The (Surprising) Simplicity of Syntax

Derivation trees, subregular complexity, and what it implies for language and cognition

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You can get the slides here under "News"

A Mathematical Distinctness Theorem

- From a computational perspective,
  there is a split between "P-side" and "S-side".

regular $<$ context-free $<$ mildly context-sensitive $< \cdots$

Phonology

Morphology

Syntax

- Matches linguistic practice
  (despite attempts at unification, e.g. DM)
- Why is syntax the outlier?

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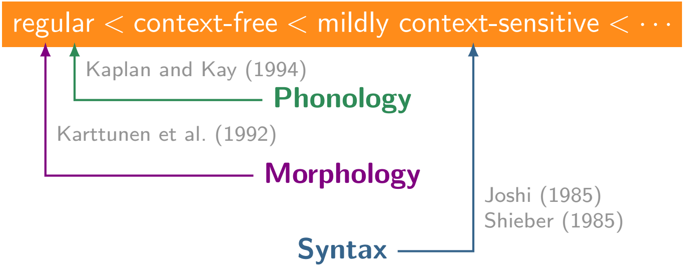

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An Alternative: Simple Syntax

- The postulated split is misleading.
- If we probe deeper, we find that
  - syntax is just as simple,
  - phonology, morphology, and syntax are weaker than regular $\Rightarrow$ **subregular**
  - relativized locality plays a major role,
  - and is approximated by the formal class **TSL**.
- This has repercussions for
  - cognitive architecture of language,
  - learning,
  - processing.

Outline

The Subregular Program

- **Received view**: class of regular (= finite-state) string languages maximally complex
- **Subregular hierarchy**: even weaker/simpler subclasses
- The **tier-based strictly local (TSL)** languages have emerged as particularly important.

Jeff Heinz

Jane Chandlee

Adam Jardine

Kevin McMullin

Example: Word-Final Devoicing

- Captured by forbidding voiced segments at the end of a word
- **German**: Don't have **z$** or **v$** or **d$** (where **$** = word edge).

Example: German

	***z$**
* **$** r a **d** **$**	***v$**
	***d$**

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- **Suppose**:
  - $[-\text{voice}] = \{$s,ʃ$\}$
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A Problem: Samala Sibilant Harmony

- If multiple sibilants occur in the same word, they must all be +anterior (**s**,**z**) or −anterior (**ʃ**,**ʒ**).
- In other words: Don't mix **purple** and **teal**.

*sʃ *sʒ *zʃ *zʒ
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- **But:** Sibilants can be arbitrarily far away from each other!

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*$ h a s x i n t i l a w a ʃ $

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Making Long-Distance Dependencies Local

- Let's take a clue from phonology: create locality with **tiers**. (Goldsmith 1985; Heinz et al. 2011)
- Enforce constraints on tier, rather than string

Jeff Heinz

Example: Samala Revisited

1. Project sibilant tier
2. *sʃ, *sʒ, *zʃ, *zʒ, *ʃs, *ʒs, *ʃz, *ʒz

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```
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  |     |                 | |
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  |   |          | |        |   |            | |
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Tier projection controlled by

1. label of segment
2. local context
3. symbols already on tier

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ITSL
$1 + 2$

TSL
1

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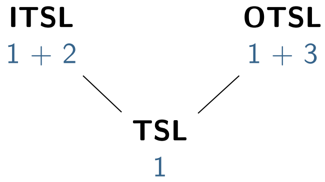

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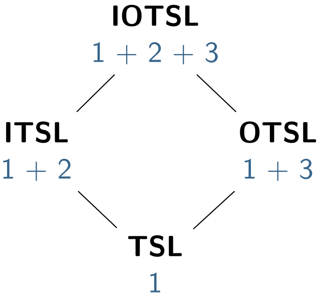

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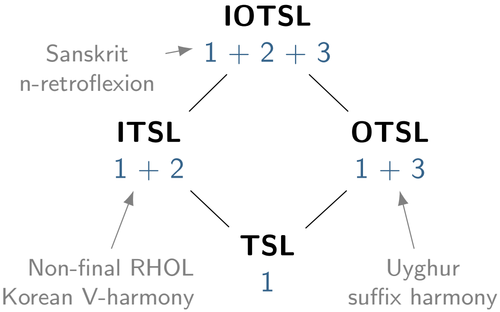

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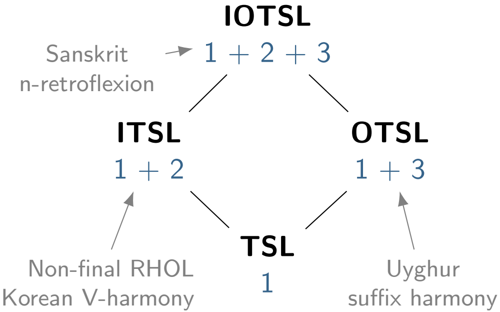
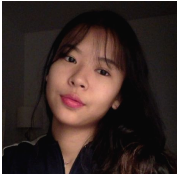


Hyunah Baek

Aniello De Santo

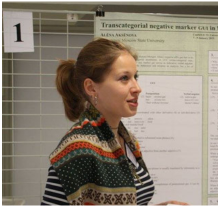
Connor Mayer



Suji Yang

TSL Across Language Modules

- Phonological dependencies fall within the TSL region.
- Morphological dependencies do, too.
  (Aksënova et al. 2016; Aksënova and De Santo 2017; Chandlee 2017)
- Phonology and morphology are **computationally similar**.



