Minimalist Parsing as a Psycholinguistic Model

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IUSS
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Let's Start with Data!

Asymmetries in Italian Relative Clauses

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

(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**

SRC > ORC

Postverbal Subjects and Ambiguity

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

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

b. "The horse that the lion chased" **ORCp**

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a. "The horse that chased the lion" **SRC**

b. "The horse that the lion chased" **ORCp**

SRC > ORCp

Agreement can disambiguate:

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

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

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

Forward to the Past

The relation between grammatical operations and cognitive processes?

> *A realistic grammar should [...] contribute to the explanation of linguistic behavior and to our larger understanding of the human faculty of language.*
>
> *(Bresnan 1978: pg. 58)*

Derivational Theory of Complexity (Miller and Chomsky, 1963)

- Processing complexity ∼ 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?
- What is costly? And why?

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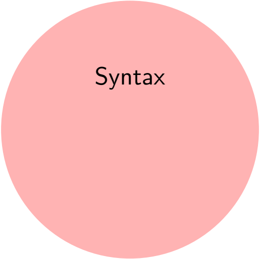

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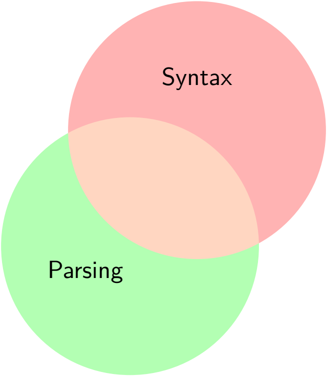

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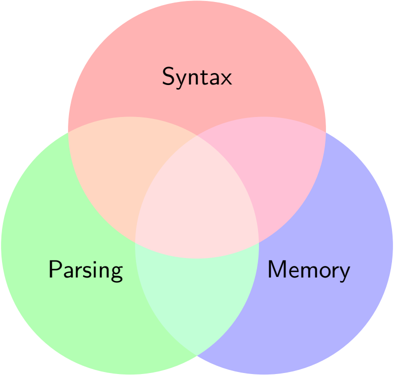
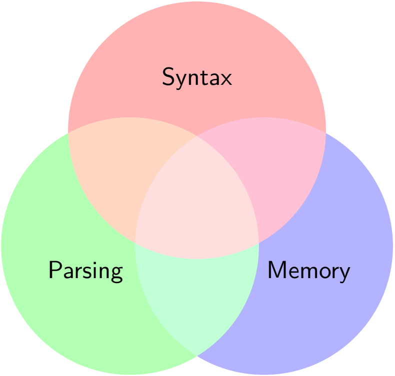


A Formal Model of Sentence Processing



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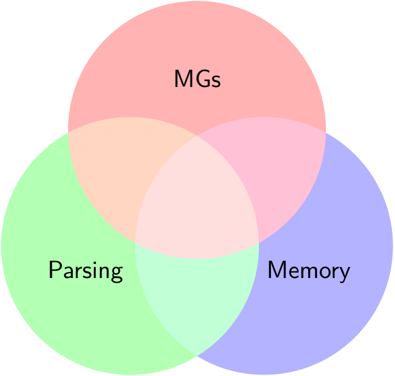

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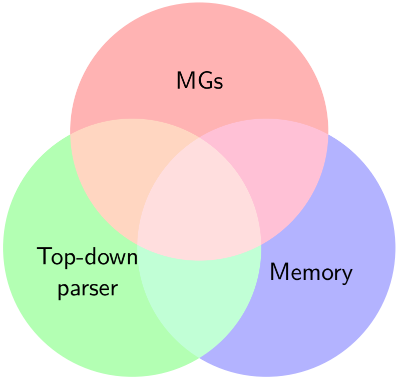

1. An explicit syntactic theory → Minimalist grammars (MGs)
2. A theory of how structures are built → top-down parser

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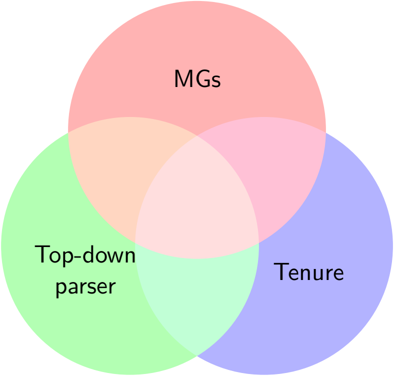

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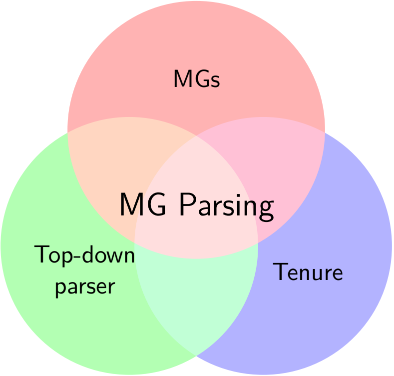

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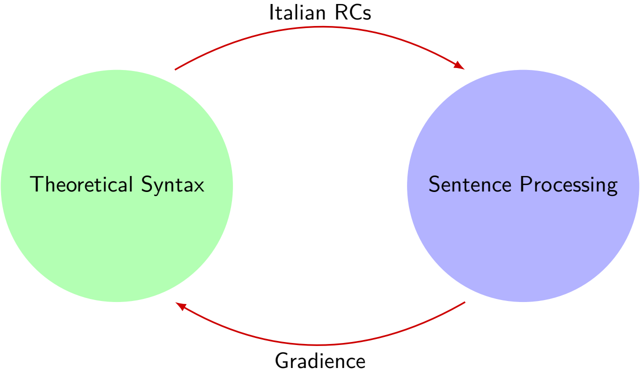
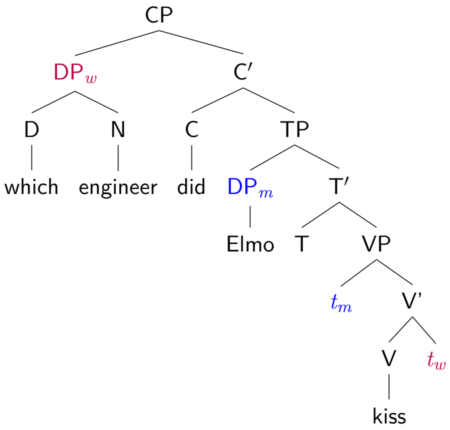
Building Bridges



Outline

Minimalist Grammars (MGs) & Derivation Trees



Phrase Structure Tree

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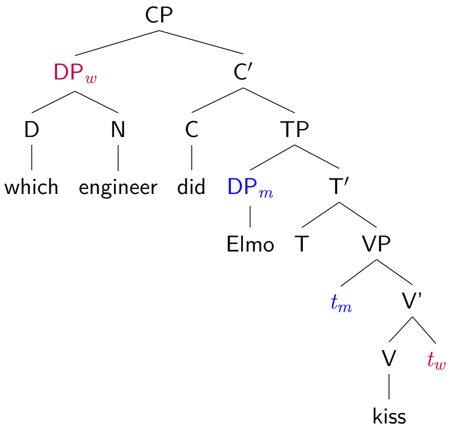

