It's a (Sub-)Regular Conspiracy

Locality and Computation in Phonology Morphology, Syntax, and Semantics

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CLS
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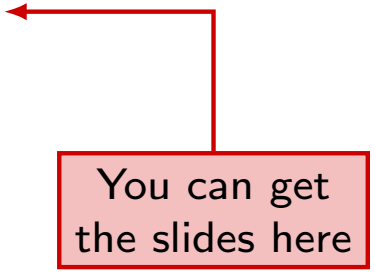

The Big Linguistic Questions

- What are the laws that govern each structural level?
- How **complex** are these laws? How hard are they to compute?
- How are they learned?
- Do we find **typological gaps**, i.e.
  patterns that should exist but don't appear in any language?
- What can we infer about human cognition?

The Opportunistic Program for Lazy Researchers Like Me

- Stand on the shoulders of giants.
- Computer scientists have figured out a lot about complexity, so let's apply their ideas to language.

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A Mathematical Distinctness Theorem

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

$$\text{regular} < \text{context-free} < \text{mildly context-sensitive} < \cdots$$

Phonology

Morphology

Syntax

- Matches linguistic practice
  (despite attempts at unification, e.g. DM)
- A unified Theory of Everything is not on the linguistic horizon.

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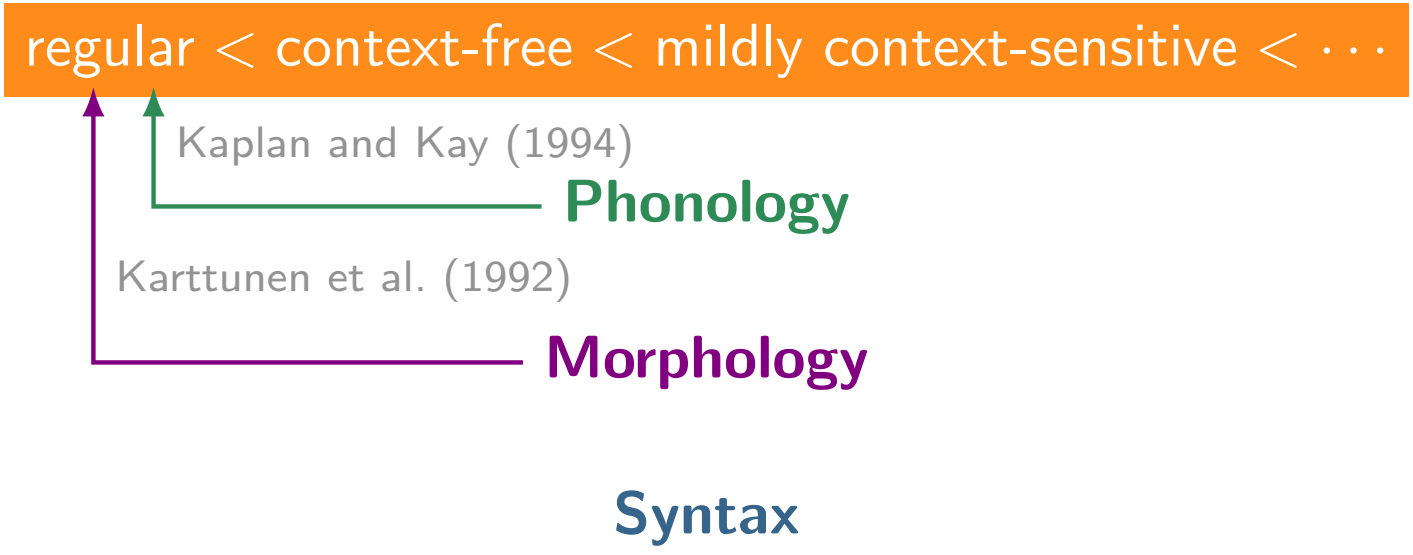