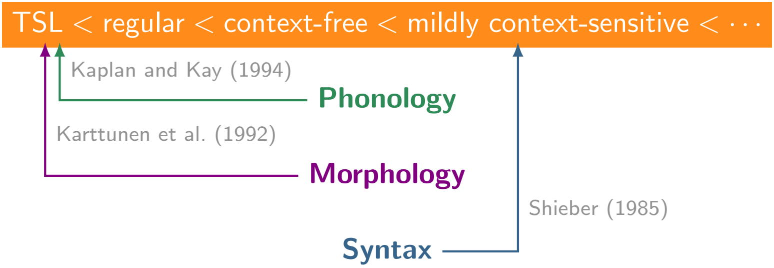
Alëna Aksënova

Sophie Moradi

Why is TSL Relevant?

- Linguistically natural
- Captures wide range of phonotactic dependencies
- Correct and efficient learning algorithms
  (I/O-TSL work in progress)
  (Jardine and McMullin 2017)
- Low resource demand
  - remember the last n symbols of a specific type
  - requires little working memory
  - no complex memory architecture
- Rules out unattested patterns
  - center embedding
  - harmony only if separated by even number of segments

Could Syntax Also be Subregular?



- Syntax seems even more like an outlier. . .
- Don't look at strings!
  What about **syntactic dependencies**?

Nazila Shafiei

c-Strings

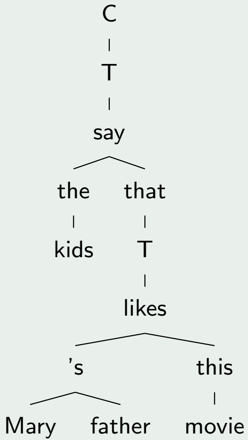
Command-Strings

The **c[ommand]-string** of a node n contains

- n and
- every node that commands n.

- easily computed from dependency trees
- c-command constraints seem to be largely **IOTSL over c-strings**

Example



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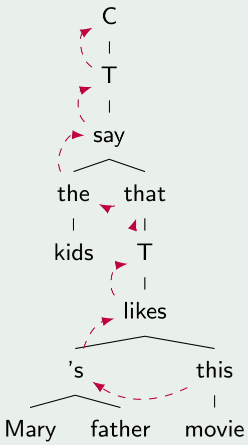

this 's likes T that the say T C

Principle A

Principle A (as a distributional constraint)

Every reflexive must be c-commanded by a DP in the same TP.

Equivalent c-String Constraint

If the c-string starts with a reflexive,
then at least one D must occur before the first T.

TSL Strategy for Principle A

1. Always project first symbol (ITSL)
2. Project D/T if previous symbol is Refl (OTSL)
3. Constraint: ***Refl T** (bigram)

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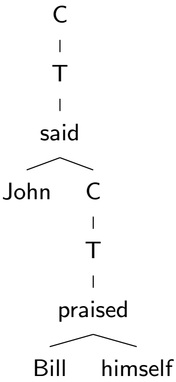

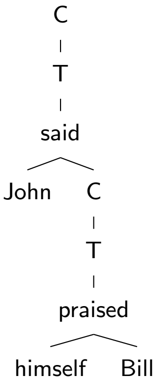

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himself **Bill** praised T C · · ·

$ **himself** **T** $

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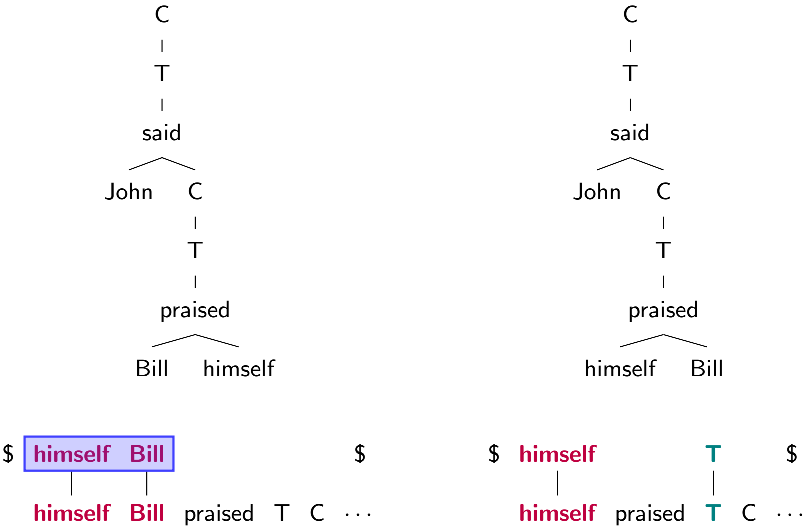

