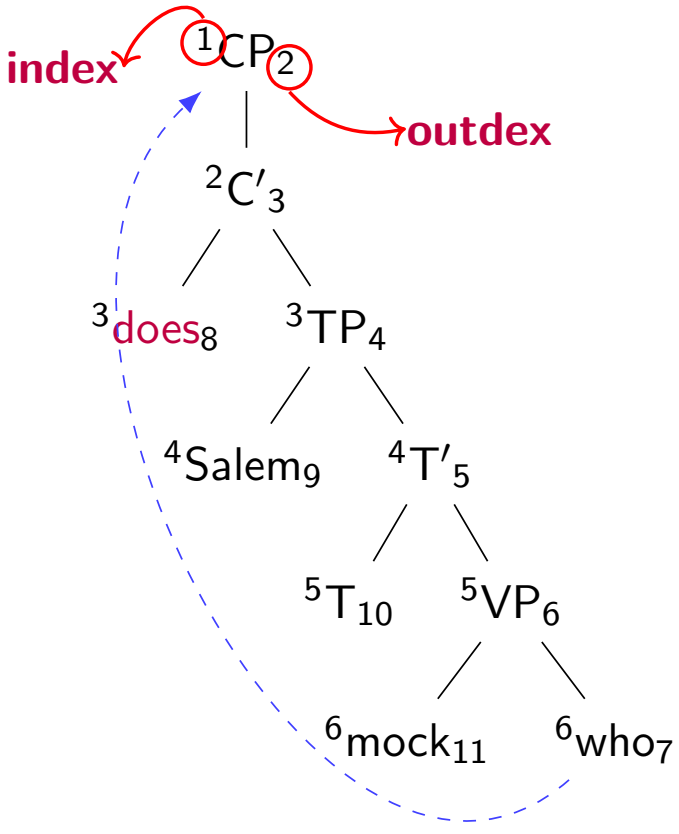
Computing Metrics: An Example



Tenure how long a node is kept in memory

Computing Metrics: An Example



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

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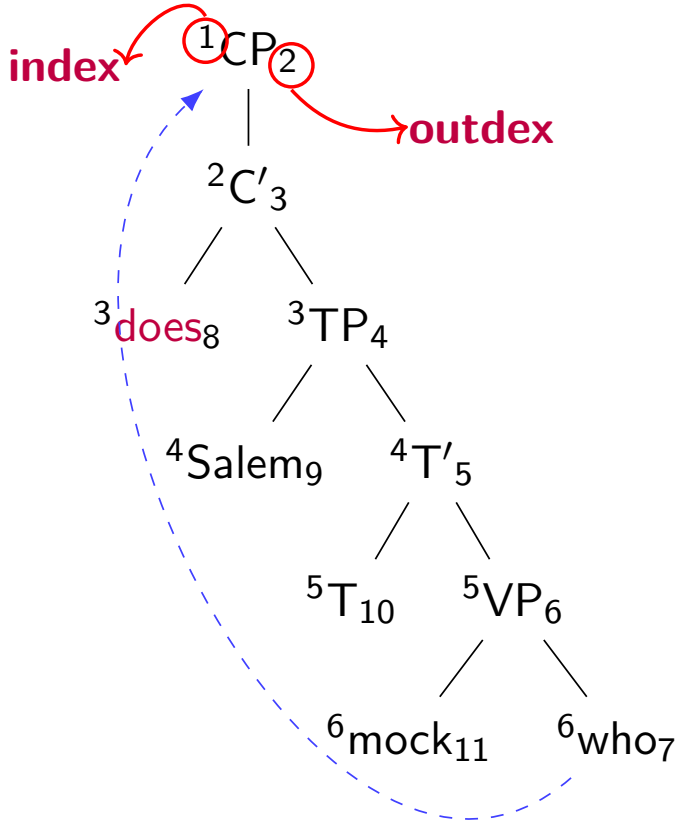


Tenure how long a node is kept in memory

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

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

Automatizing Helps!

mgproc: A Python Package for MG Processing Research

This is a collection of Python3 scripts to facilitate the investigation of human processing from the perspective of Minimalist grammars (MGs).

Background

MGs were developed in Stabler (1997) as a formalization of Chomsky's Minimalist program. A top-down parser for MGs is defined in Stabler (2013) and has been implemented in a number of languages. A number of subsequent works have successfully used this parser to make predictions about relative difficulty in sentence processing. Good starting points with a review of the previous literature are Gerth (2015) and Graf et al. (to appear).

- Gerth, Sabrina: Memory Limitations in Sentence Comprehension
- Graf, Thomas, James Monette, and Chong Zhang (to appear): Relative Clauses as a Benchmark for Minimalist Parsing (link to be added soon)
- Stabler, Edward (1997): Derivational Minimalism
- Stabler, Edward (2013): Two Models of Minimalist, Incremental Syntactic Analysis

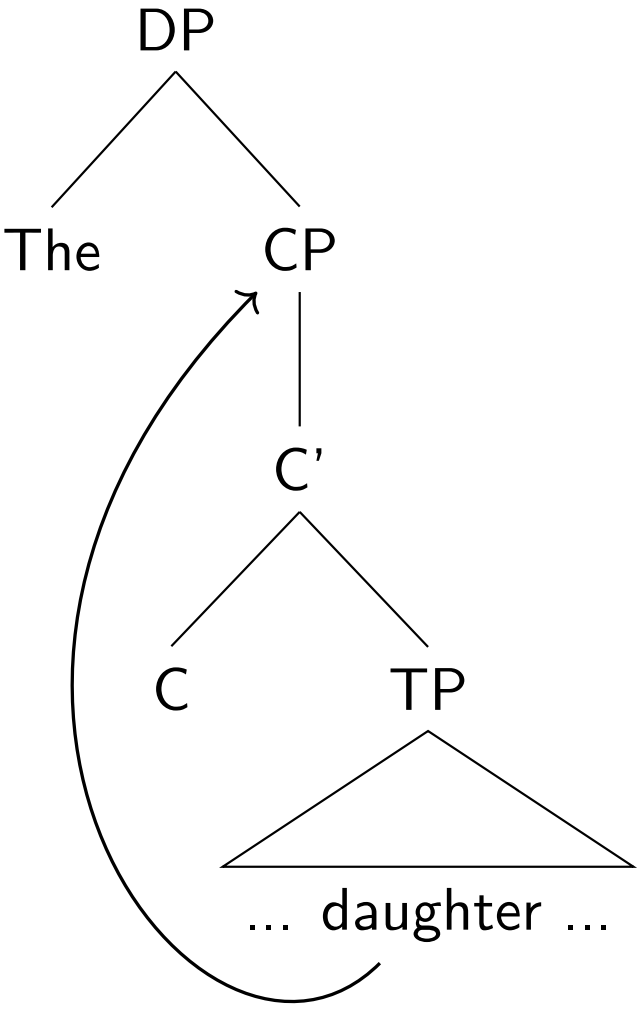
Quick Start Guide

With *mgproc* you can easily compare MG derivation trees with respect to thousands of complexity m
processing. The scripts integrate well with a LaTeX-centric workflow, following the ideal of OpenScie
publication form a cohesive unit. Usually a parsed derivation tree is specified by four files. Assuming
`foo`, we have:

- Open source ⇒ in prep. for *Journal of Open Source Software*
- User-friendly!
- Easy to modify!

Kayne's Promotion Analysis (Kayne 1994)

- RC is selected by an external D^0
- the RC head is a nominal constituent
- the RC head raises from its base position to [Spec, CP]



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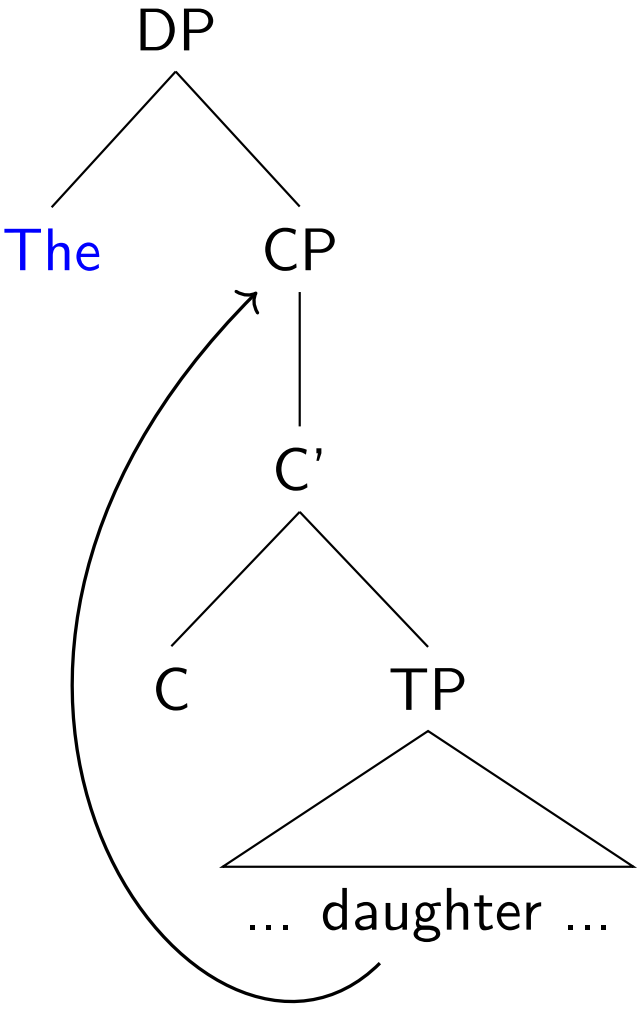

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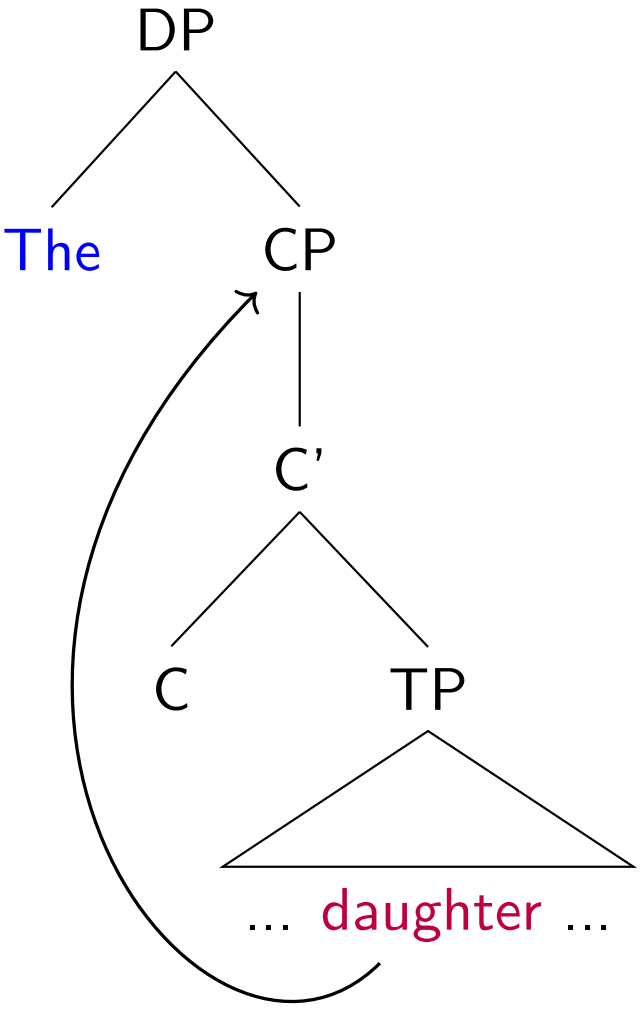

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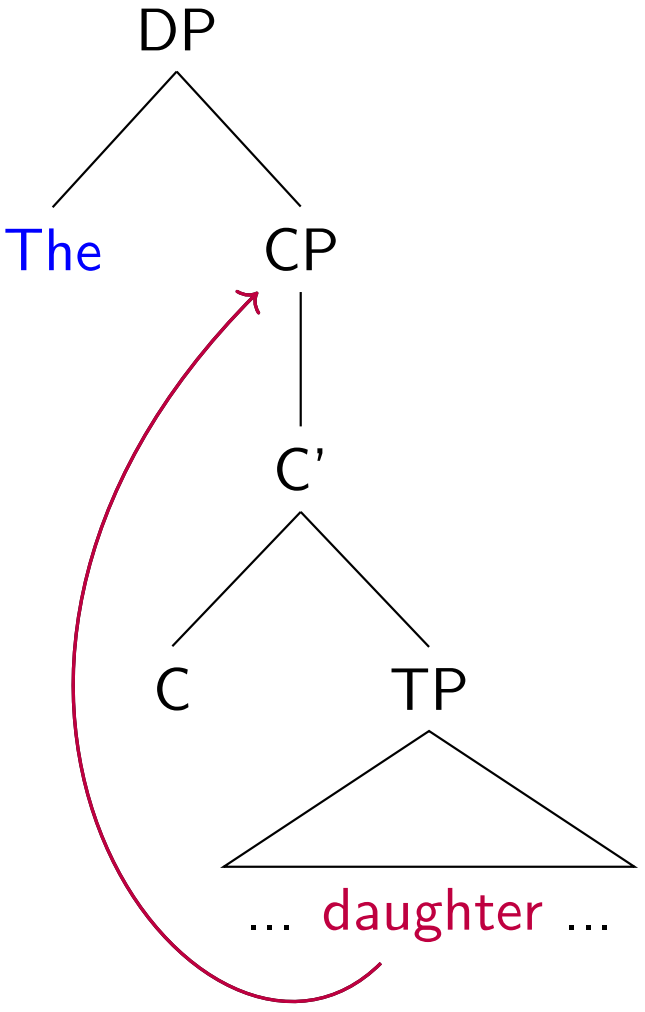

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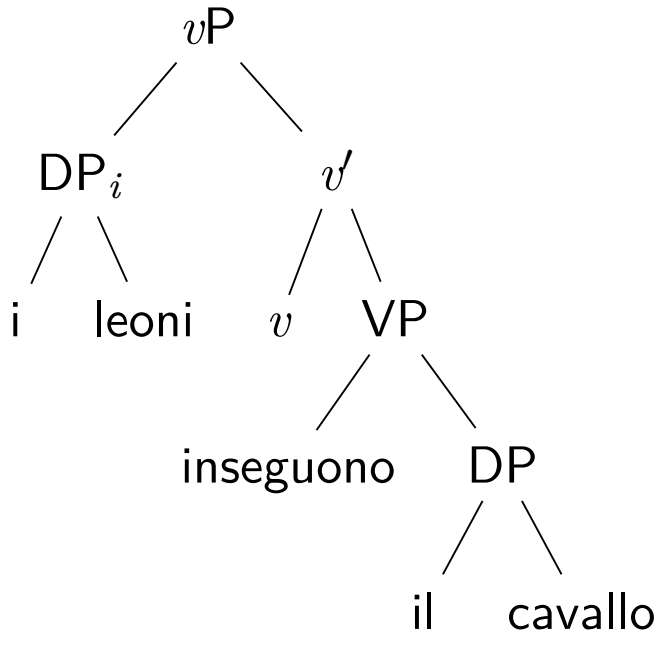
Postverbal Subjects (Belletti & Leonini 2004)

(7) Inseguono il cavallo i leoni
Chase the horse the lions
"The lions chase the horse"

- the subject DP raises to Spec, FocP
- The whole vP raises to Spec,TopP

Technical details!