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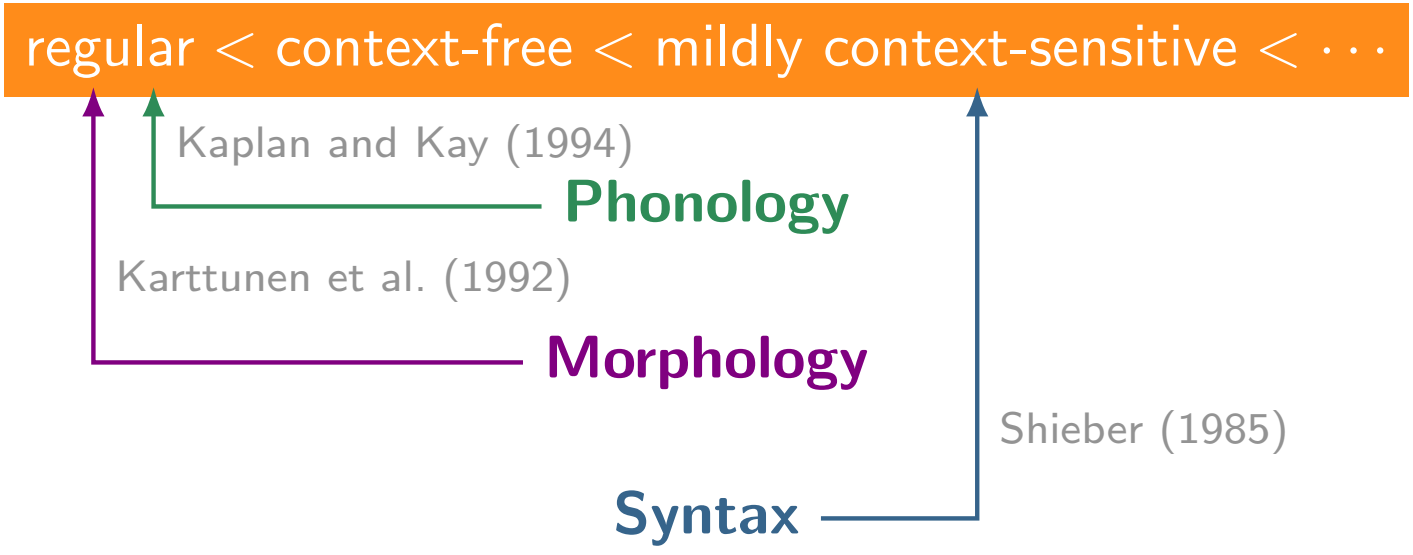

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The Subregular Conspiracy...

- The postulated split is misleading.
- If we probe deeper, we find that
  - different modules are remarkably similar,
  - their dependencies are weaker than regular
    $\Rightarrow$ **subregular**
  - relativized locality plays a major role,
  - and is approximated by the formal class **TSL**.

Subregular Conspiracy

- TSL crops up everywhere.
- TSL is shockingly useful.

Outline

1 Locality and Tiers in Phonology

2 TSL Morphotactics

3 TSL Morpho-Semantics

4 Syntax
- Minimalist Grammars
- Merge is TSL
- Move is TSL

TSL: Tier-Based Strictly Local

- There are a variety of subregular classes to choose from.
- TSL is among the weaker ones.
- TSL works well empirically.

Tier-Based Strictly Local Dependencies

- All patterns described by markedness constraints that are
  - inviolable,
  - locally bounded,
  - formalized as n-grams.
- Non-local dependencies are **local over tiers**.
  (Goldsmith 1976)
- **Linguistic core idea:**
  Dependencies are local over the right structure.

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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

*$ r a d $

*z$

*v$

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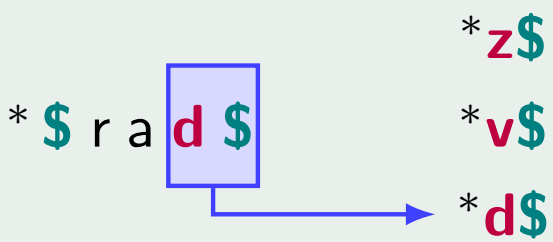

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- **Then**: don't have **asa**, **aʃa**, **asi**, **aʃi**, ...

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- 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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Making Long-Distance Dependencies Local

- Let's take a clue from phonology: create locality with **tiers**.
- Tier projection is determined by the segments, not their environment. (Heinz et al. 2011)

Jeff Heinz

Example: Samala Revisited

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

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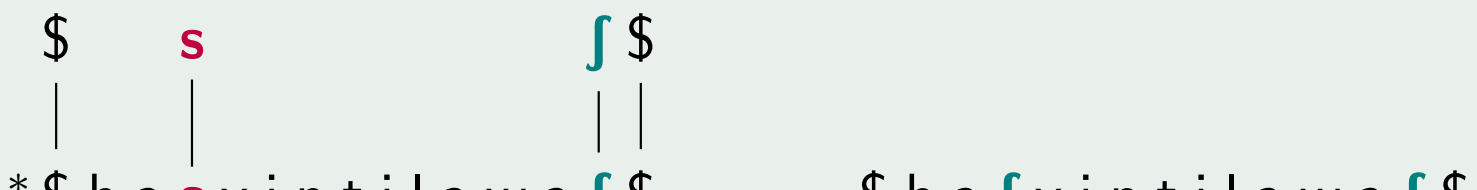