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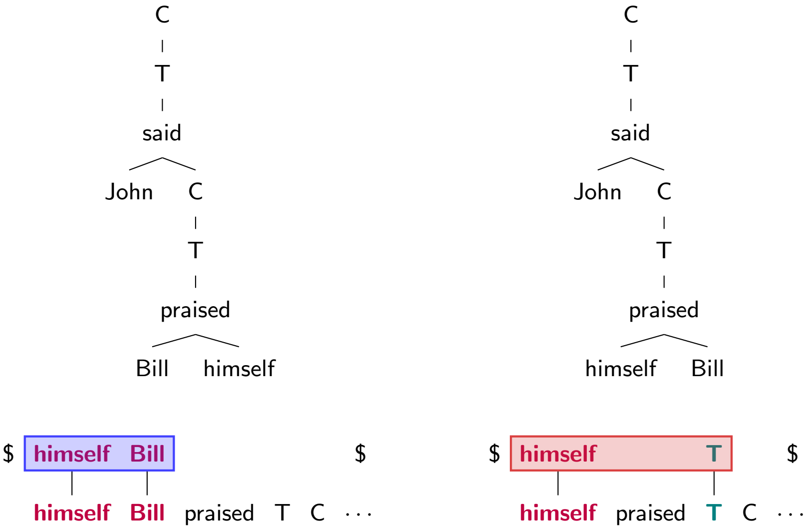

Another Example: Swedish *sig*

- Swedish *sig* must be non-locally bound.

(1) a. John said Bill praised sig.

b. * Bill praised sig.

TSL Strategy for *sig*

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2. Project T if previous symbol is sig (OTSL)
3. Project D if previous symbol is T (OTSL)
4. Constraint: ***sig T $** (trigram)

$	**sig**			**T**		**John**	$
	sig	Bill	praised	**T**	C	**John**	···

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$ $\boxed{\textbf{sig} \quad \textbf{T} \quad \textbf{John}}$ $

sig Bill praised **T** C **John** · · ·

$ **sig** **T** **$**

sig Bill praised **T** C

Another Example: Swedish *sig*

- Swedish *sig* must be non-locally bound.

(1) a. John said Bill praised sig.
  b. * Bill praised sig.

TSL Strategy for *sig*

1. Always project first symbol (ITSL)
2. Project T if previous symbol is sig (OTSL)
3. Project D if previous symbol is T (OTSL)
4. Constraint: ***sig T $** (trigram)

$ **sig** **T** **John** $
sig Bill praised **T** C **John** ...

$ **sig** **T** **$**
sig Bill praised **T** C

Comparison to Phonology and Morphology

Similarities

- mostly bigram and trigram constraints
- simple structural contexts
- dependencies in phonology are also c-command-like (Graf 2018a)

Differences

- OTSL seems more common in syntax

A Typological Prediction

Formal typology of syntactic constraints
should mirror phonology and morphology.

Connection to Parsing

- A tree is well-formed only if
  each node has a well-formed c-string.
- verifiable by deterministic top-down tree automaton
  with finite look-ahead
  $\Rightarrow$ **efficient incremental parsing**

An Intriguing Hypothesis

- Why c-command (rather than, say, precedence)?
- Because it allows for more efficient processing!

- But syntax isn't just c-command.
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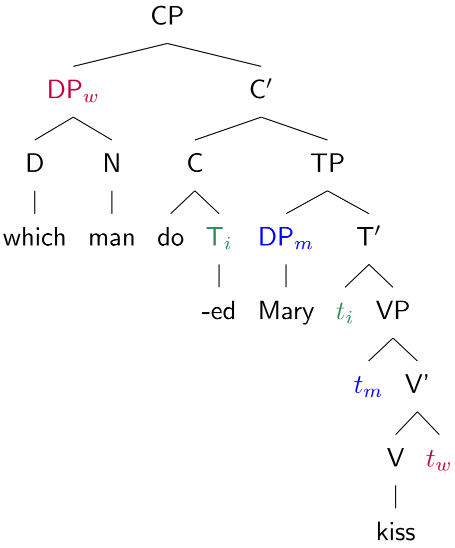
Minimalist Grammars

Ed Stabler

- Minimalist grammars (MGs) are a formalization of Minimalist syntax. (Stabler 1997, 2011)
- Operations: **Merge** and **Move**
- Adopt Chomsky-Borer hypothesis: Grammar is just a finite list of feature-annotated lexical items

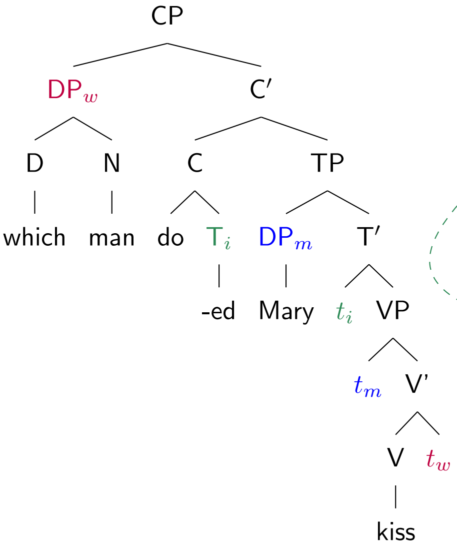
Chemistry	Syntax
atoms	words
electrons	features
molecules	sentences