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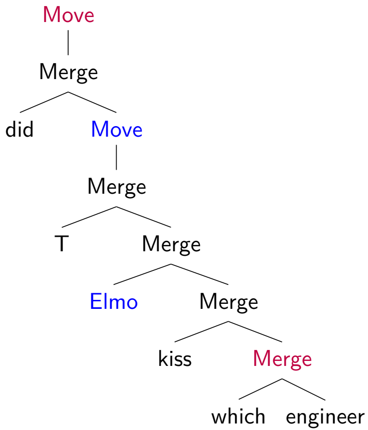
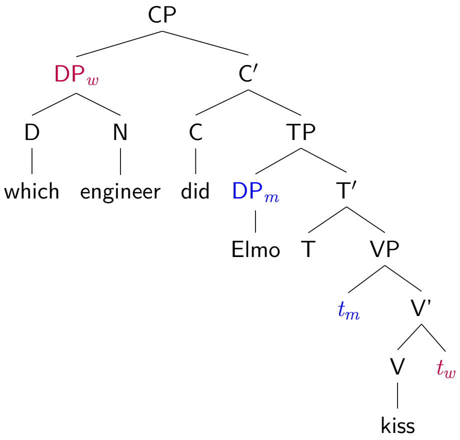


Derivation Tree

MG Syntax: Derivation Trees



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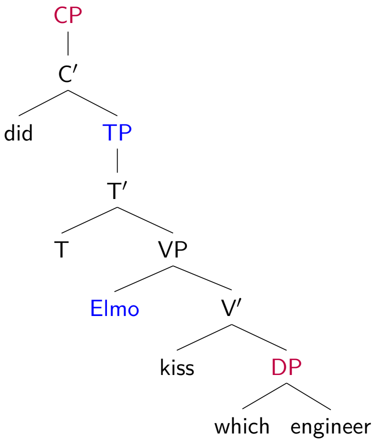
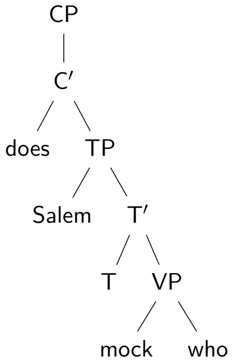


Derivation Tree

The Job of a Parser

Who does Salem mock?



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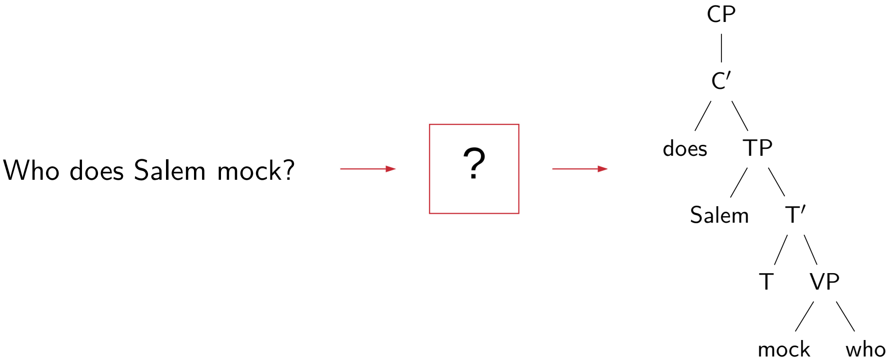

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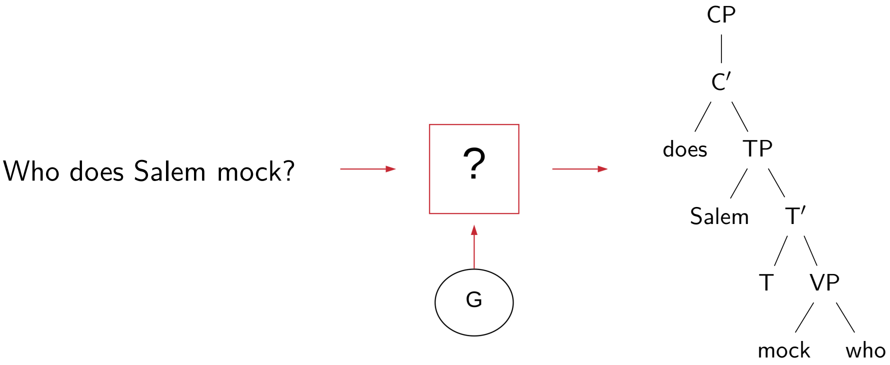

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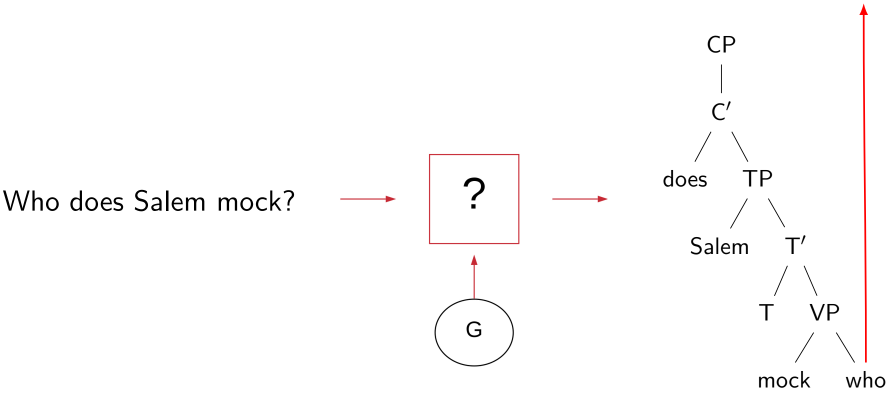

- Bottom-up

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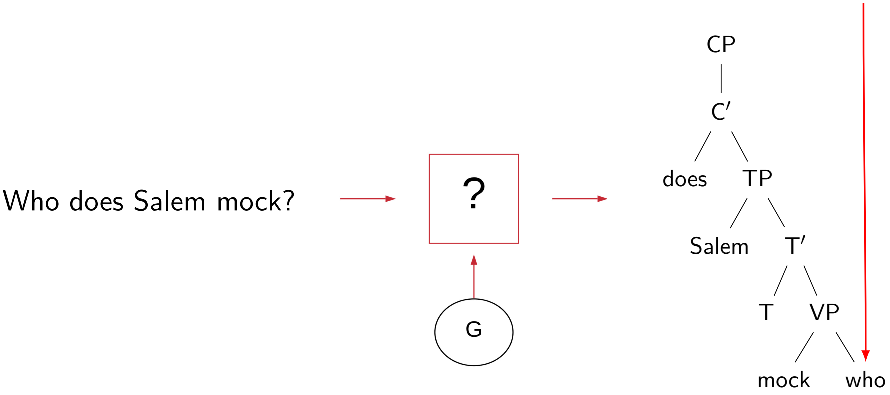