- an expletive *pro* is base generated in Spec,TP



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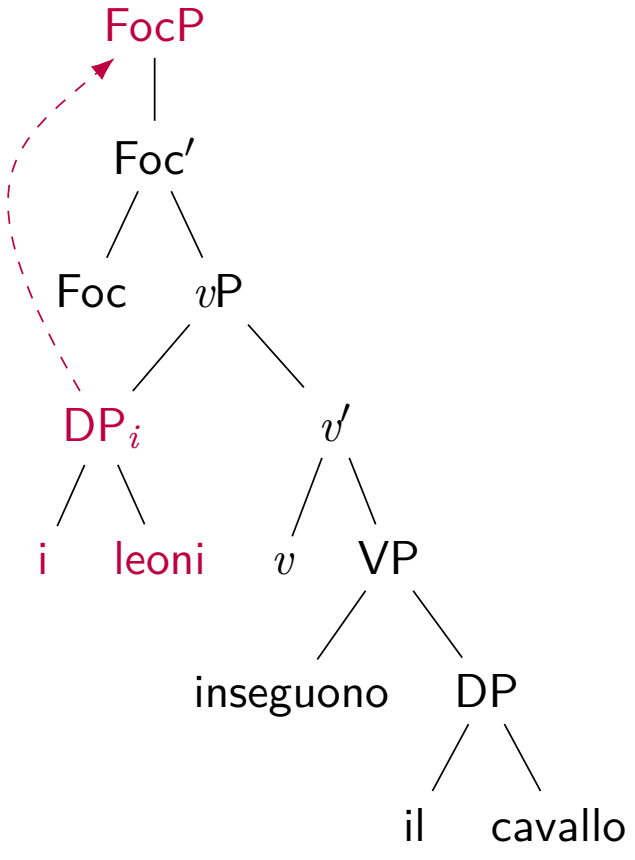

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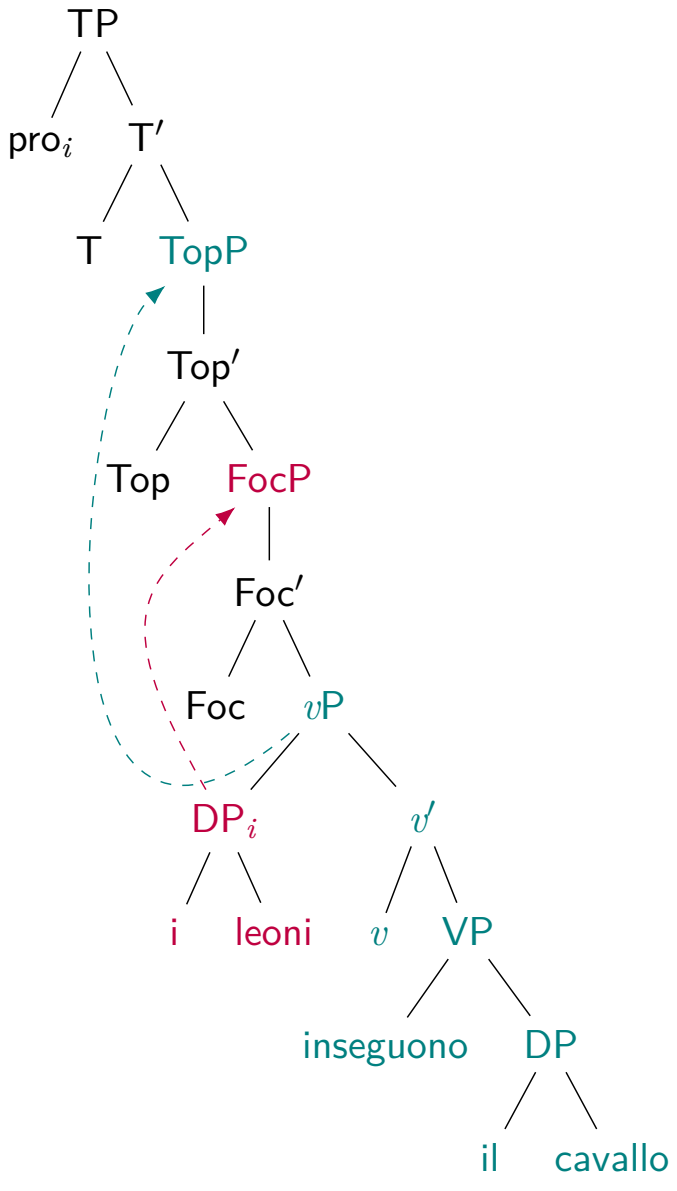

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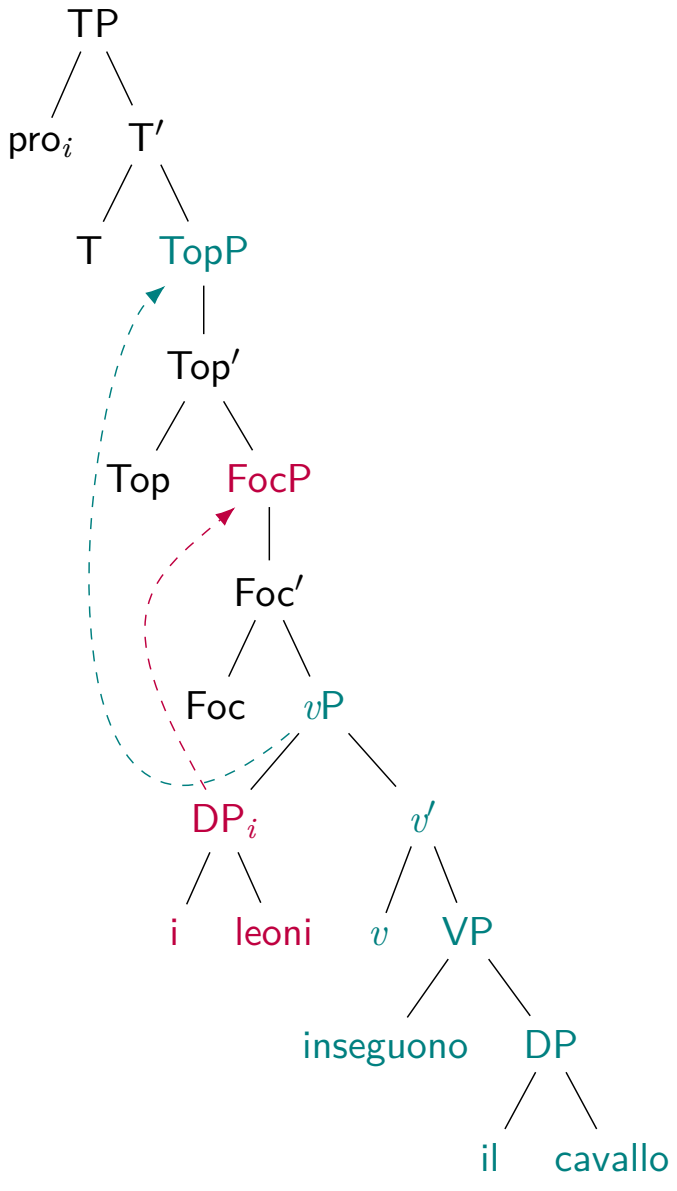
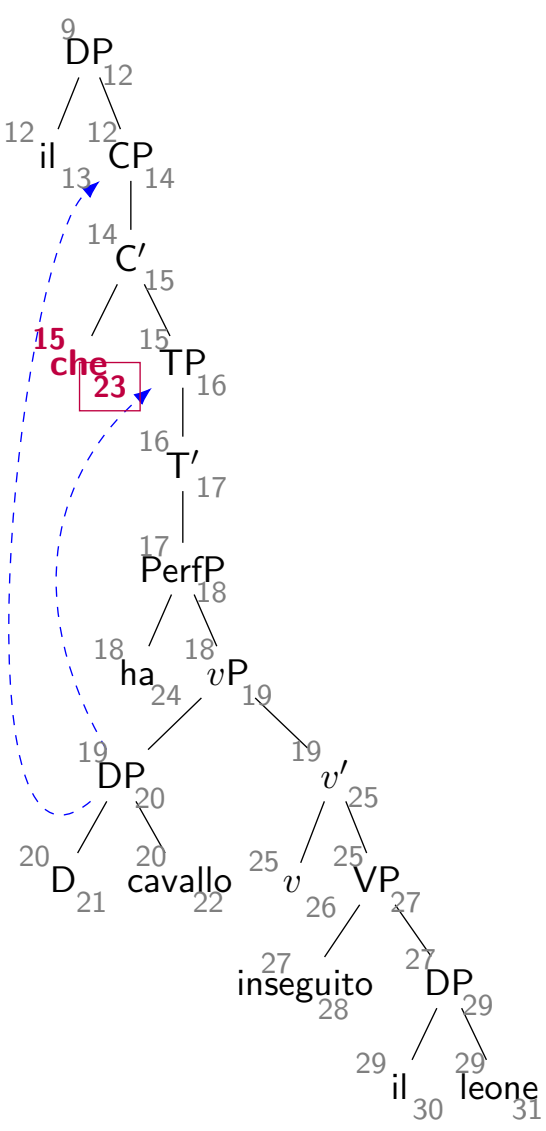
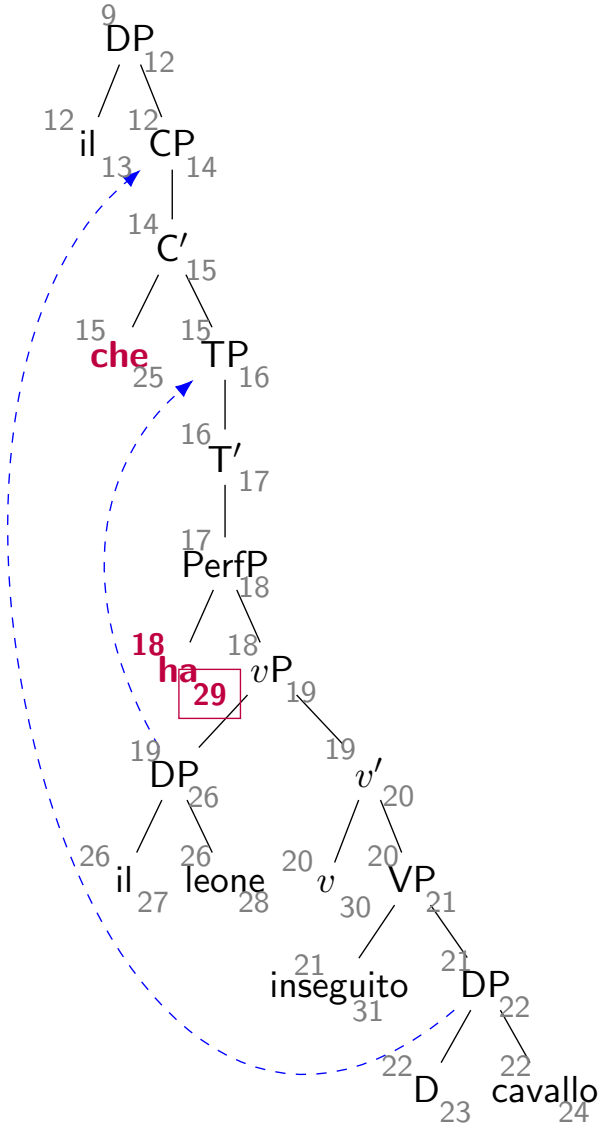