MG Syntax in Action



Phrase Structure Tree

MG Syntax in Action



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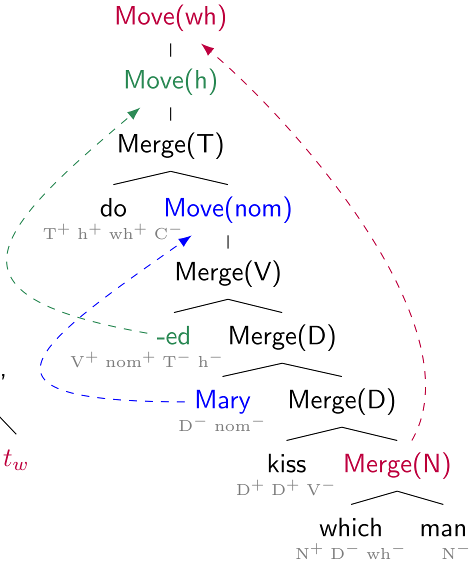
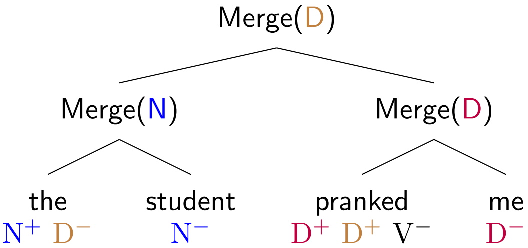


Derivation Tree

The Central Role of Derivation Trees

- Derivation trees are rarely considered in generative syntax.
  (but see Epstein et al. 1998)
- Satisfy Chomsky's structural desiderata:
  - no linear order
  - label-free
  - extension condition
  - inclusiveness condition
- Contain all information to produce phrase structure trees
  $\Rightarrow$ **central data structure** of Minimalist syntax

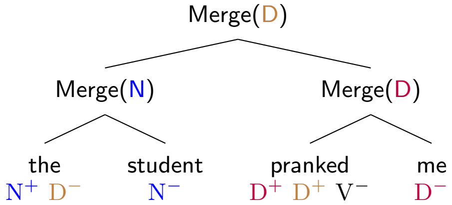
Merge is TSL



- The selector features of the head have to match the category features of the arguments.
- 1-to-1 match between selector features and category features.
- This is naturally expressed as **TSL over trees**.

Category Tiers for Merge

- Project tree tier for each category X.
- Every X^- has a Merge node as its mother.
- Every Merge node has exactly one X^- among its daughters.



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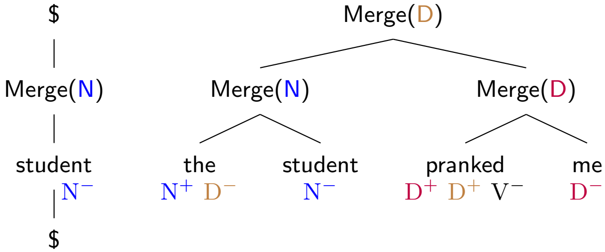

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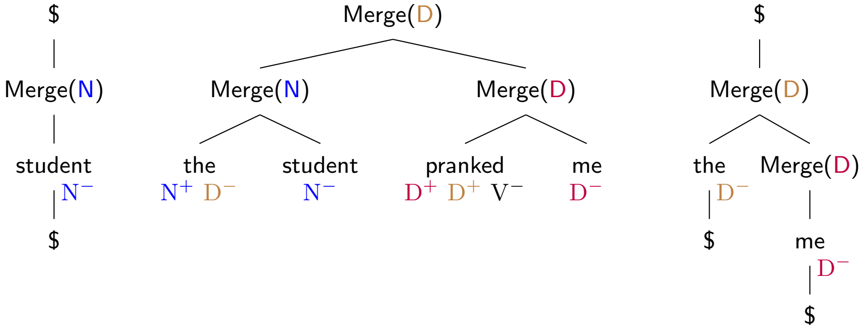
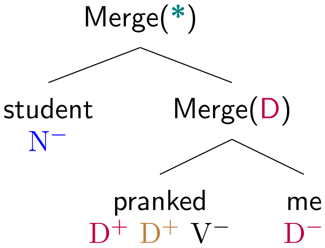


Illicit Merge Yields Ill-Formed Tiers



- This handles Merge.
- Moving on to Move. . .

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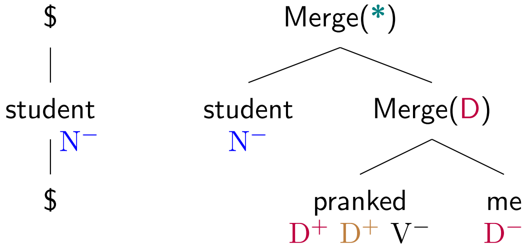

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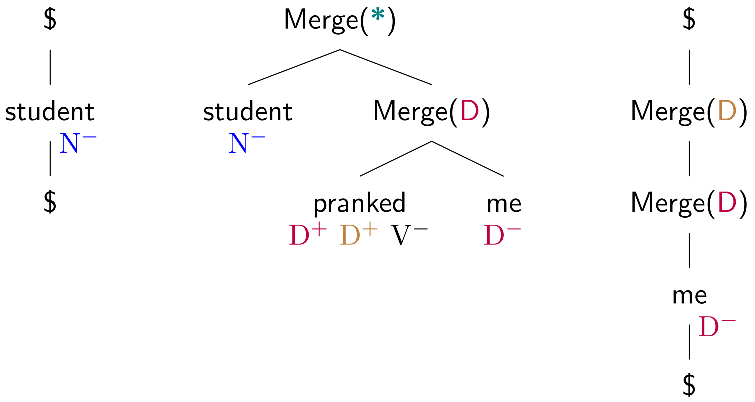