- Bottom-up
- Top-down

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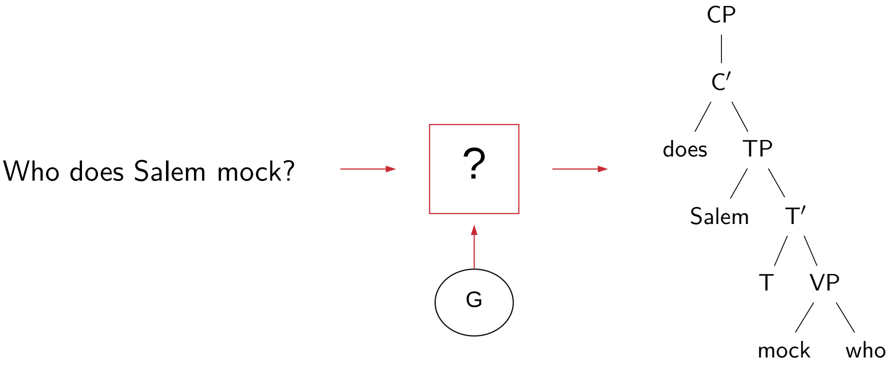

- Bottom-up
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  - Psychologically plausible(-ish)

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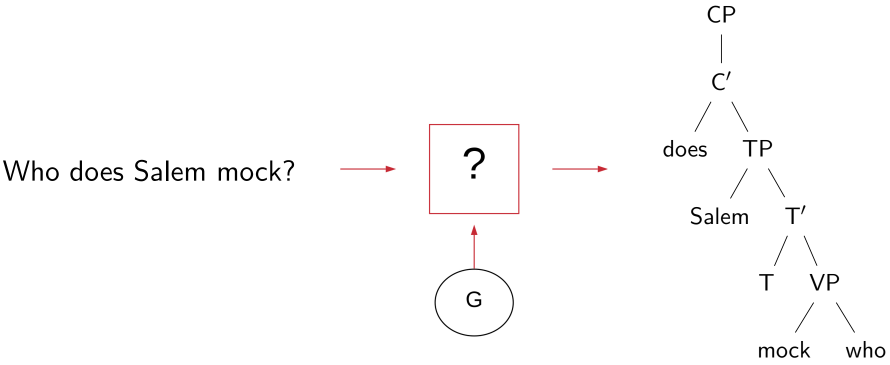

- Bottom-up
- Top-down
  - Psychologically plausible(-ish)
  - Insight: We can build lexicalized grammars top-down!
  - Assumption: Parser as an oracle!

Top-Down Parsing: The Intuition

Who does Salem mock?

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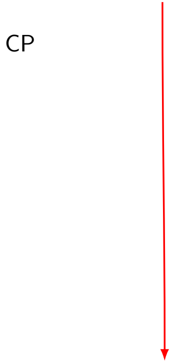

- Builds the structure from top to bottom
- Takes elements in an out of memory
- Complexity of the structure $\approx$ how much memory is used!

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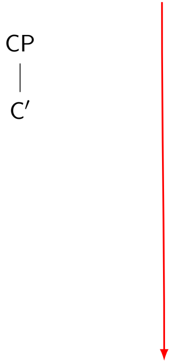

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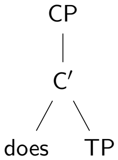

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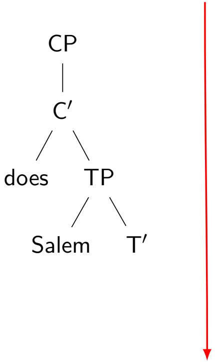

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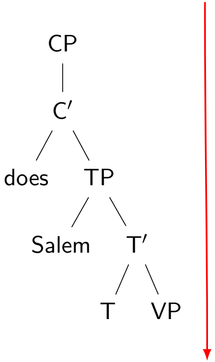

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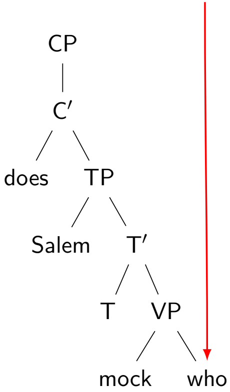

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Incremental Top-Down Parsing

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
step 7	who is found
step 8	does is found
step 9	Salem is found
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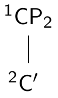

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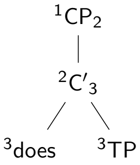

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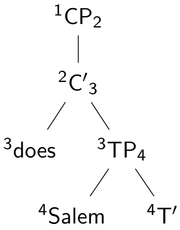

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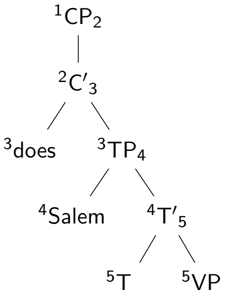

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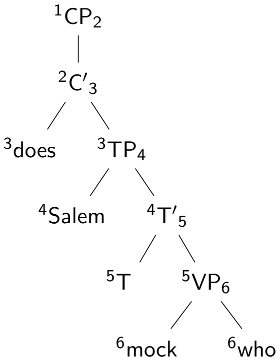

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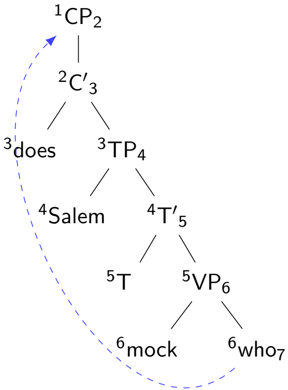

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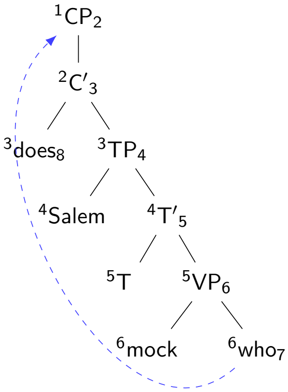

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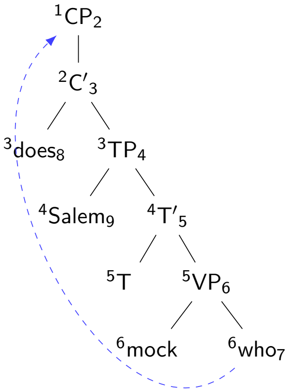

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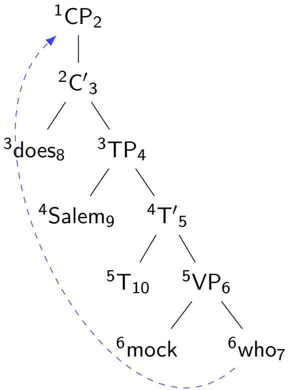