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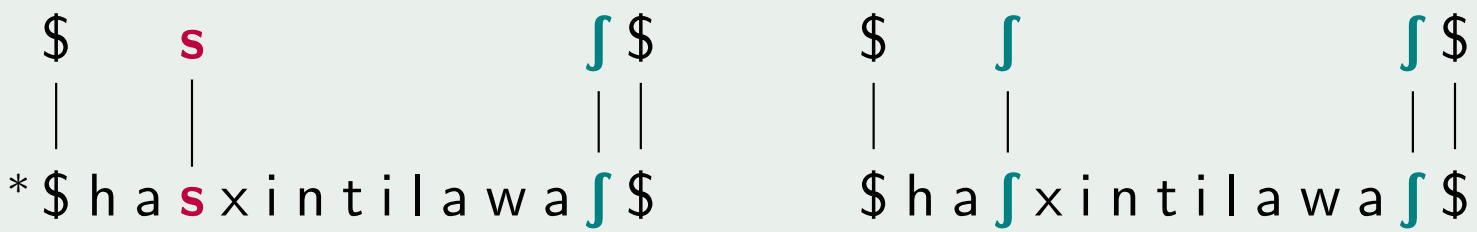

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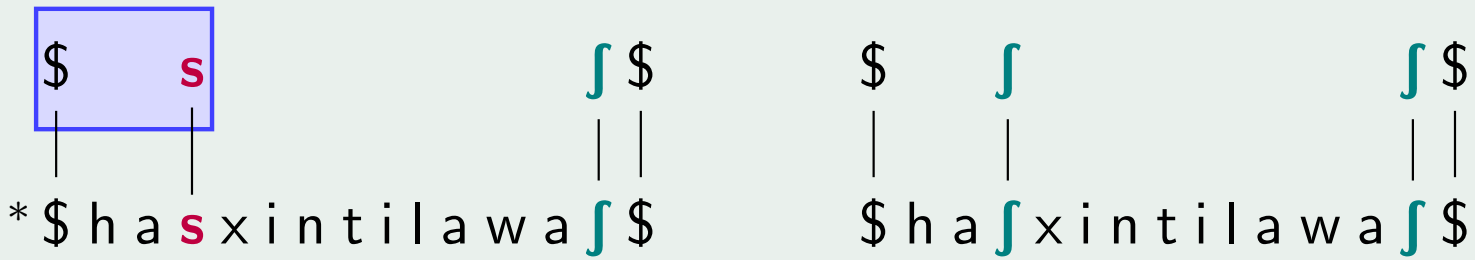

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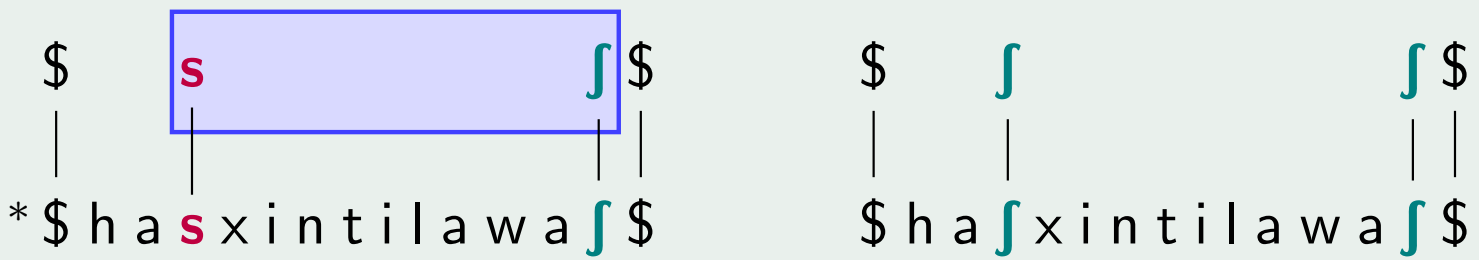