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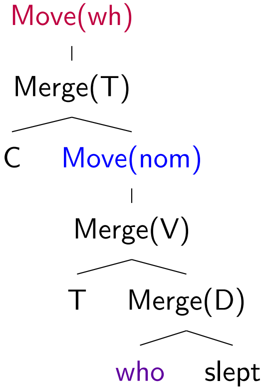
Move: Single Movement Normal Form

- **Assumption:** every phrase at most one movement feature
- Intermediate landing sites not feature-triggered
  (Graf et al. 2016)



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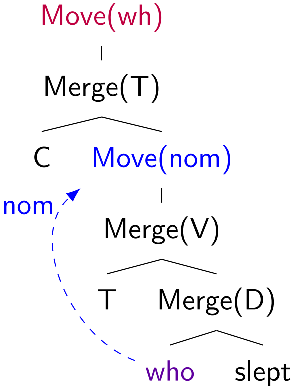

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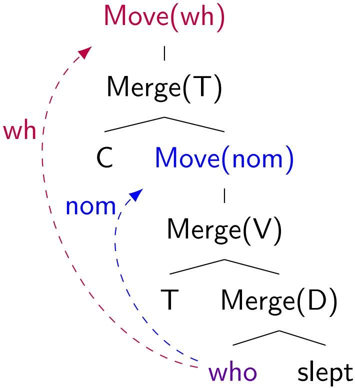

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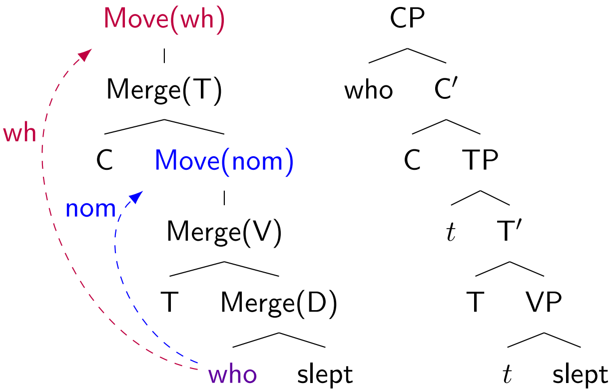

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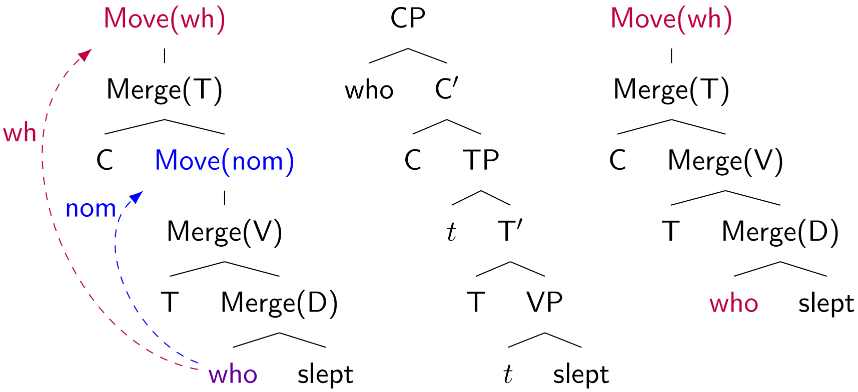

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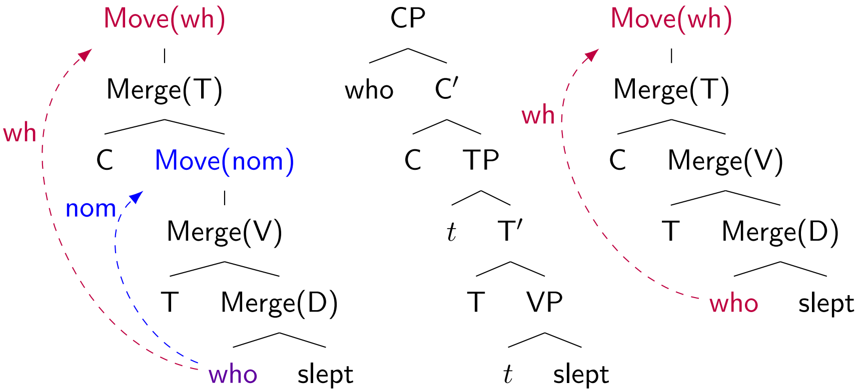

Movement Tiers for Move

- Project tree tier for each movement type x.
- Every x^- has a Move node as its mother.
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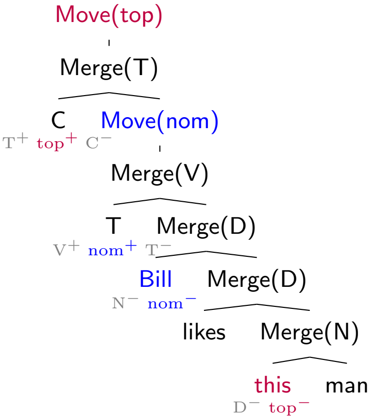