Results: SRC > ORC





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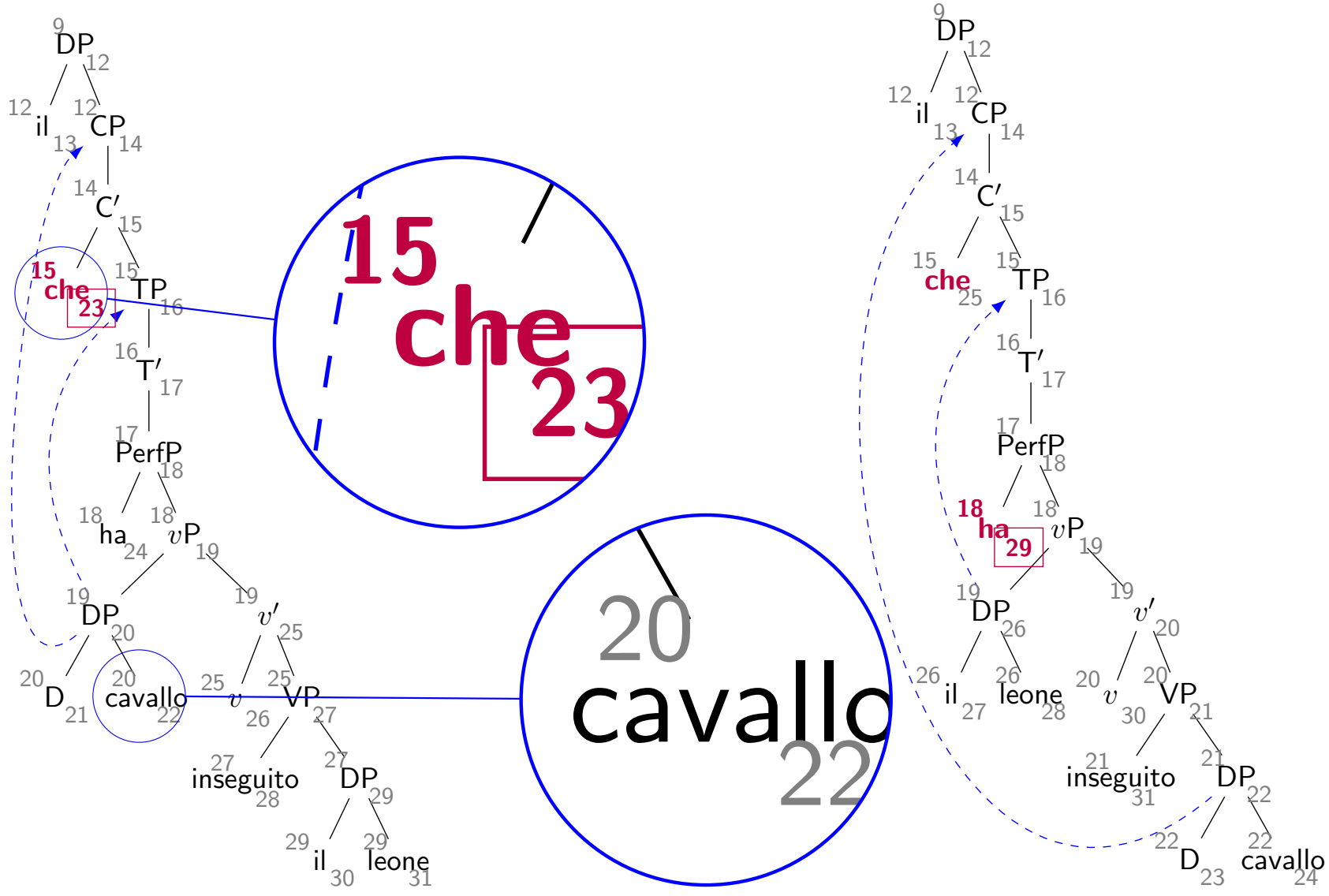

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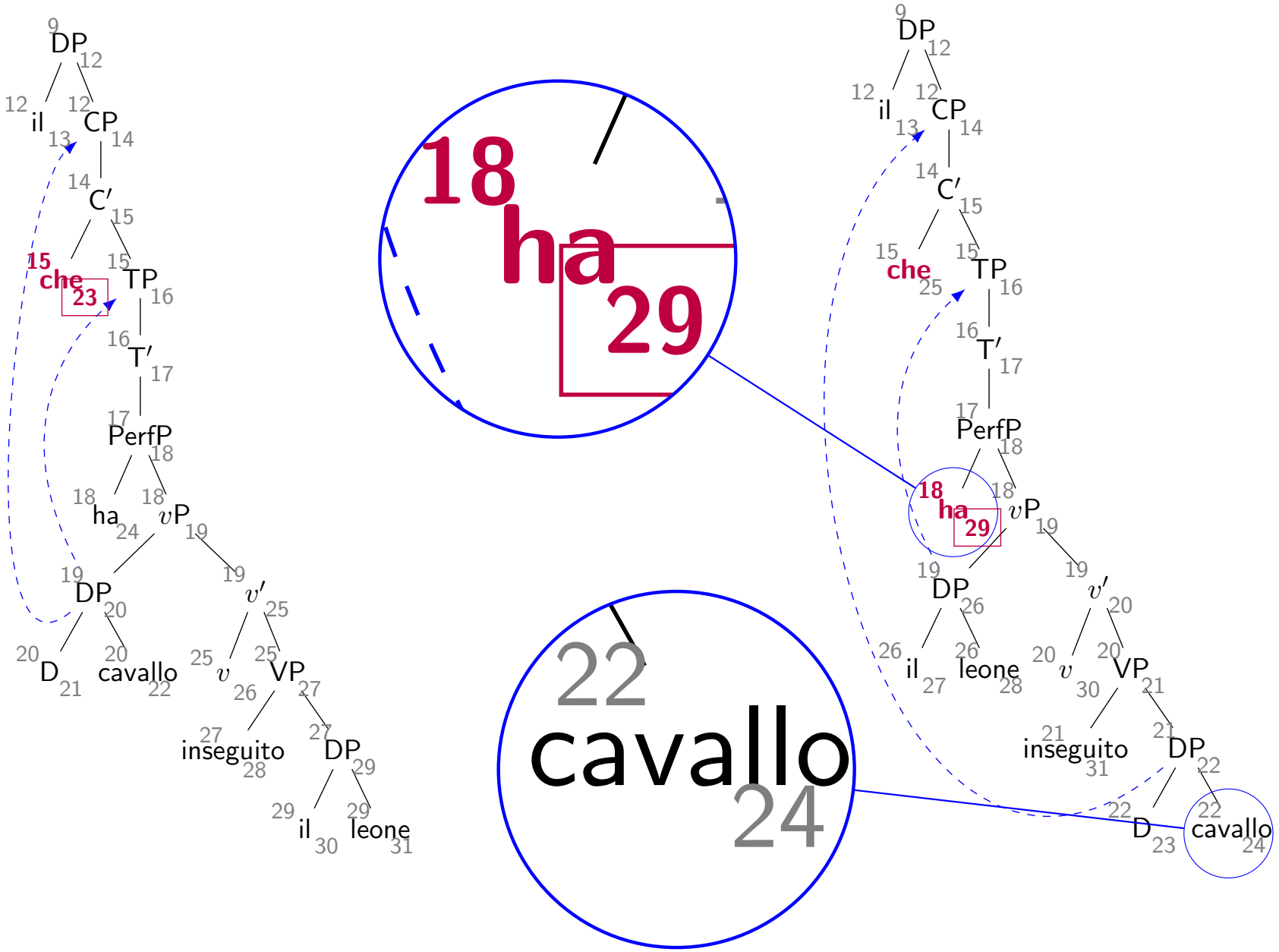

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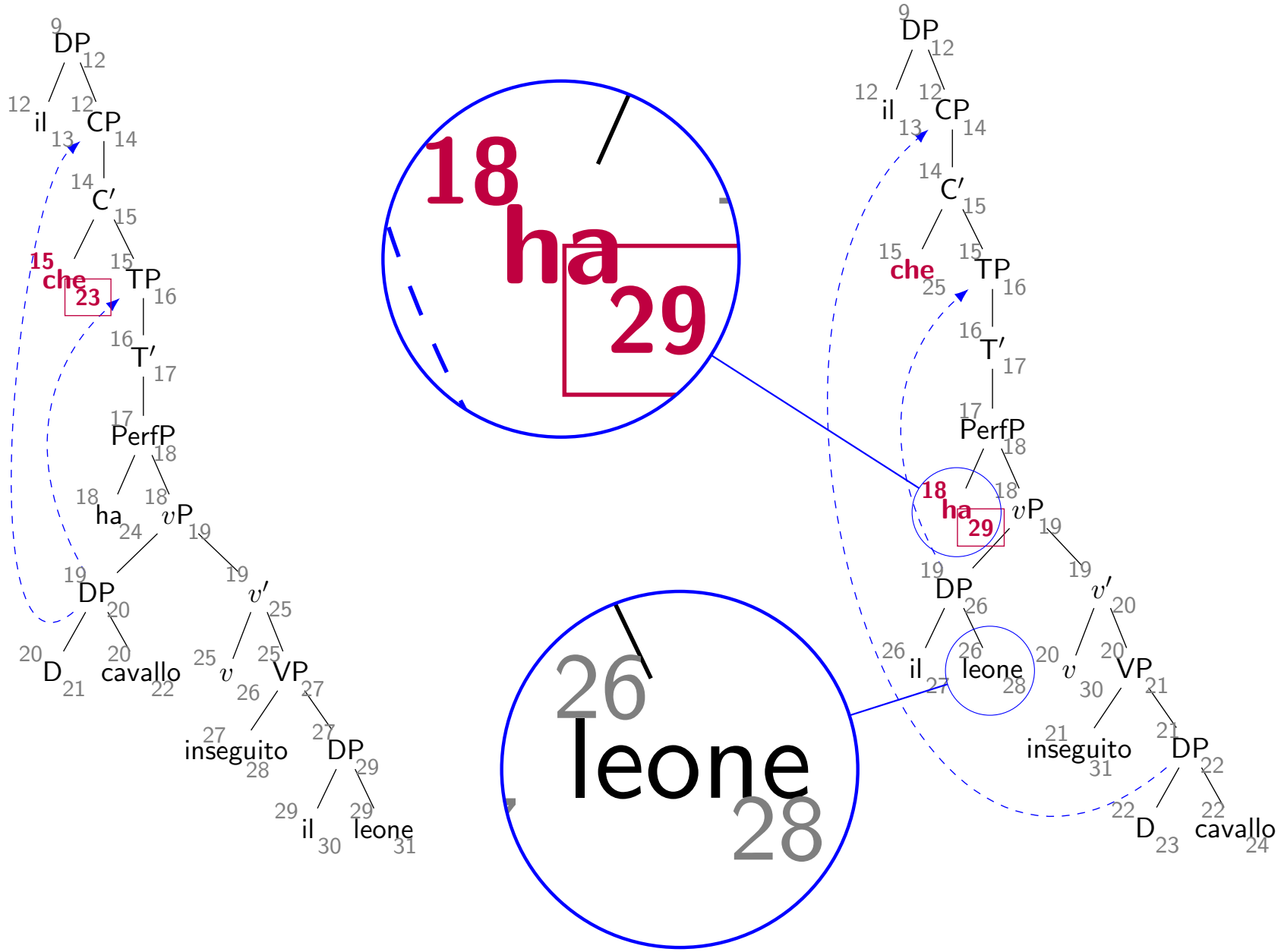

Italian Subjects: Probing the Results

Clause Type	MaxT	SumS
obj. SRC	8/*che*	18
obj. ORC	11/*ha*	24
obj. ORCp	16/*Foc*	31
subj. SRC	21/v'	37
subj. ORC	21/v'	44
subj. ORCp	28/v'	56
matrix SVO	3/*ha*/v'	7
matrix VOS	7/*Top*/*Foc*	11
VS unacc	2/vP	3
VS unerg	7/*Top*/*Foc*	11

Table: Summary of MaxT (*value*/*node*) and SumS by construction. Obj. and subj. indicate the landing site of the RC head in the matrix clause.

Postverbal Asymmetries: Possible Accounts?

SRC > ORC

- DLT, active-filler strategy, Competition model, ...

ORC > ORCp

- more problematic (e.g., for DLT)
- can be explained by
  1. economy of gap prediction + structural re-analysis;
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Can we give a purely structural account?