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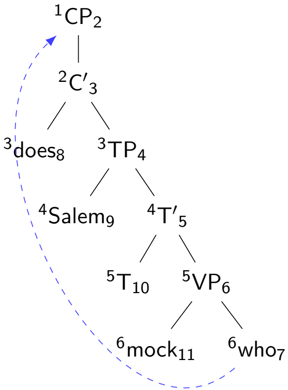

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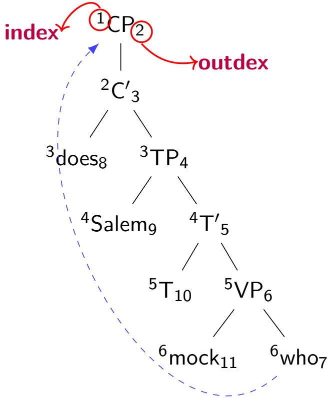

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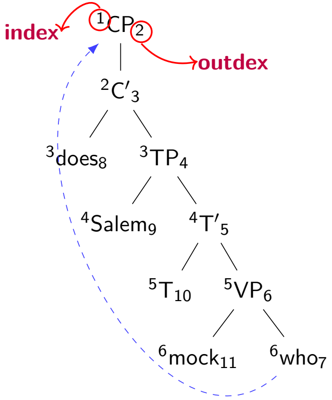
step 1	*CP* is conjectured
step 2	*CP* expands to *C'*
step 3	*C'* expands to *does* and *TP*
step 4	*TP* expands to *Salem* and *T'*
step 5	*T'* expands to *T* and *VP*
step 6	*VP* expands to *mock* and *who*
step 7	*who* is found
step 8	*does* is found
step 9	*Salem* is found
step 10	*T* is found
step 11	*mock* is found



Index and Outdex are our connection to memory!

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 **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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Processing Asymmetries All the Way Down

<MaxT,SumS> makes correct predictions cross-linguistically!

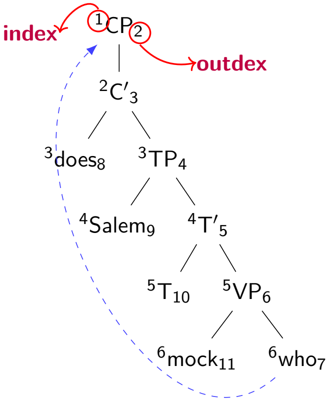
Across Many Constructions

- Right > center embedding (Kobele et al. 2012)
- Crossing > nested dependencies (Kobele et al. 2012)
- SC-RC > RC-SC (Graf & Marcinek 2014)
- SRC > ORC (Graf et al. 2017)
- Postverbal subjects in Italian (De Santo 2019)
- Persian attachment ambiguities (De Santo & Shafiei 2019)
- RC attachment in Mandarin, Korean, Japanese (De Santo & Lee in prep.)

Across Languages

- English, German, Italian
- Korean, Japanese, Mandarin Chinese
- Persian, ...

Computing Metrics: An Example



Tenure how long a node is kept in memory

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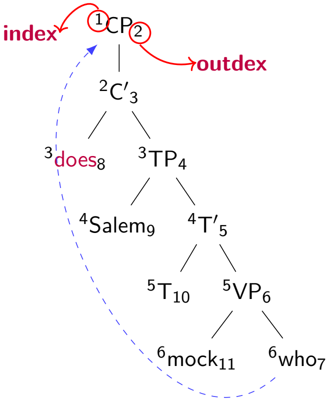

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Tenure($does$**)** $= 8 - 3 = 5$

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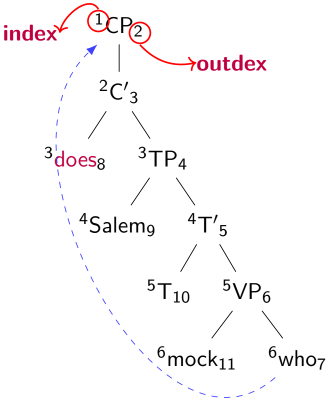


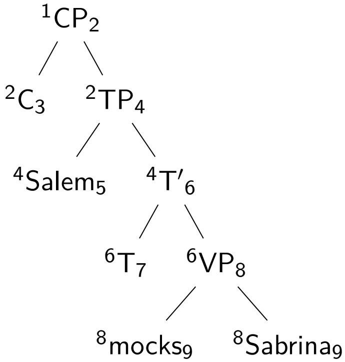
Tenure how long a node is kept in memory

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

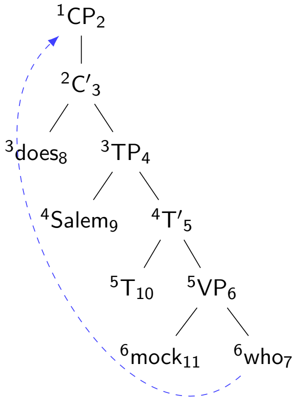
MaxTenure $= max\{$**Tenure**$(does),$ **Tenure**$(Salem), \ldots\} = 5$

Contrasting Derivations

MaxTenure $= 2$



MaxTenure $= 5$



Summary of the Approach

General Idea

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

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

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**

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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
  ⇒ Top-down parser
- Complexity Metrics
  ⇒ MaxTenure and SumSize

Degrees of freedom: Syntactic analyses

1. RC constructions → (Kayne 1994)
2. Postverbal subjects → (Belletti & Leonini 2004)

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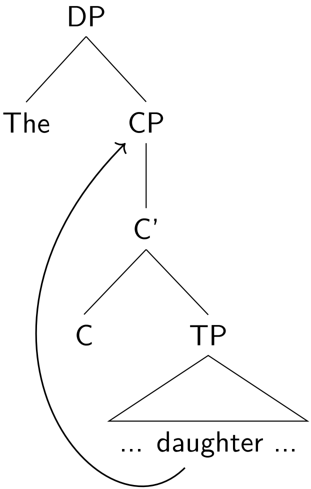
Kayne's Promotion Analysis (Kayne 1994)



- 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]

$[_{DP}$ The $[_{CP}$ daughter$_i$ [that t_i was on the balcony]]]

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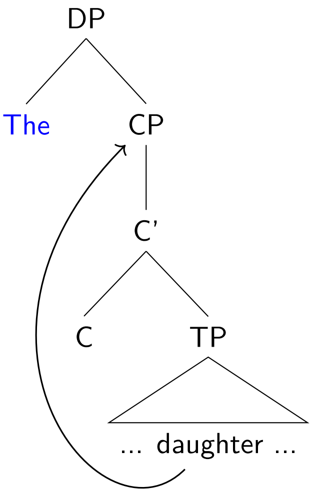