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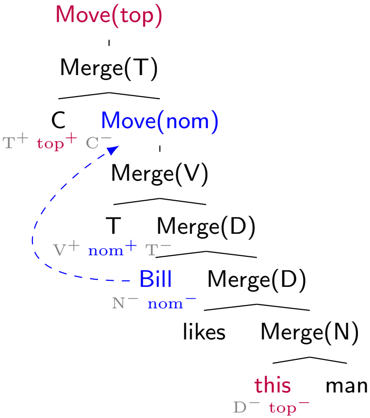

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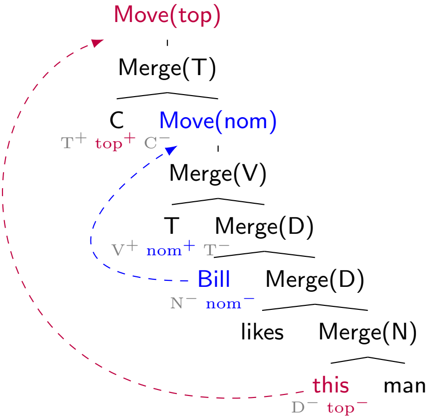

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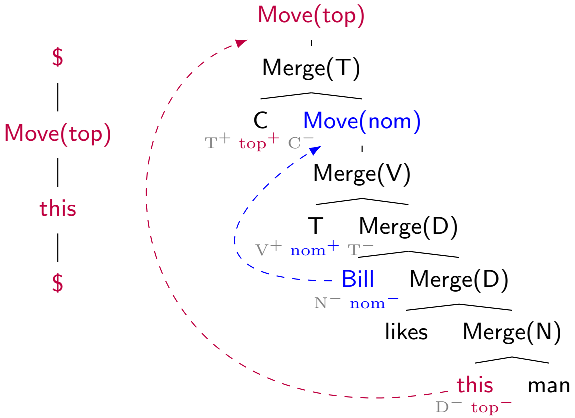

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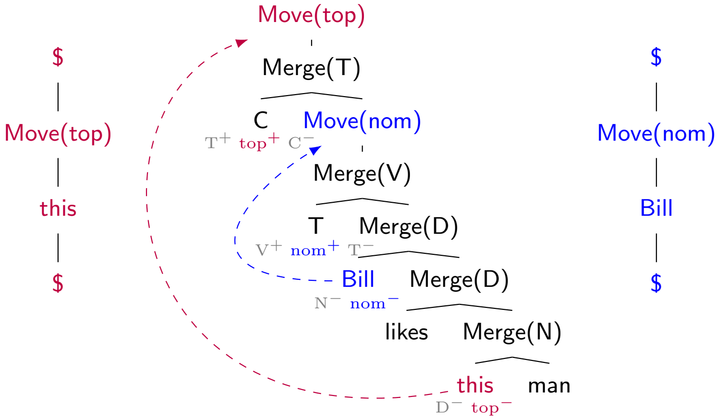
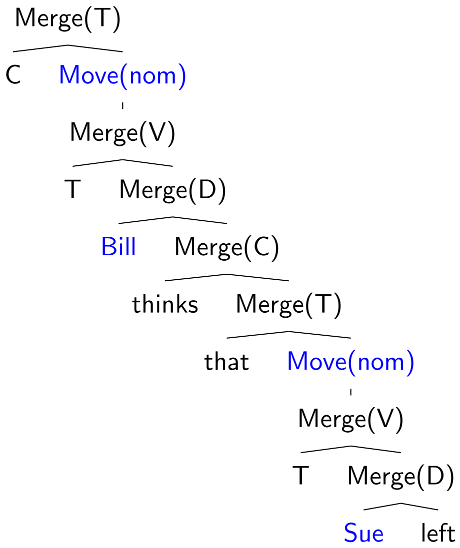


A Tier With Multiple Movers



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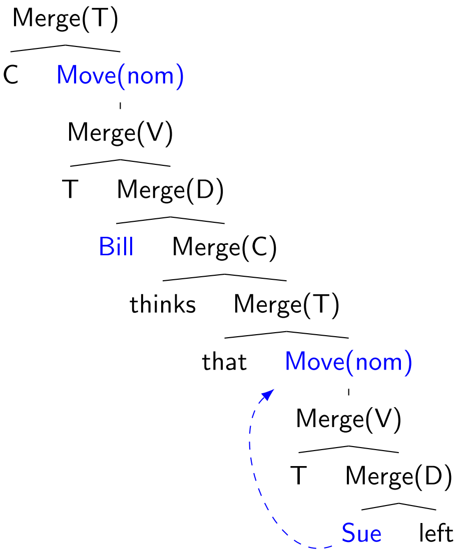

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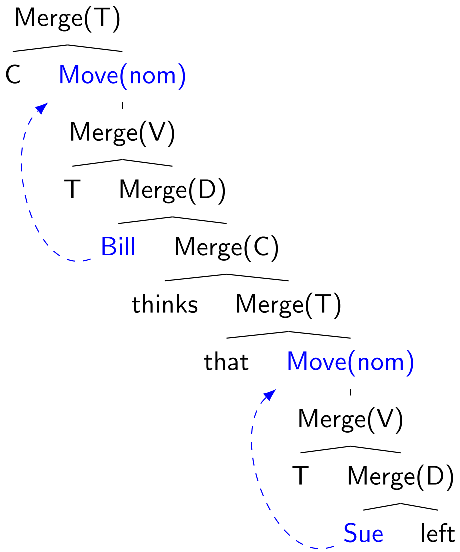