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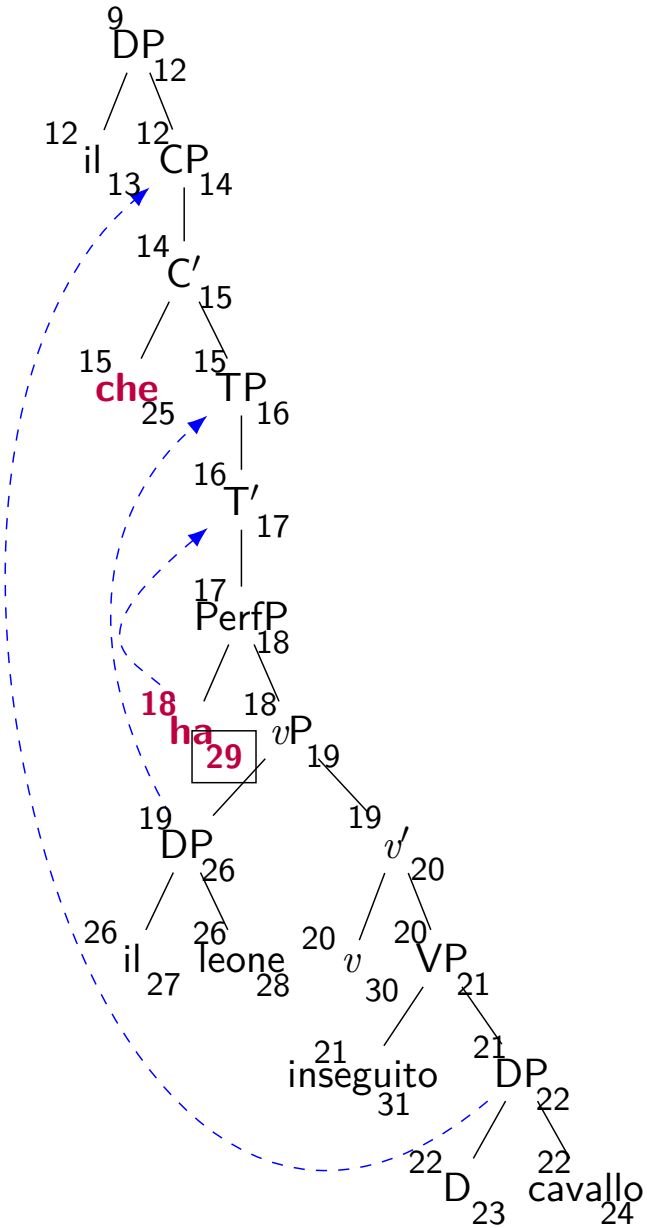
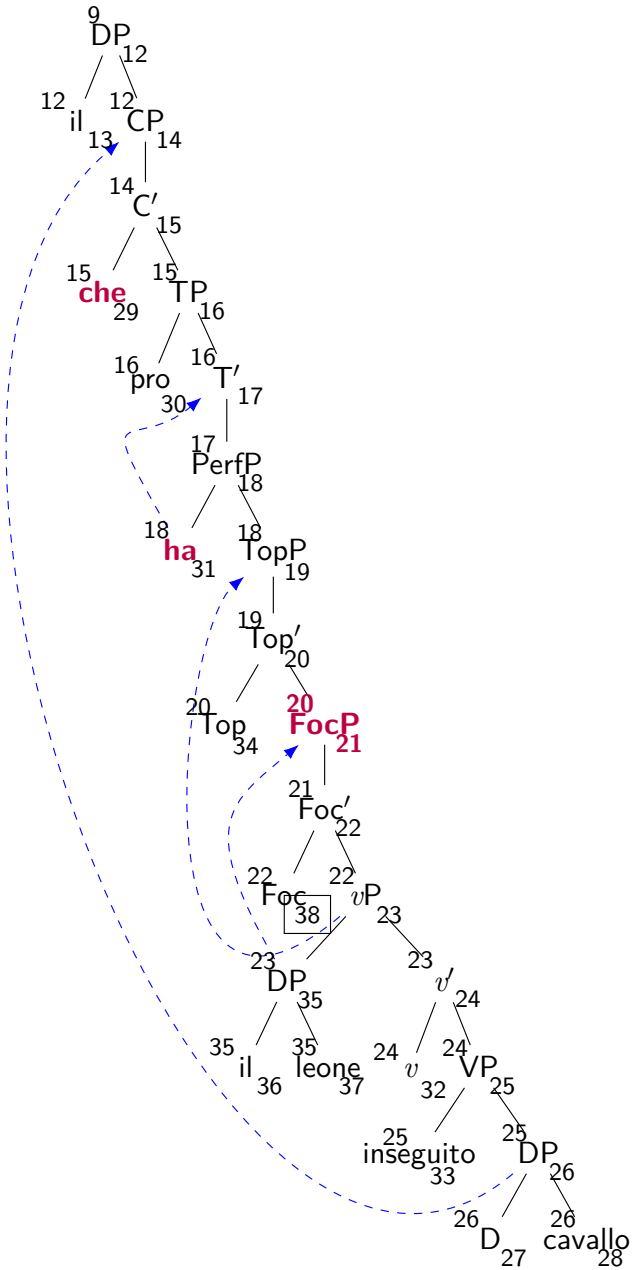




Additional Constructions

- Ambiguity in Matrix Clauses

(10) Ha chiamato Gio
Has called Giovanni

a. "He/she/it called Gio" **SVO**

b. "Gio called" **VS**

- Unaccusatives vs. Unergatives

(11) È arrivato Gio
Is arrived Gio

"Gio arrived" **Unaccusative**

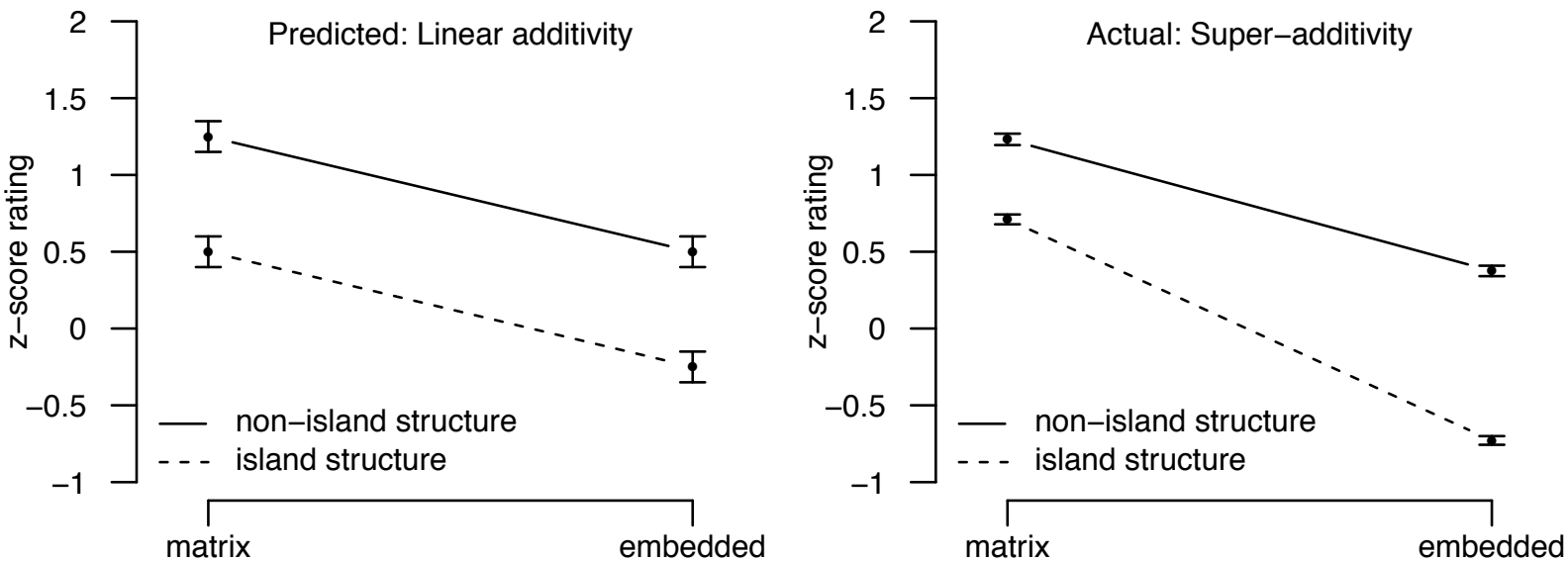
(12) Ha corso Gio
Has ran Gio

"Gio ran" **Unergative**

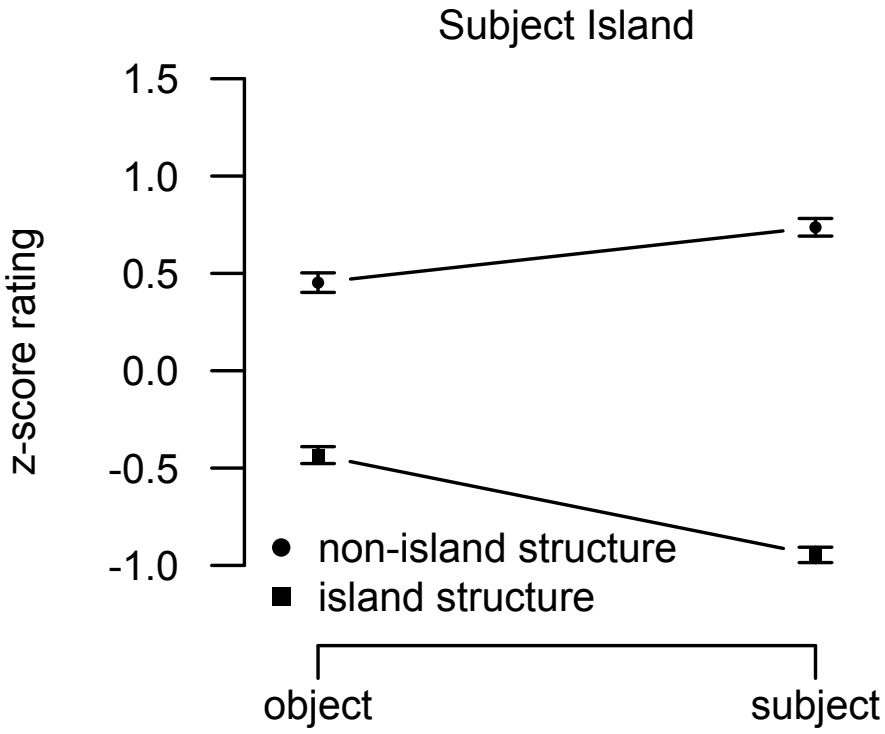
Gradience in Islands

A factorial design for islands effect:

- Gap Position × Structure



Deriving Pairwise Comparisons



- Subj | Non Island > Obj | Non Island
- Subj | Non Island > Obj | Island
- Subj | Non Island > Subj | Island
- etc.

A Caveat on Island Effects

The Goal

Can gradience in acceptability judgments arise from a categorical grammar due to processing factors?

- Sprouse et al.'s (2012) design is ideal for the MG model.

But I am not interested in island effects *per se*:

- Islands: grammatical or processing effects?
  (Hofmeister et al., 2012a; Sprouse et al., 2012a,b)
  - hence, not modeling super-additivity
  - spoilers: maybe we get some insights?
- Islands: syntax or semantics?
  (Truswell, 2011; Kush et al., 2018; Matchin et al., 2018)

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Models of Gradience

(At least two) theories of gradience:

- Gradience incorporated in the grammar
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- Gradience due to extra-grammatical factors
  (Chomsky 1975; Schütze 1996)

The contribution of formal models?

Quantify what each approach needs to account for the data:

- Additional syntactic assumptions
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Subject Islands

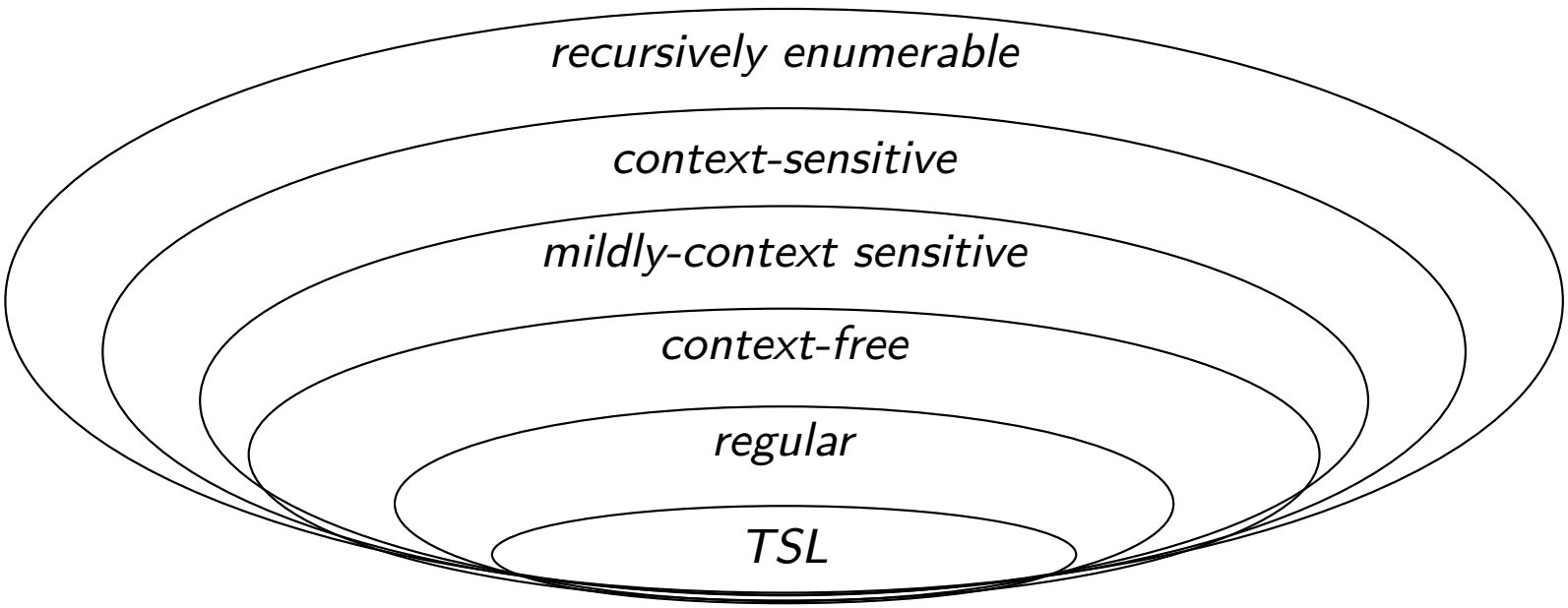
Case 1:

(13)
a. What do you think the speech interrupted *t*? Obj | Non Island
b. What do you think *t* interrupted the show? Subj | Non Island
c. What do you think the speech about global warming interrupted the show about *t*? Obj | Island
d. What do you think the speech about *t* interrupted the show about global warming? Subj | Island

Case 2:

(14)
a. Who *t* thinks the speech interrupted the primetime TV show? Matrix | Non Island
b. What do you think *t* interrupted the primetime TV show? Emb. | Non Island
c. Who *t* thinks the speech about global warming interrupted the primetime TV show? Matrix | Island
d. What do you think the speech about *t* interrupted the primetime TV show? Emb. | Island