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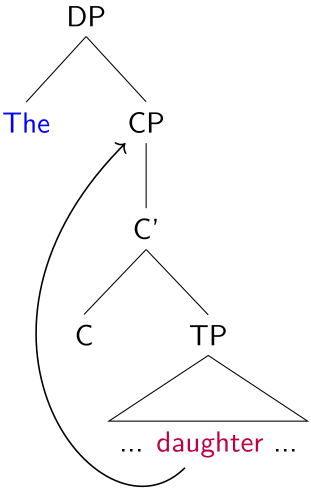

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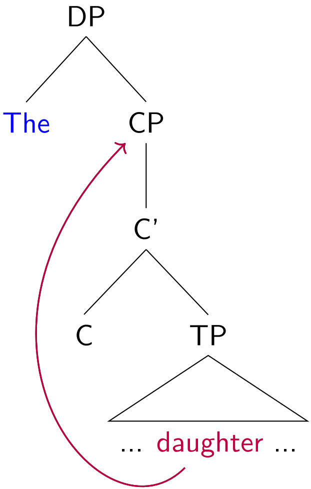

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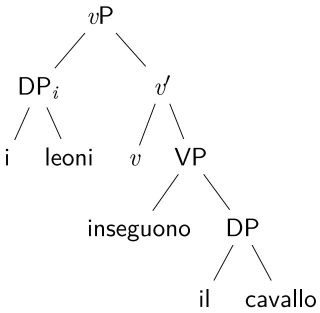
Postverbal Subjects (Belletti & Leonini 2004)

(5) 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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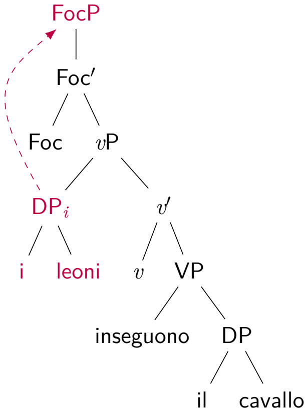

Postverbal Subjects (Belletti & Leonini 2004)

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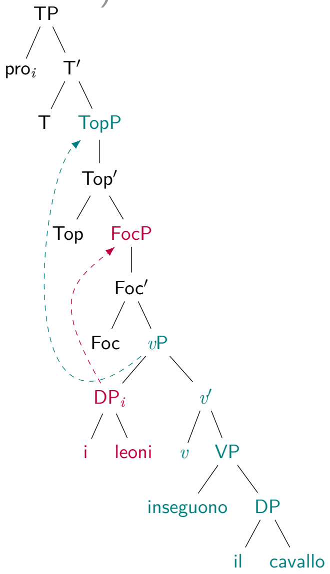

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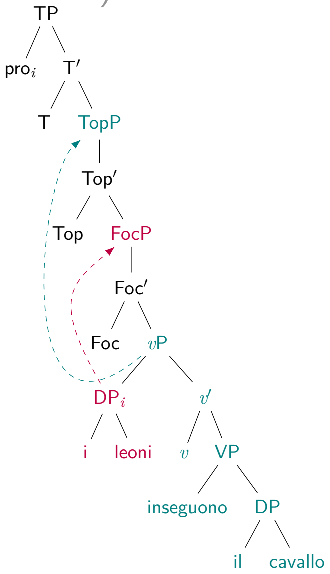

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	SRC	>	ORC	>	ORCp
MaxTenure	8/che		11/ha		16/Foc
SumSize	18		24		31

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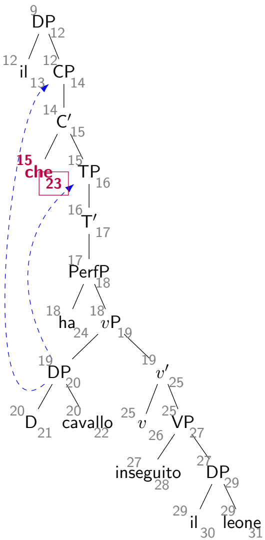
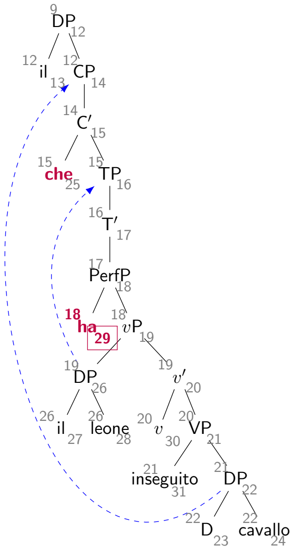
MaxTenure	8/che		11/ha		16/Foc	✓
SumSize	18		24		31	✓

Results: SRC > ORC





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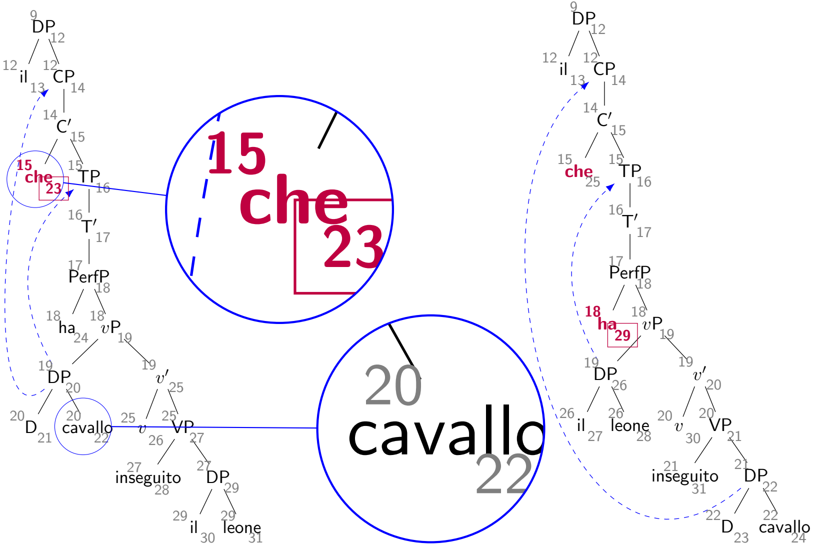

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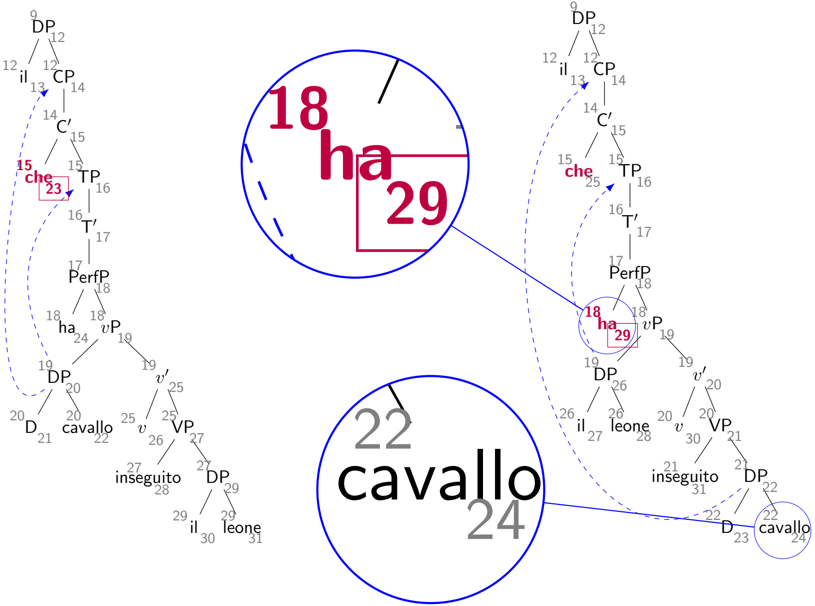