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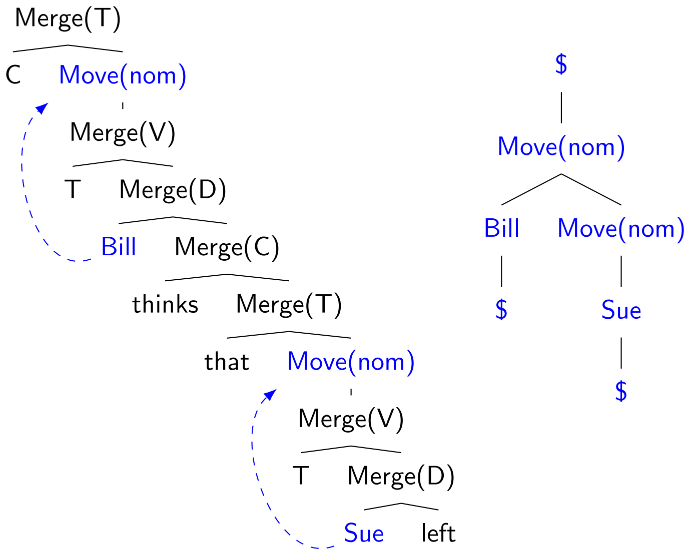
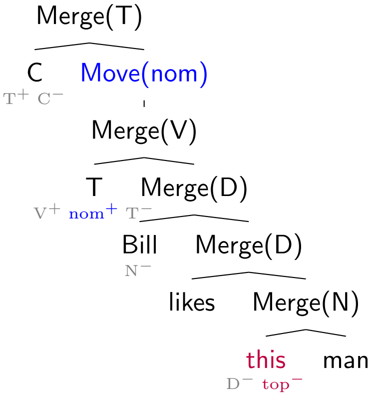


Blocking Simple Cases of Illicit Movement



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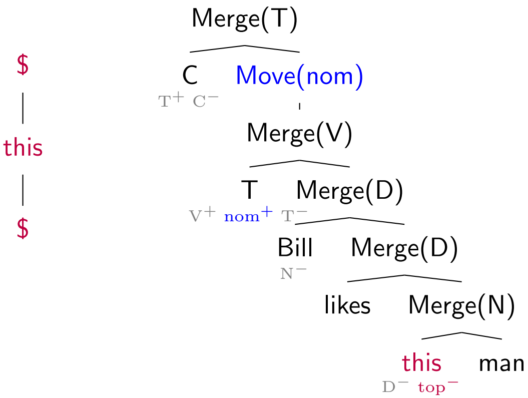

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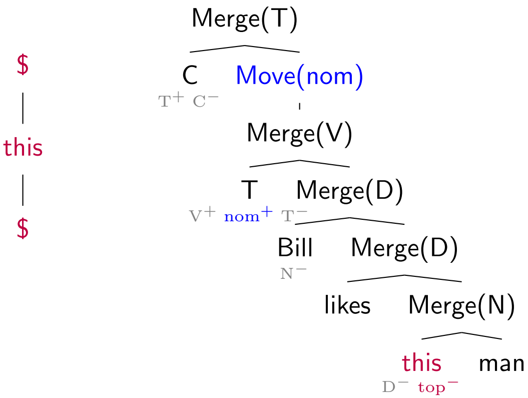

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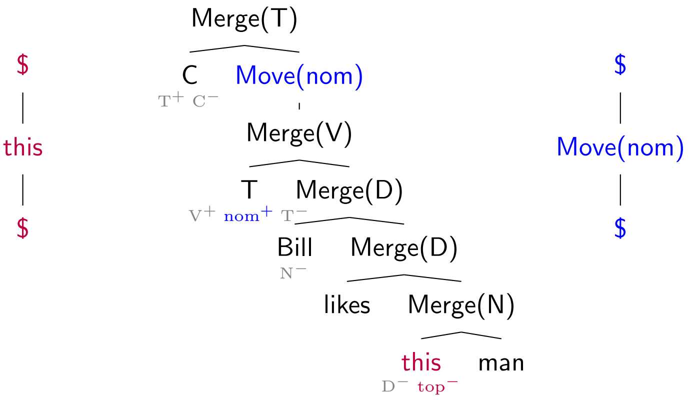

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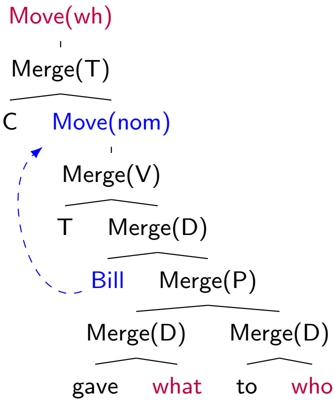

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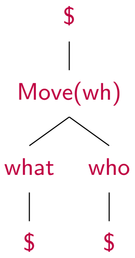

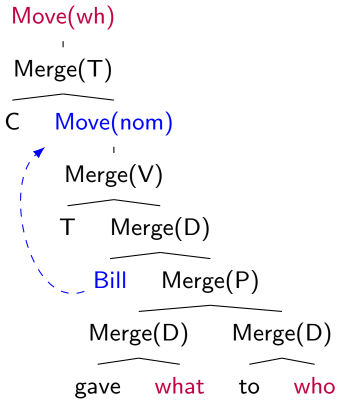

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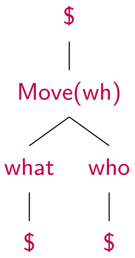