Subregular Complexity



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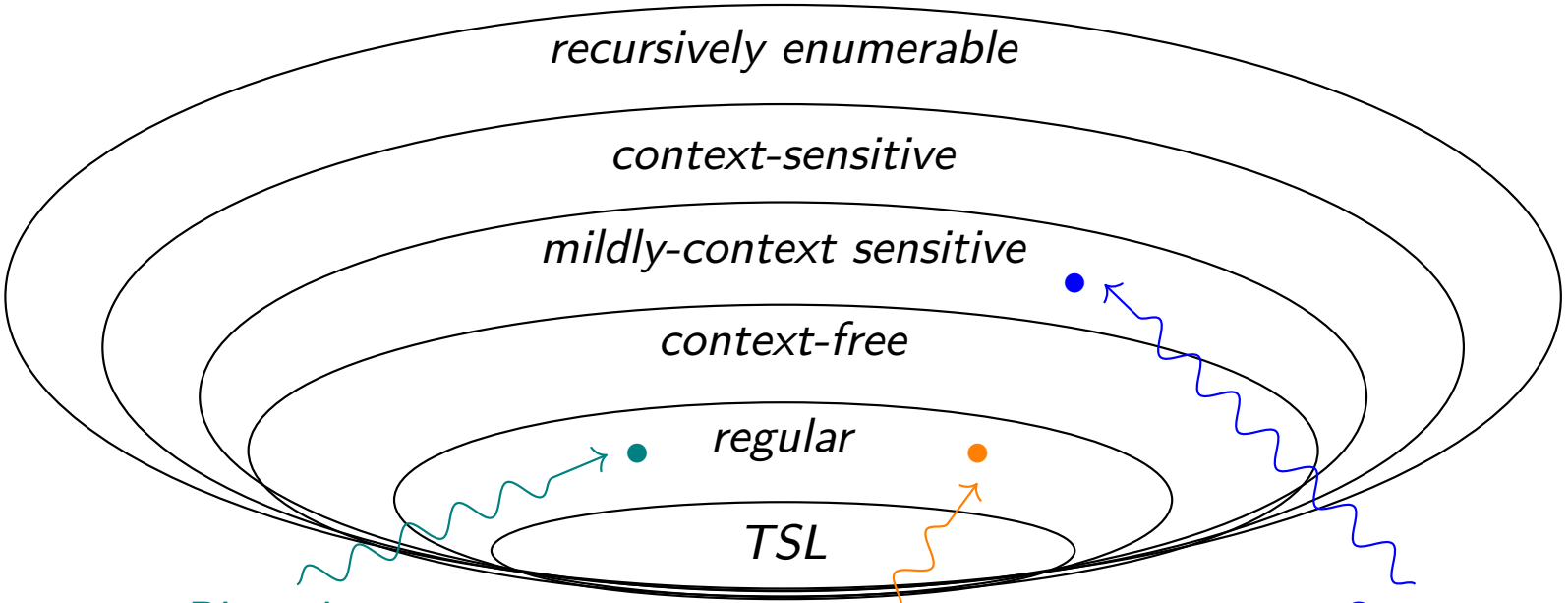
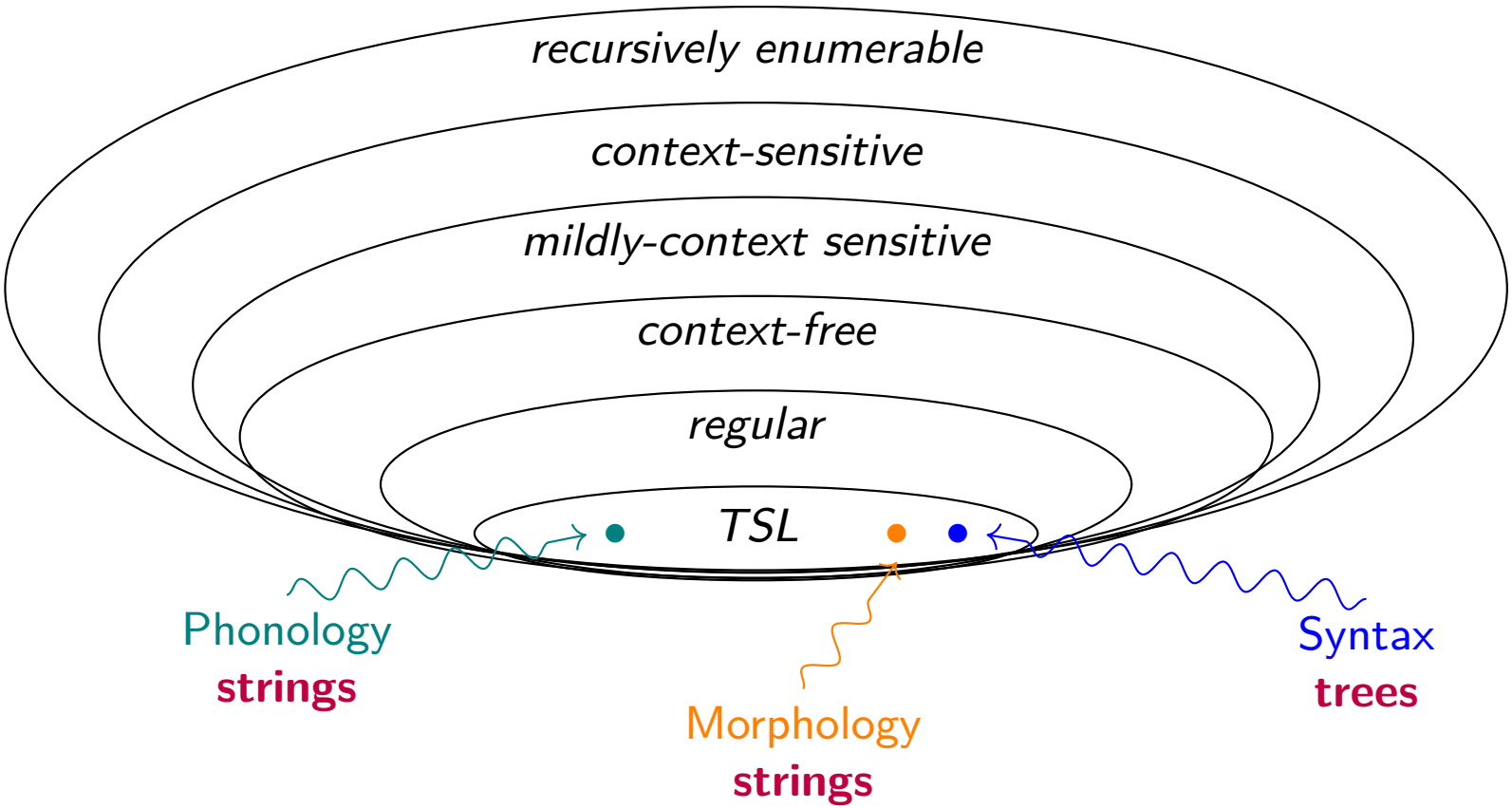


Phonology
Kaplan and Kay (1994)
strings

Morphology
Karttunen et al. (1992)
strings

Syntax
Shieber (1985)
strings

Subregular Complexity



Cognitive Parallelism

Strong Cognitive Parallelism Hypothesis

Phonology, (morphology), and syntax have the **same subregular complexity** over their respective **structural representations**.

We gain a unified perspective on:

- typology
- learnability
- cognition

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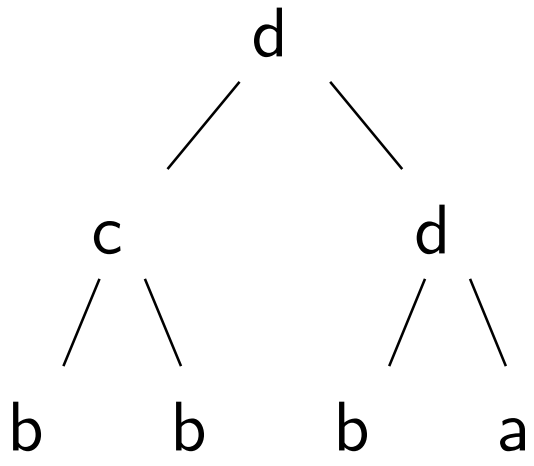
  Finite, flat memory

Top-down Parsing + Grammaticalized Constraints?

Graf & De Santo (2019)

Sensing Tree Automata (Martens 2006) as a subregular bound on the complexity of syntactic dependencies.



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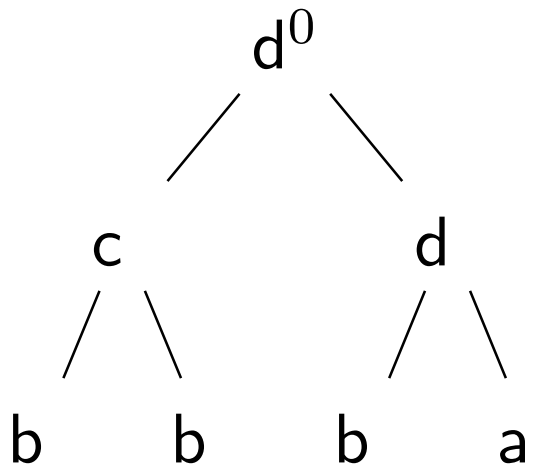

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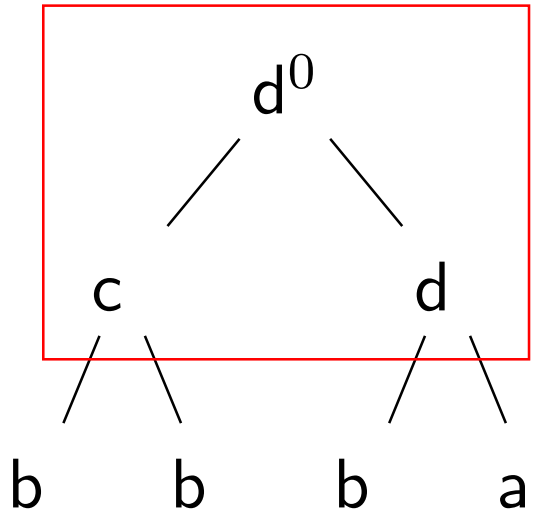

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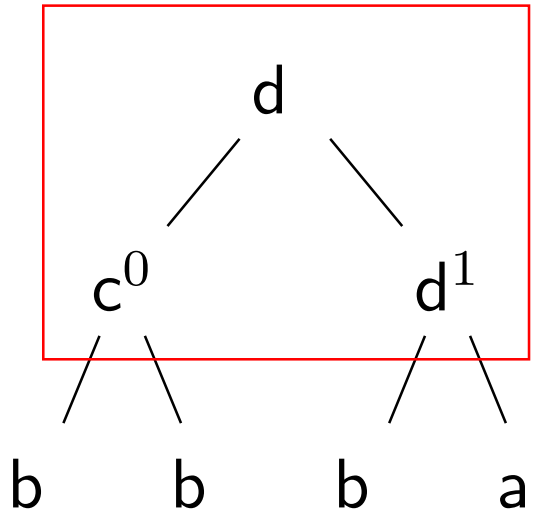

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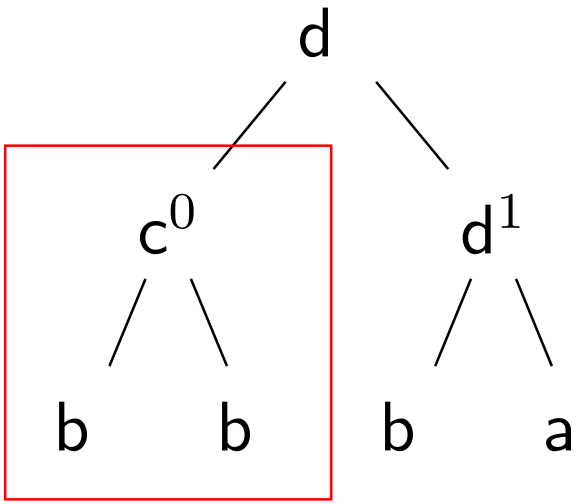

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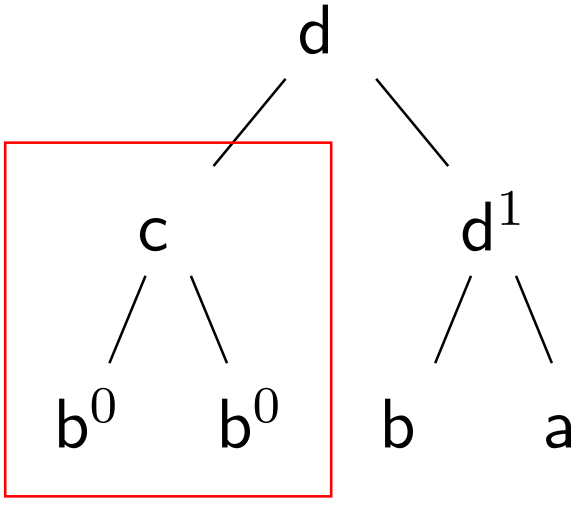

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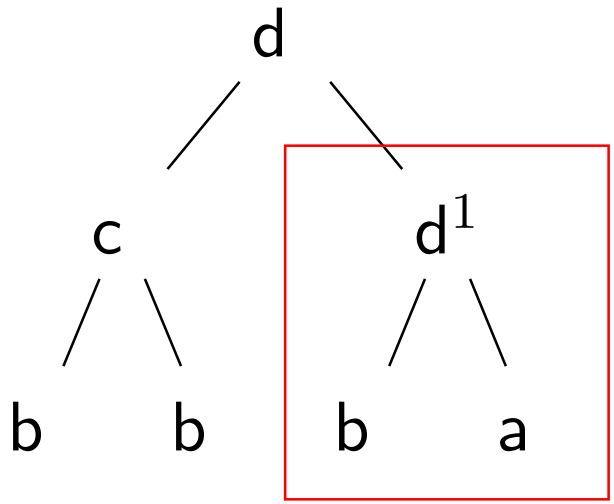

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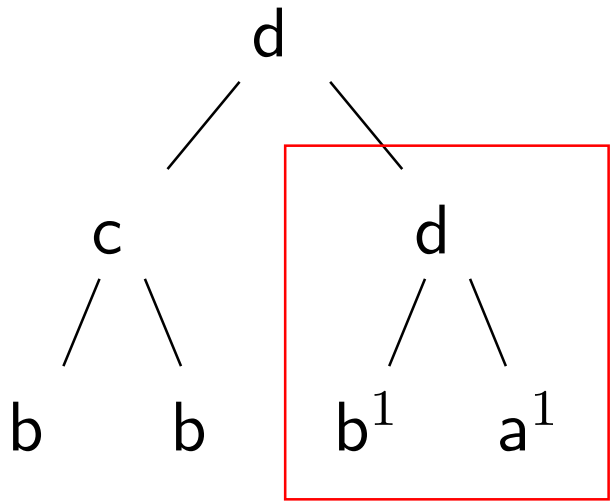