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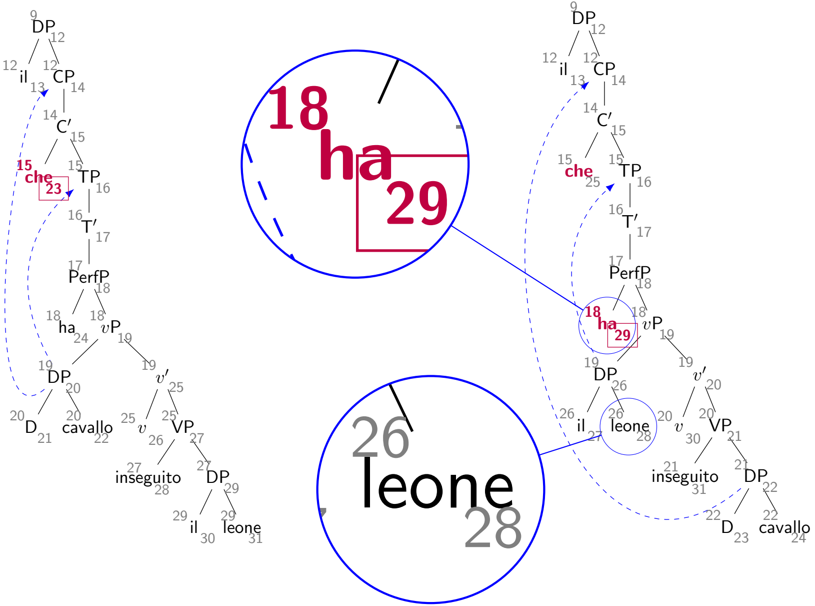


Summary of Results (De Santo 2019)

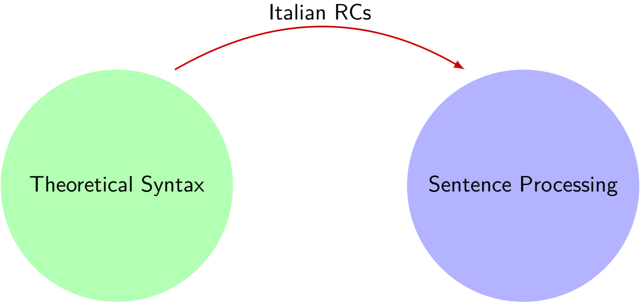
Clause Type	<MaxTenure,SumSize>
obj. SRC > ORC	✓
obj. SRC > ORCp	✓
obj. ORC > ORCp	✓
subj. SRC > ORC	✓
subj. SRC > ORCp	✓
subj. ORC > ORCp	✓
matrix SVO > VOS	✓
VS unacc > VS unerg	✓

Table: Predictions of the MG parser by contrast.

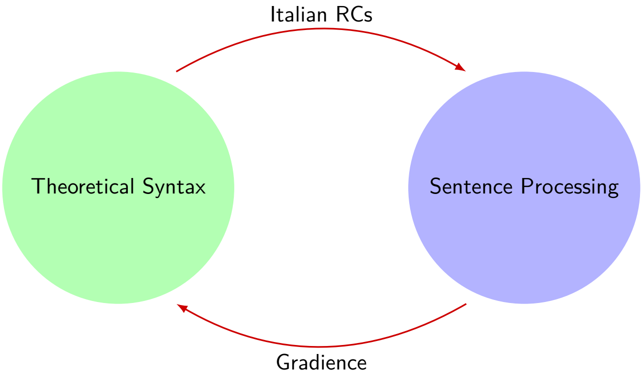
Interim Summary

- Asymmetries in Italian postverbal subject constructions
  - Derived just from **(fine-grained) structural differences**!
- <MaxT,SumS> gives consistent results!
  - Right vs. center embedding, attachment ambiguities, relative clause preferences
  - English, German, Korean, Japanese, Persian, Mandarin Chinese
  - More?

Moving on



Moving on


Italian RCs
Theoretical Syntax
Sentence Processing
Gradience

Acceptability and Grammaticality

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2. *What do you wonder whether John bought *t*?

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Acceptability judgments ≈ Grammaticality judgments

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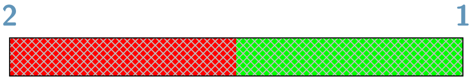

Gradience in Acceptability Judgments

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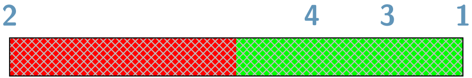

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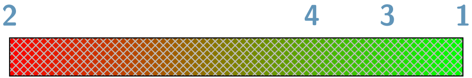

Gradient Acceptability and Categorical Grammars

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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But mainstream syntactic theories rely on categorical grammars!

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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!

Hypothesis

We can use the MG parser to test the relation between categorical grammar, processing difficulty, and gradience!

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Results in pairwise comparisons ideal for the MG parser

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Gradience in Islands: Sprouse et al. (2012)

A factorial design for islands effects:

1. Gap Position: Matrix vs. Embedded
2. Structure: Island vs. Non-Island
   (Kluender & Kutas 1993)

Results in pairwise comparisons ideal for the MG parser

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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

1. Matrix vs. Embedded
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Sprouse at al. (2012)

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Gap Position × Structure

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Modeling Results (De Santo 2020)

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.	✓

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	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.	✓
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	Matrix | Isl.	>	Matrix | Isl.	✓
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	Matrix | Non Isl.	=	Matrix | Isl.	✓
	Matrix | Non Isl.	>	Emb. | Isl.	✓
	Matrix | Isl.	>	Emb. | Isl.	✓
	Matrix | Isl.	>	Matrix | Isl.	✓
	Emb. | Non Isl.	>	Emb. | Isl.	✓

TL;DR

Success in all cases but one!