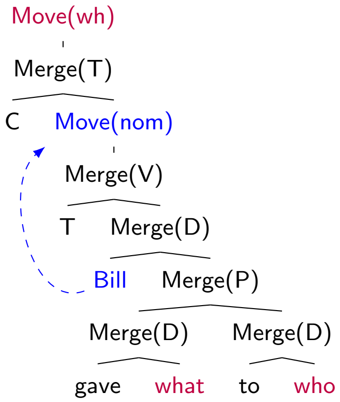

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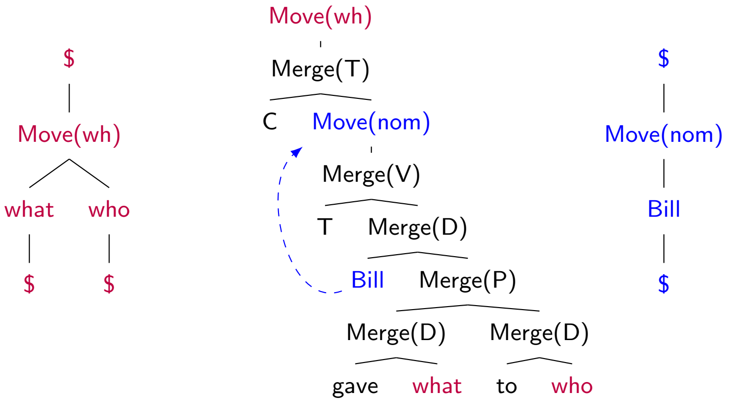

The Common Core of Merge and Move

TSL Strategy for Merge

- Project tree tier for each **category** X.
- Every X^- has a **Merge** node as its mother.
- Every **Merge** node has exactly one X^- among its daughters.

TSL Strategy for Move

- Project tree tier for each **movement type** x.
- Every x^- has a **Move** node as its mother.
- Every **Move** node has exactly one x^- among its daughters.

Note: constraints again **highly local**

Summary

- Syntax looks like a complex outlier.
- But not if we choose appropriate representations:
  - c-command dependencies are TSL over c-strings
  - Merge and Move are TSL over derivation trees
- **Computational parallelism**:
  - phonology is TSL
  - morphology is TSL
  - syntax is TSL

Work In Progress

- **Movement**
  - Interaction of movement and c-command
  - Complexity without Single Movement Normal Form
- **Empirical work**
  - limits of c-string constraints
  - unified treatment of island constraints
  - modeling specific phenomena (e.g. case assignment)
- **Processing & Learning**
  - compiling c-string constraints into MG parser
  - learning via semantic bootstrapping

Open Issues

- experimental evidence for computational parallelism
- even tighter subclasses of TSL
- full predicted typology
- model concrete aspects of acquisition

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Join the program!

Resources and Readings

1. **Survey papers:** Pullum and Rogers (2006); Heinz (2011a,b, 2018); Rogers and Pullum (2011); Chandlee and Heinz (2016)
2. **TSL and its extensions:** Heinz et al. (2011); McMullin (2016); Baek (2017); De Santo (2017); De Santo and Graf (2017); Graf (2017c); Graf and Mayer (2018); Mayer and Major (2018); Yang (2018)
3. **TSL morphology:** Aksënova et al. (2016); Graf (2017b)
4. **TSL morpho-semantics:** Graf (2017d)
5. **TSL syntax:** Graf (2012a, 2018b); Graf and Shafiei (2019); Vu (2018); Vu et al. (2019)
6. **Mappings:** Courcelle and Engelfriet (2012); Chandlee (2014, 2017); Jardine (2016)
7. **Learnability:** Heinz (2010); Kasprzik and Kötzing (2010); Heinz et al. (2012); Jardine et al. (2014); Lai (2015); Jardine and Heinz (2016); Jardine and McMullin (2017)

Appendix

Psychological Reality of Derivation Trees

Central role of derivation trees backed up by **processing data**:

- Derivation trees can be parsed top-down (Stabler 2013)
- Parsing models update Derivational Theory of Complexity, make correct processing predictions for
  - right $<$ center embedding (Kobele et al. 2013)
  - crossing $<$ nested dependencies (Kobele et al. 2013)
  - SC-RC $<$ RC-SC (Graf et al. 2017)
  - SRC $<$ ORC in English (Graf et al. 2017)
  - SRC $<$ ORC in East-Asian (Graf et al. 2017)
  - quantifier scope preferences (Pasternak 2016)
  - stacked relative clauses (Zhang 2017)
  - Korean attachment ambiguities

Technical Fertility of Derivation Trees

Derivation trees made it easy for MGs to accommodate the full syntactic toolbox:

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

Even More MG Extensions

- local and global constraints (Kobele 2011; Graf 2012a, 2017a)
- transderivational constraints (Graf 2010, 2013)
- Principle A and B (Graf and Abner 2012)
- GPSG-style feature percolation (Kobele 2008)
- idioms (Kobele 2012)
- grafts (multi-rooted multi-dominance trees) (Graf in progress)

Long Story Short

Derivation trees are a more useful and fertile data structure than phrase structure trees.

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