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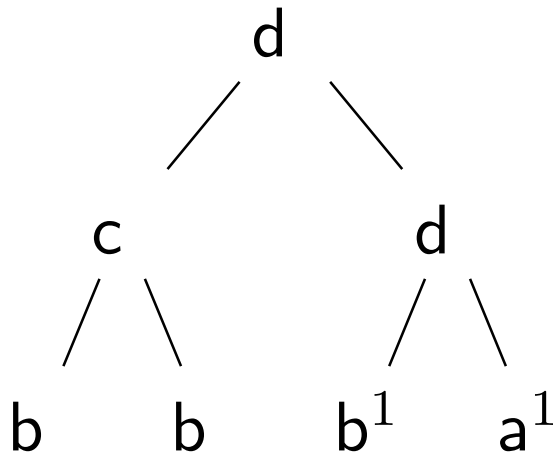

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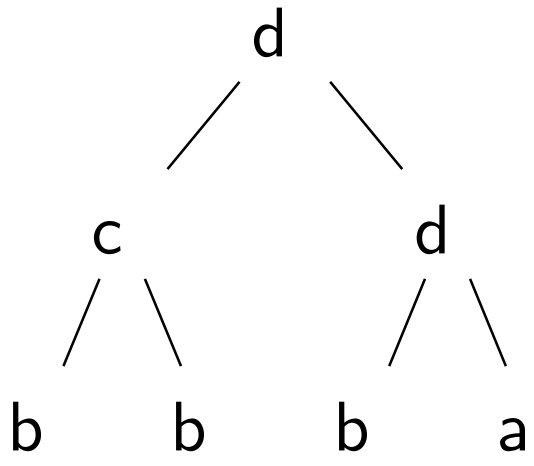

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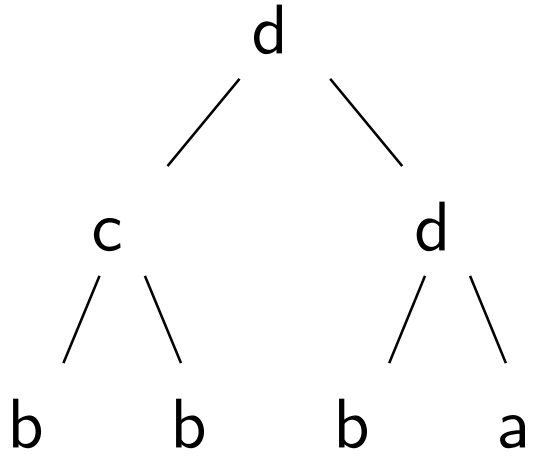

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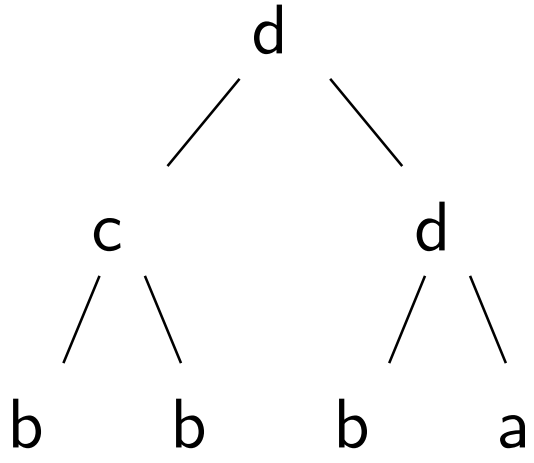

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- Constraints improve parsing performance by **exponentially reducing** the search space (Stabler 2013)
- Can be pre-compiled in the MG parse schema as a deterministic **top-down filter** (De Santo & Graf, in prep.)

Stacked RCs and Parallelism Effects

English Stacked RCs (Zhang, 2017)

(15) **The horse** [$_{RC_1}$ that t chased the wolf] [$_{RC_2}$ that t kicked the elephant] ... **ss**

(16) **The horse** [$_{RC_1}$ that the wolf chased t] [$_{RC_2}$ that t kicked the elephant] ... **os**

(17) **The horse** [$_{RC_1}$ that the wolf chased t] [$_{RC_2}$ that the elephant kicked t] ...**oo**

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- Zhang (2017) found **parallelism effects** in stacked RC processing:
  SS << OS, OO << SO.
- But she also showed that no combination of metrics can account for these effects.
- Proposal: metric encoding memory reactivation

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Feature Reactivation

REACTIVATION For each node m_i associated to a movement feature f^-, its reactivation is $i(m_i) - o(m_{i-1})$; the index of m_i minus the outdex of the closest preceding node also associated to f^-, if it exists.

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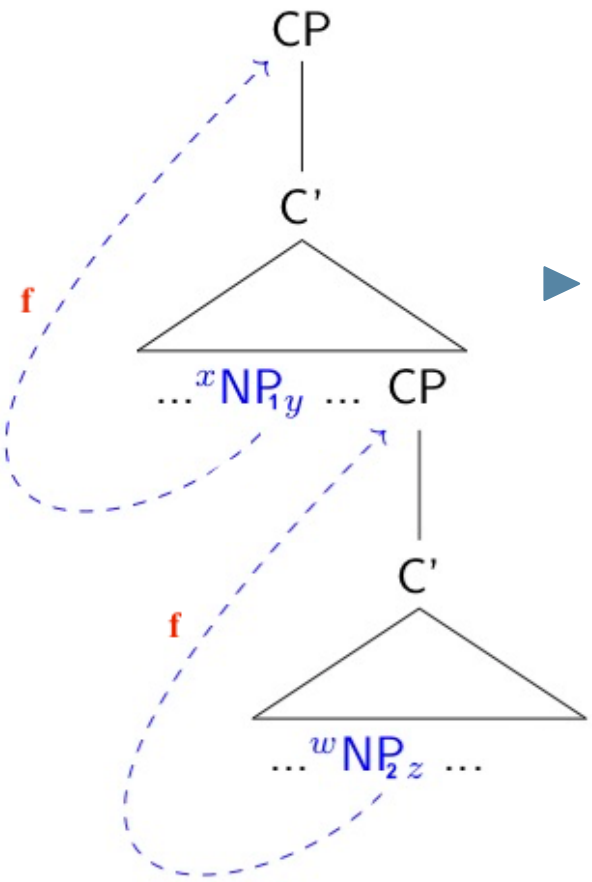

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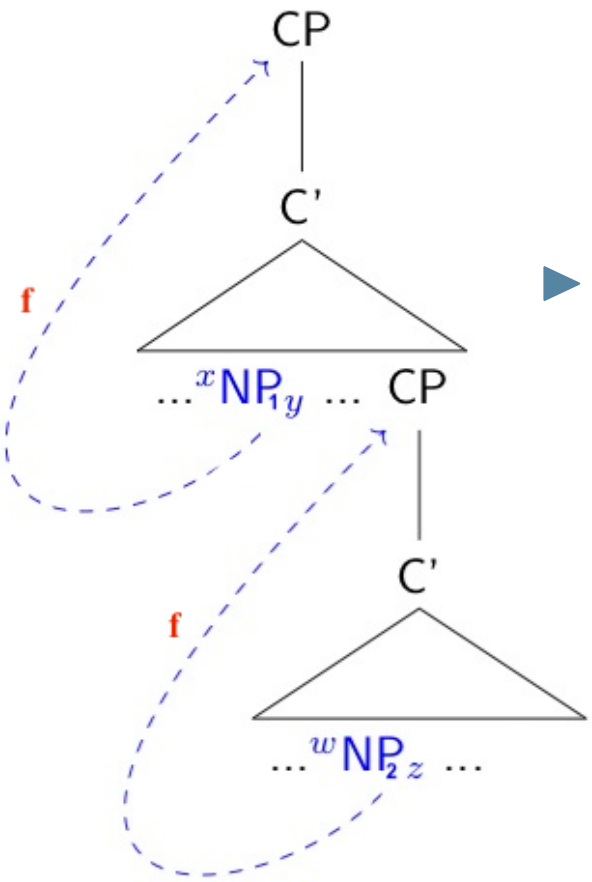

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  TENURE (NP_1) $y - x$

  TENURE (NP_2) $z - w$

  REACTIVATION(NP_2) $w - y$

Feature Reactivation: Base Metrics

- feature-associated metrics

  $\textsc{SumR}^f$ $\sum_{m_i \in M^f} i(m_i) - o(m_{i-1})$

  $\textsc{MaxR}^f$ $max(\{i(m_i) - o(m_{i-1}) | m_i \in M^f\})$

  $\textsc{AvgR}^f$ $\frac{\textsc{SumR}}{|M^f|}$

- comprehensive metrics

  $\textsc{SumR}$ $\sum_{f \in \mathcal{M}} \textsc{SumR}^f$

  $\textsc{MaxR}$ $max(\{\textsc{SumR}^f | f \in \mathcal{M}\})$

  $\textsc{AvgR}$ $\frac{\textsc{SumR}}{|\mathcal{M}|}$

Priming Effects

(19) I saw

a. $[_{RC_1}$ the horse that chased the lions $]$ **SRC**

b. and $[_{RC_2}$ the mouse that kissed the chicken $]$ **SRC**

(20) I saw

a. $[_{RC_1}$ The horse that chased the lions$]$ **SRC**

b. and $[_{RC_2}$ the mouse that the chicken kissed $]$ **ORC**

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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**:
  → The PR-First Hypothesis for Italian
  → MG model as a testing framework!

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**:
  → The PR-First Hypothesis for Italian
  → MG model as a testing framework!

So Young Lee

Attachment 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

English: **LA** interpretation

- Late Closure (Frazier 1978),
  Recency (Gibson 1991, Gibson et al. 1996), ...

Universal locality principles?

- Spanish: **HA** interpretation
  - Tuning Hypothesis
    (Cuetos & Mitchell 1988, Mitchell & Cuetos 1991)
    Construal (Frazier & Clifton 1996), ...

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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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Grillo & Costa: Pseudo-RCs in Italian

(23) (Io) Ho visto **[la nonna della ragazza che gridava]**
(I) have seen the grandma of the girl that screaming
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- RC: HA
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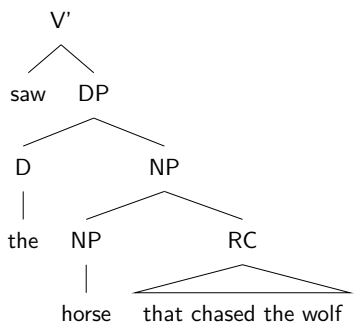
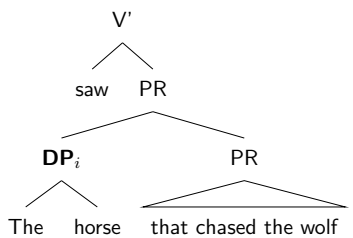
- PR





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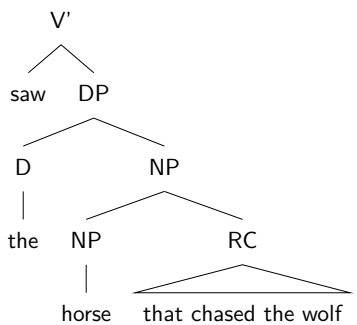

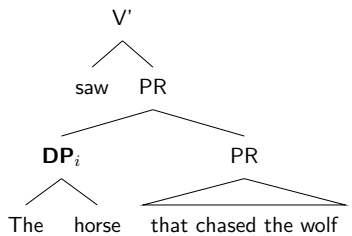

- RCs are NP-modifiers and denote properties of entities
- PRs are complements of VPs and denote events/situations
  - **Only** compatible with a **HA** reading!

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)
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Syntactic tests (Guasti 1999, Cinque 1992, Casalicchio 2013, a.o.)

- Appear freely with proper names, no relative pronouns, ...
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- Tense/aspect restrictions

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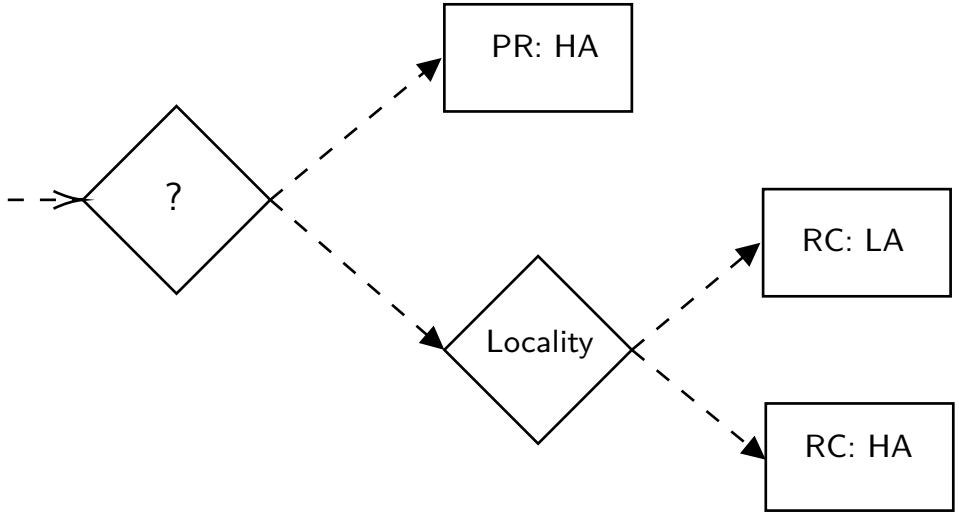