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

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Obj. | Non Isl.	>	Obj. | Isl.	✓
Obj. | Non Isl.	>	Subj. | Isl.	✓
Obj. | Isl.	>	Subj. | Isl.	×

Clause Type	MaxT	SumS
Obj./Non Island	14/*do*	19
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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
- Other examples of gradience
- Cognitive vs. grammatical constraints? (Ferrara-Boston 2012)
- Syntactic constraints ∼ pruning the parsing space (Stabler 2013)
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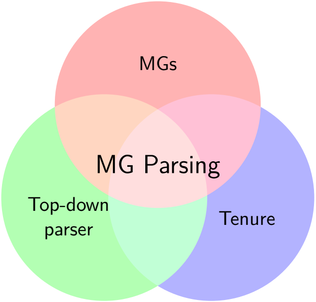
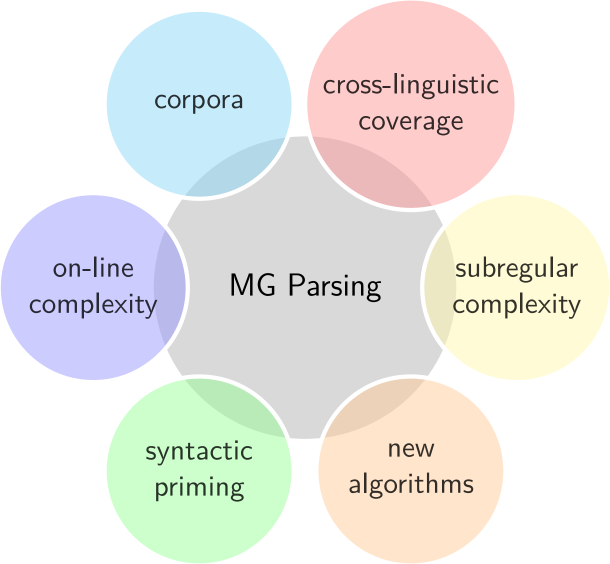
From the Trees (back) to the Forest

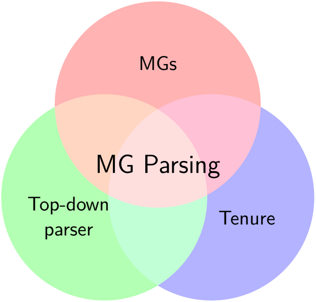


- Fully specified parsing model allows for precise predictions
- Tight connection with current generative syntax
- Successful on a variety of cross-linguistic constructions
- + insights about the structure of the grammar

Looking Ahead: A Collaborative Enterprise



From the Trees (back) to the Forest [cont.]



> *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)*

Thank you!

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Appendix

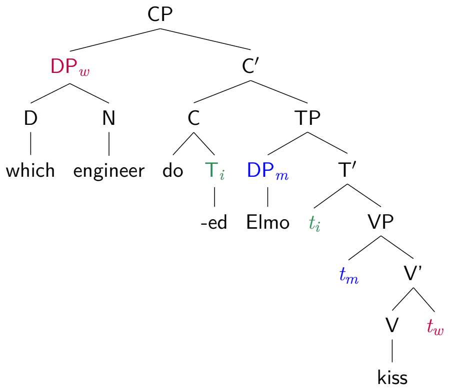
Why MGs?

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
     ⇒ cf. TAG (Rambow & Joshi, 1995; Demberg, 2008)

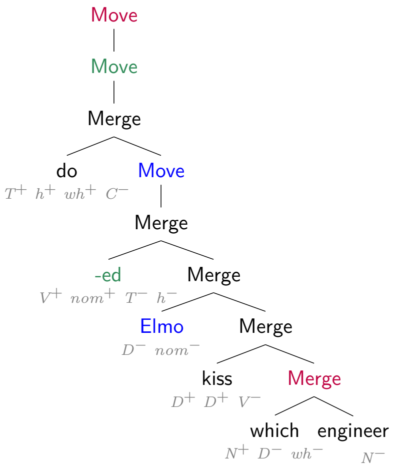
Some Important Properties of MGs

- 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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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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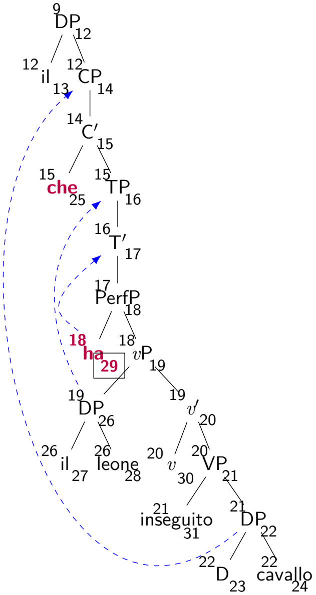
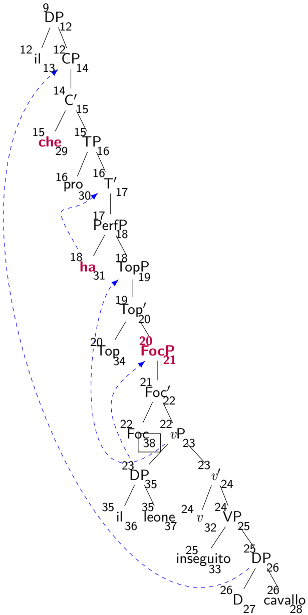
Results: ORC > ORCp





Additional Constructions

- Ambiguity in Matrix Clauses

(7) Ha chiamato Gio
Has called Giovanni
a. "He/she/it called Gio" **SVO**
b. "Gio called" **VS**

- Unaccusatives vs. Unergatives

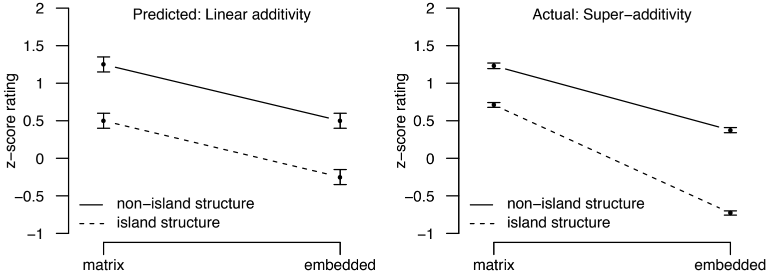
(8) È arrivato Gio
Is arrived Gio
"Gio arrived" **Unaccusative**

(9) Ha corso Gio
Has ran Gio
"Gio ran" **Unergative**

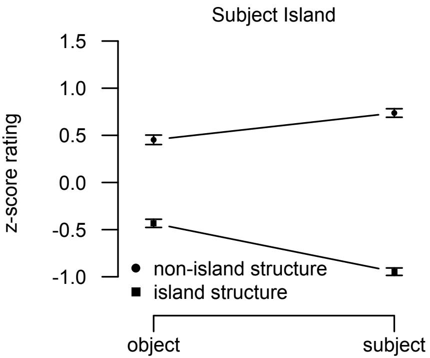
Gradience in Islands

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
  (Keller 2000; Featherston 2005; Lau et al. 2014)
- 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:

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Subject Islands

Case 1:

(10)
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:

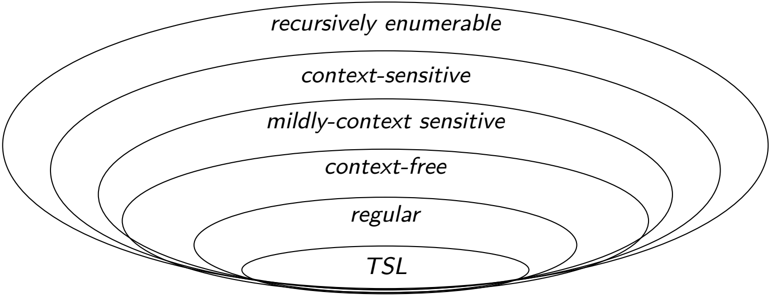
(11)
a. Who *t* thinks the speech interrupted the primetime TV show? — Matrix | Non Island

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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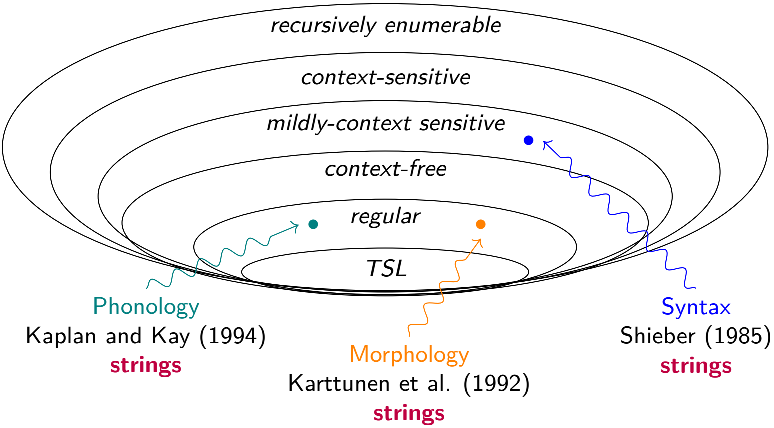

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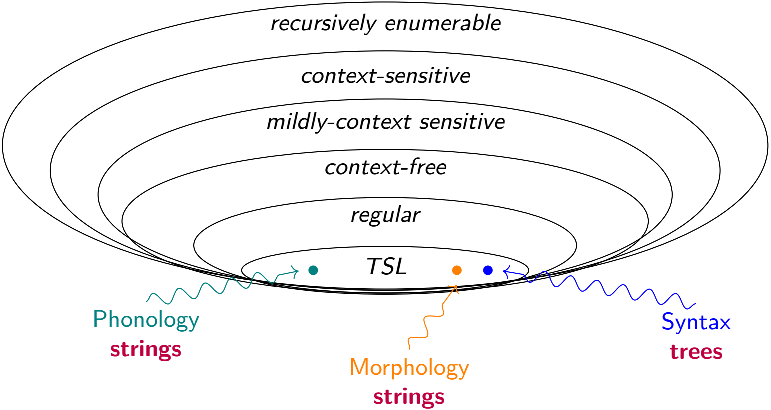

Cognitive Parallelism

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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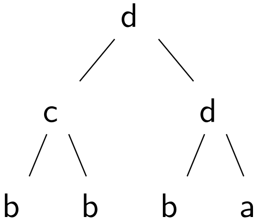
  Finite, flat memory

Top-down Parsing + Grammaticalized Constraints?

Graf & De Santo (2019)

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



- $0(b) \rightarrow b$; $1(b) \rightarrow b$
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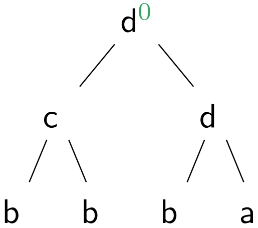

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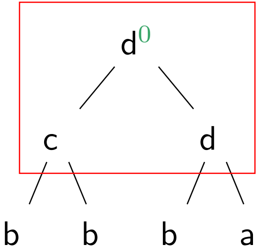

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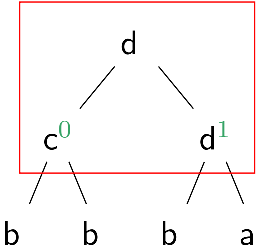

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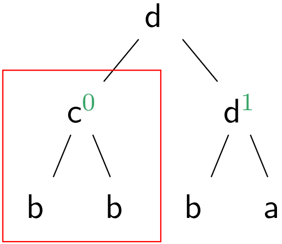

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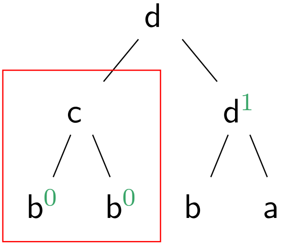

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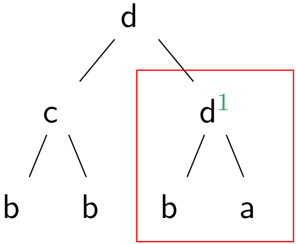

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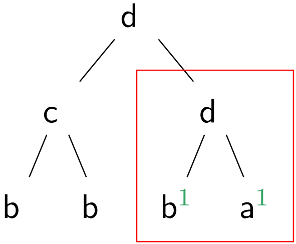

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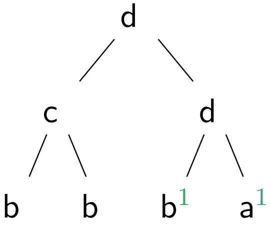

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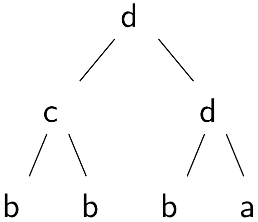

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- Some island constrains arise naturally from this perspective (e.g., Adjunct Island Constraint, SpIC, ATB movement)

Top-down Parsing + Grammaticalized Constraints?

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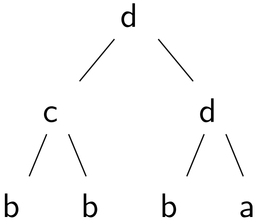
Sensing Tree Automata (Martens 2006) as a subregular bound on the complexity of syntactic dependencies.



- $0(b) \rightarrow b$; $1(b) \rightarrow b$
- $1(a) \rightarrow a$

- Some island constrains arise naturally from this perspective (e.g., Adjunct Island Constraint, SpIC, ATB movement)
- Constraints improve parsing performance by **exponentially reducing** the search space (Stabler 2013)

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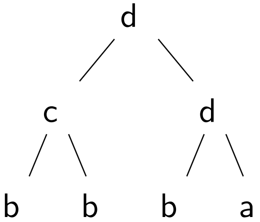

- $0(b) \to b$; $1(b) \to b$
- $1(a) \to a$

- Some island constrains arise naturally from this perspective (e.g., Adjunct Island Constraint, SpIC, ATB movement)
- 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)

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

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

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

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

- 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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  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

(16) I saw

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

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

(17) I saw

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

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

(18) I saw

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

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

(19) I saw

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

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