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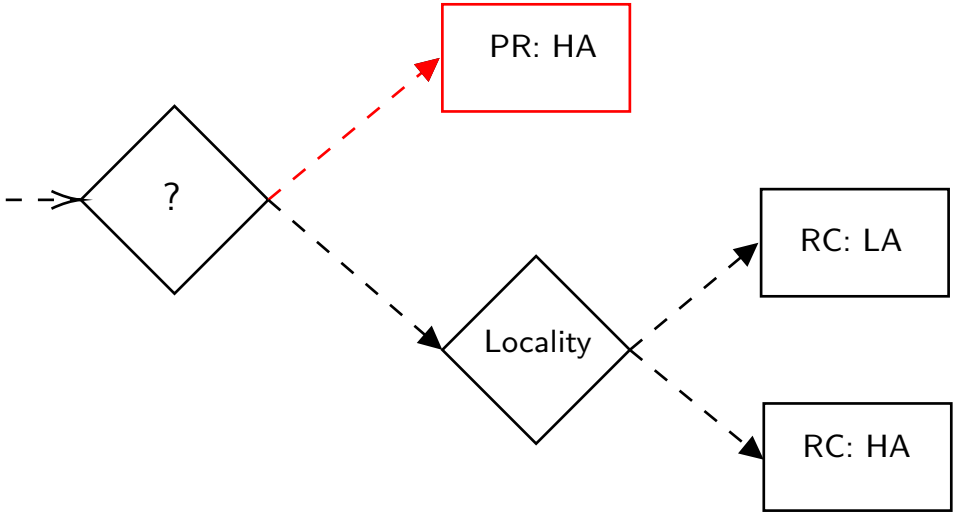

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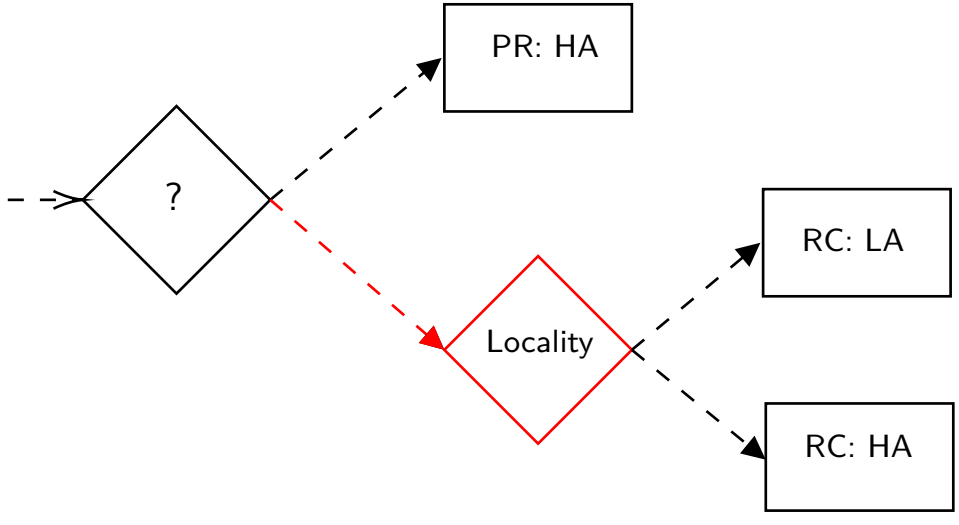

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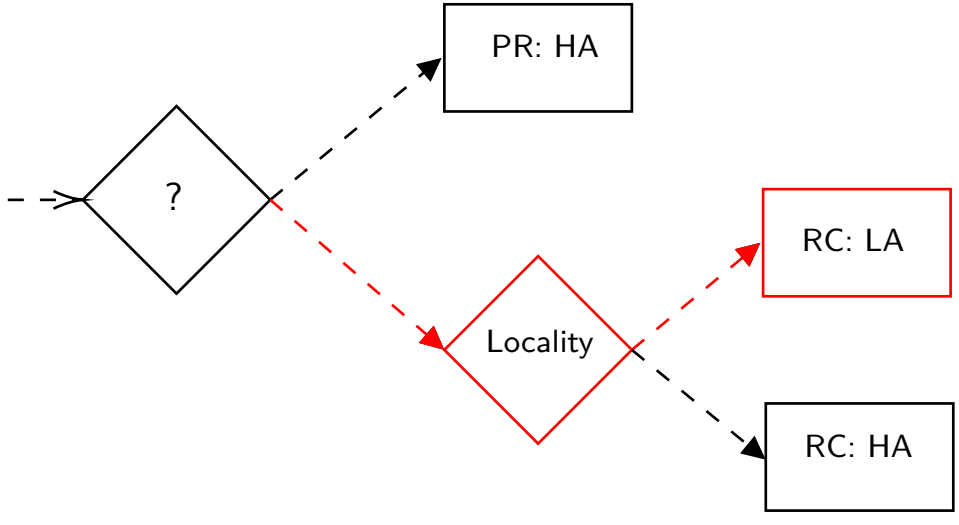

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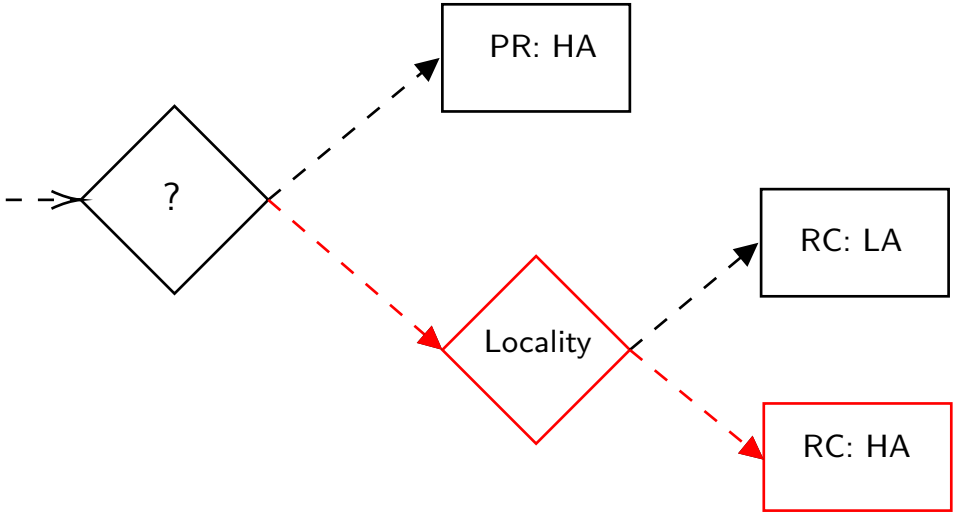

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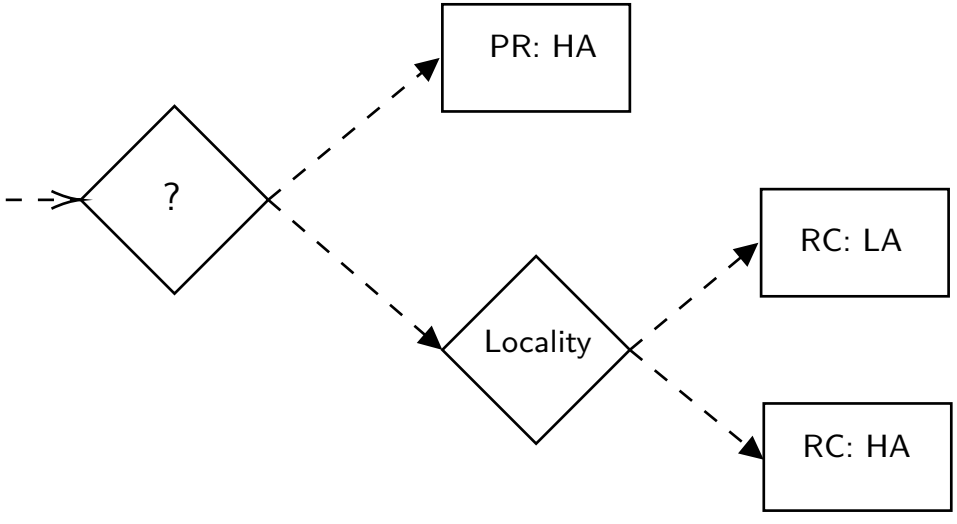

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Grillo and Costa (2014)

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

Online tool!

- Italian: De Santo & Lee (2022a)
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(57) **Stimuli Experiment II**

a. PR/ RC CONDITION: PR-VERBS
Gianni ha visto il figlio del medico che correva.
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Table 6
Percentage of high attachment preferences.

Eventive	Stative
78.6%	24.2%

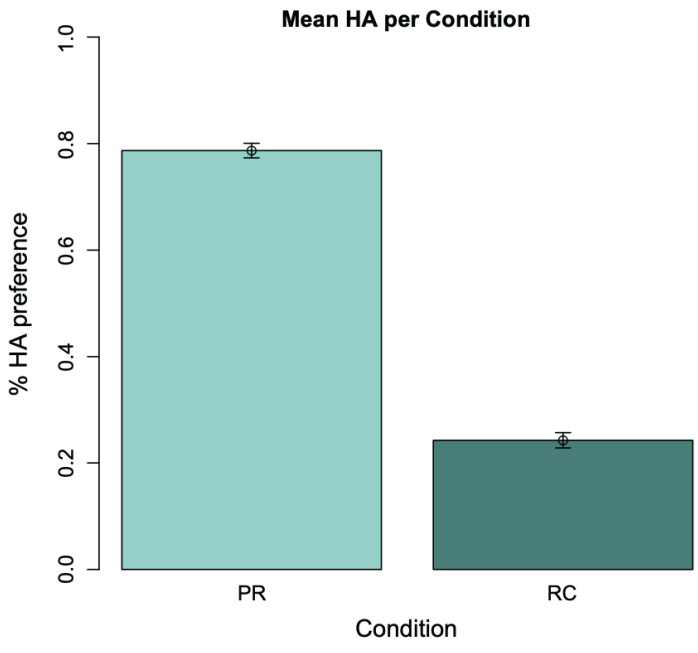

Fig. 2. Summary of attachment preference experiment 2.

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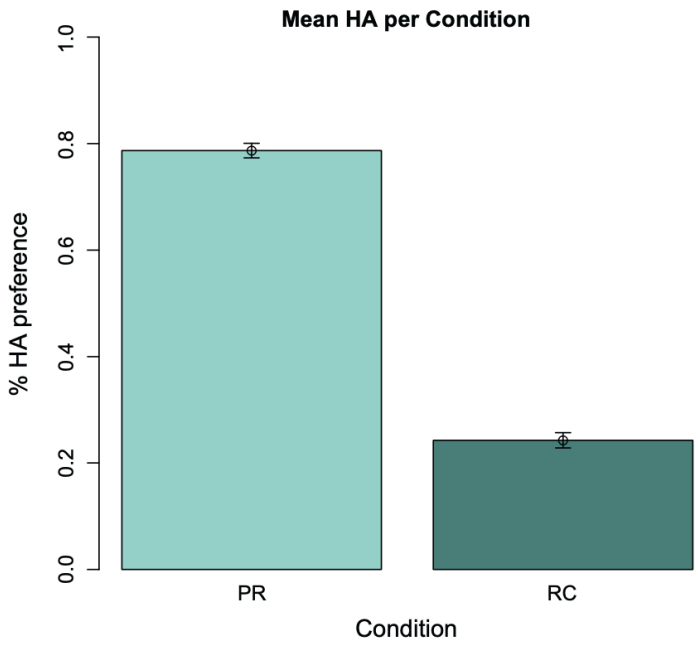

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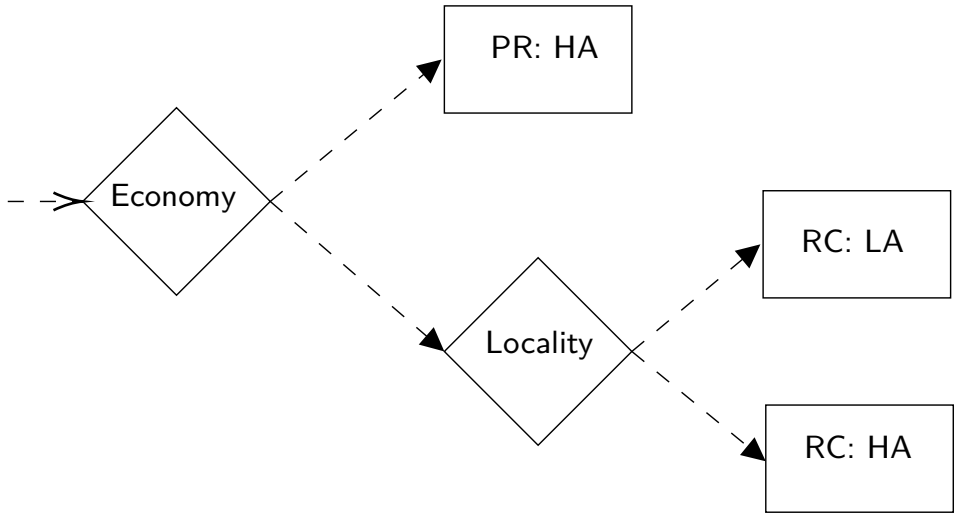
PR-First: Why?

Question

Why should PRs be preferred?



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

Can we evaluate structural economy quantitatively?

PR-First: Why?

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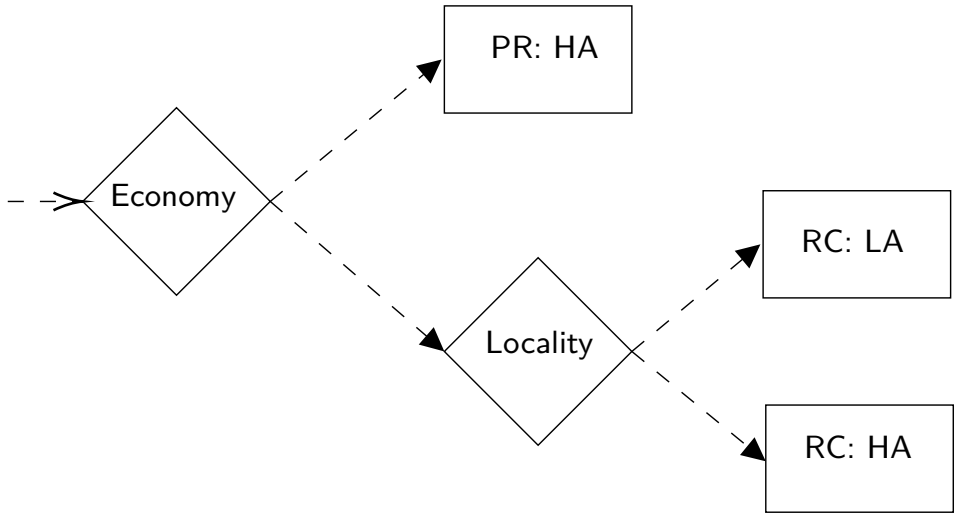

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Modeling PR-First

Why should PRs be easier/preferred?

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

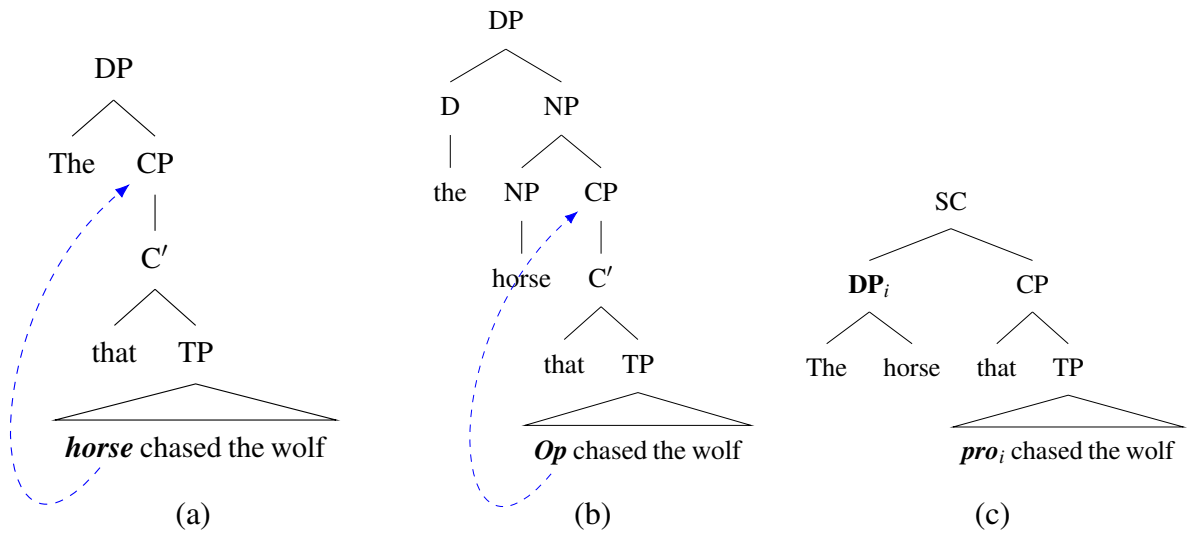

Figure 2: Sketches of the *(a)* RC with Promotion, *(b)* RC with Wh-movement, and *(c)* PR analyses for the sentence *The horse that the wolf chased*.

Modeling Results (De Santo & Lee, 2022b)

	MG Parser: MaxT
Hypothesis	
PR > HA	
PR > LA	
LA > HA	

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TI/Dr: The Value of Formal Models

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

Beyond these results

- Cross-linguistic and cross-analysis validation
- A variety of definitions for *cost* in parsing (Boston, 2012)
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    E.g. Reference Theory (Altmann & Steedman 1988)
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A Look at HA Languages (Grillo & Costa 2015)

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	✓
Serbo-Croatian	High	✓
Japanese	High	✓
Korean	High	✓
Greek	High	✓
Portuguese	High	✓

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

PRs: Modeling Results 1

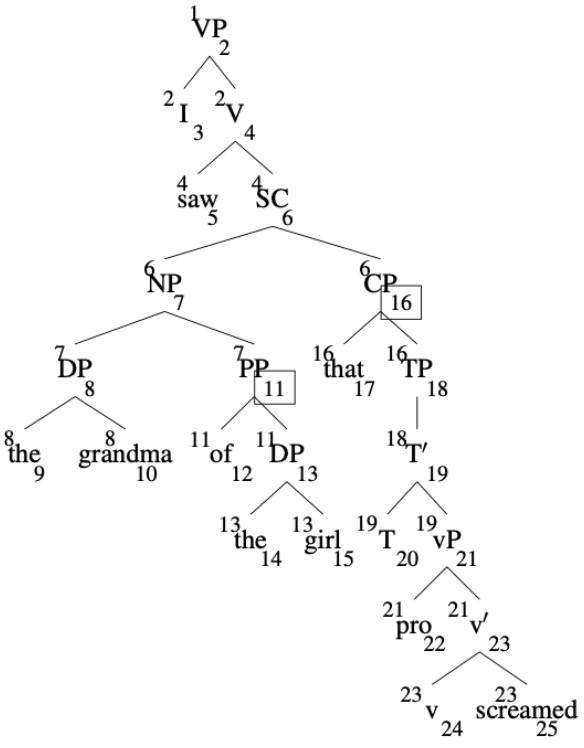


Figure 3: Annotated derivation trees for the Italian sentence *I saw the grandma of the girl that screamed*, according to a pseudo-relaive clause analysis. The tree is treated as a VP since additional structure in the matrix clause would be identical across comparisons.

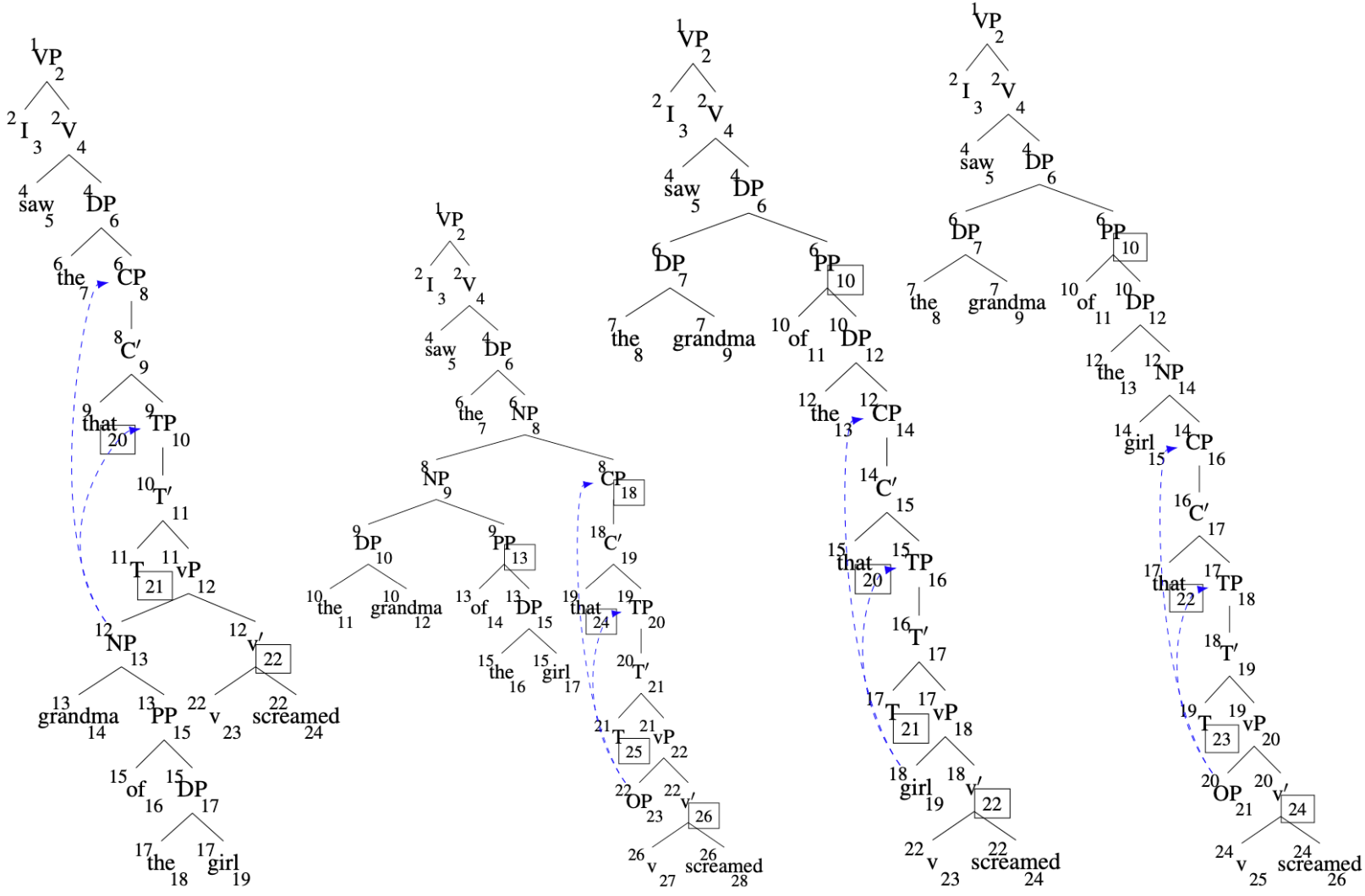
	MG Parser	
Hypothesis	**Promotion**	**Wh-mov**
PR < HA	✓	Tie
PR < LA	×	×
LA < HA	✓	✓

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.

PRs: Modeling Results 2



Our Study

Question: Online effects of PR availability in Italian?

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

(2)

	Verb	Interpretation		before	target	after	
a.	PR/RC (Perceptual)	LA	Gianni vide il figlio dei medici Gianni saw the son-SG of the doctors-PL	che who	correvano were running-PL	la the	maratona marathon
b.	PR/RC (Perceptual)	HA	Gianni vide il figlio dei medici Gianni saw the son-SG of the doctors-PL	che who	correva was running-SG	la the	maratona marathon
c.	RC only	LA	Gianni visse con il figlio dei medici Gianni lived with the son-SING of the doctors-PL	che who	correvano were running-PL	la the	maratona marathon
d.	RC only	HA	Gianni visse con il figlio dei medici Gianni lived with the son-SING of the doctors-PL	che who	correva was running-SG	la the	maratona marathon

- Counterbalancing # features (singular vs plural) on DP_1/DP_2

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- Temporal ambiguity HA/LA until # agreement on the **verb**
  - **Perceptual Verbs**: costly LA disambiguation (on verb)
  - **Non-Perceptual Verbs**: costly HA disambiguation (on verb)

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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: Perceptual Verbs

- Temporal HA/LA ambiguity until # agreement on the **verb**

(2)

	Verb	Interpretation		before	target	after	
a.	PR/RC (Perceptual)	LA	Gianni vide il figlio dei medici Gianni saw the son-SG of the doctors-PL	che who	correvano were running-PL	la the	maratona marathon
b.	PR/RC (Perceptual)	HA	Gianni vide il figlio dei medici Gianni saw the son-SG of the doctors-PL	che who	correva was running-SG	la the	maratona marathon
c.	RC only	LA	Gianni visse con il figlio dei medici Gianni lived with the son-SING of the doctors-PL	che who	correvano were running-PL	la the	maratona marathon
d.	RC only	HA	Gianni visse con il figlio dei medici Gianni lived with the son-SING of the doctors-PL	che who	correva was running-SG	la the	maratona marathon

Non-Perceptual Verbs

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

Study Details: Summary of Predictions

- 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

- 74 participants (recruited through Prolific, run on Ibex Farm)
- 24 item sets, 48 fillers
- Self-paced reading

Results: Behavioral Data

- No effect of Verb, Attachment, or Interaction

Results: Sentence Reading Time

- Effect of the Verb ($p<0.01$) and Verb*Attachment ($p<0.05$)

Results: RTs by ROI

Hypothesis

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

- Pre-Target: No Effect
- Target: Verb*Attachment ($p < 0.01$)
- Spillover: Verb*Attachment ($p < 0.001$) and Verb ($p<0.001$)

Online Effects: Stimuli and RTs

(2)

	Verb	Interpretation		before	target	after	
a.	PR/RC (Perceptual)	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.	PR/RC (Perceptual)	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.	RC only	LA	Gianni visse con il figlio dei medici	che	correvano	la	maratona
			Gianni lived with the son-SING of the doctors-PL	who	were running-PL	the	marathon
d.	RC only	HA	Gianni visse con il figlio dei medici	che	correva	la	maratona
			Gianni lived with the son-SING of the doctors-PL	who	was running-SG	the	marathon

Online Effects: Stimuli and RTs

(2)

	Verb	Interpretation		before	target	after	
a.	PR/RC (Perceptual)	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.	PR/RC (Perceptual)	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.	RC only	LA	Gianni visse con il figlio dei medici	che	correvano	la	maratona
			Gianni lived with the son-SING of the doctors-PL	who	were running-PL	the	marathon
d.	RC only	HA	Gianni visse con il figlio dei medici	che	correva	la	maratona
			Gianni lived with the son-SING of the doctors-PL	who	was running-SG	the	marathon

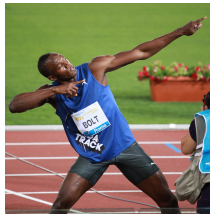
Hypothesis (@ verb)

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

See also Aguilar et al. (2021)

PRs vs RCs: Interpretative Differences

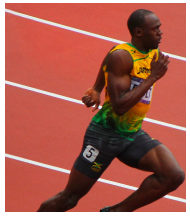
(6) RC: *John saw the man that runs*



∃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*.[8]

(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*.[9]

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 2: Tense and Aspect Restrictions

(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.'

v. Restrictions to both inner and outer aspect hold for PRs. PRs require imperfective, but not perfective, aspect (17-a), as they denote ongoing events. They are further restricted to stage level properties and cannot denote individual level properties (17-b). Neither of these restrictions applies to RCs.

(17) a. Ho visto Gianni che correva/ *che è corso a casa.
'I saw Gianni running/ that had run home.'
b. Ho visto Gianni che *aveva gli occhi rossi*/ **aveva gli occhi blu*.
I saw Gianni that had the eyes red/ had the eyes blue.
'I saw Gianni with red eyes/ with blue eyes.' (Casalicchio, 2013, p. 117, ex. 160)

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]:

(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.'