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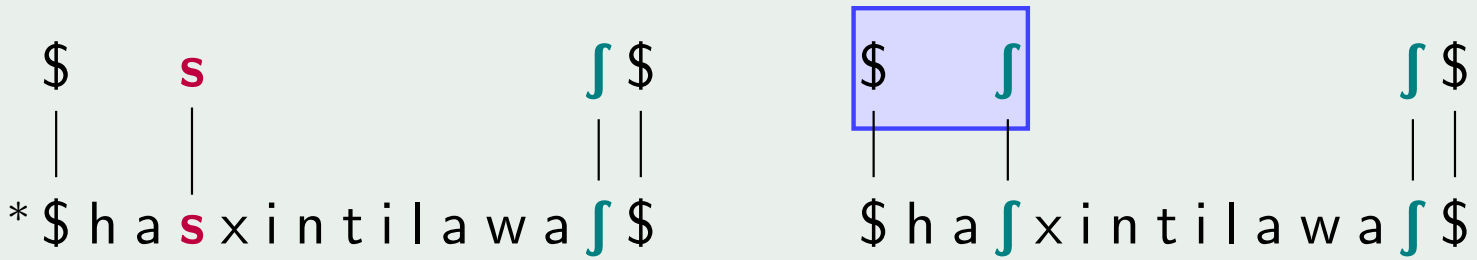

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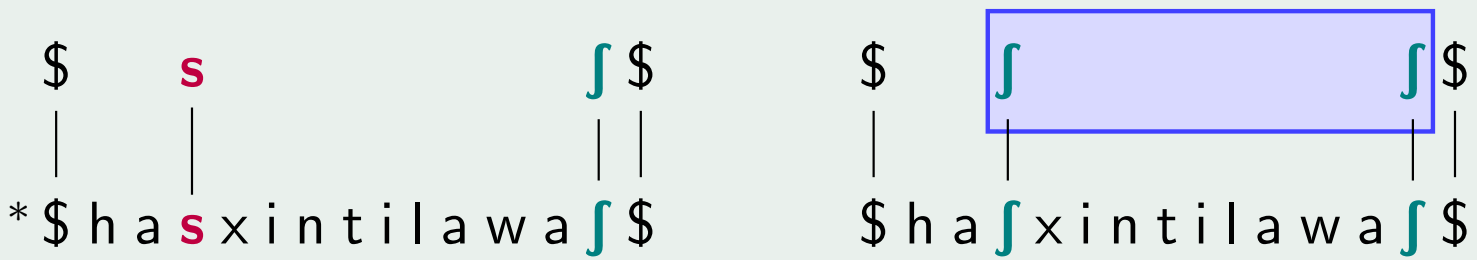

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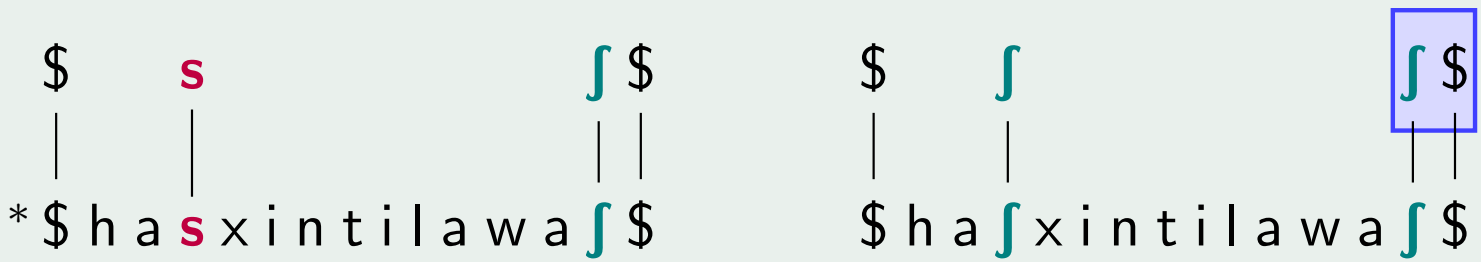

Why is TSL Interesting?

- Linguistically natural
- Correct and very efficient learning algorithm (Jardine and McMullin 2017)
- Low resource demands ⇒ cognitively plausible
- Captures wide range of phonotactic dependencies
- Cannot generate unattested patterns

Example: First-Last Harmony

- Harmony only holds between initial and final segments
- Linguistically plausible, yet unattested

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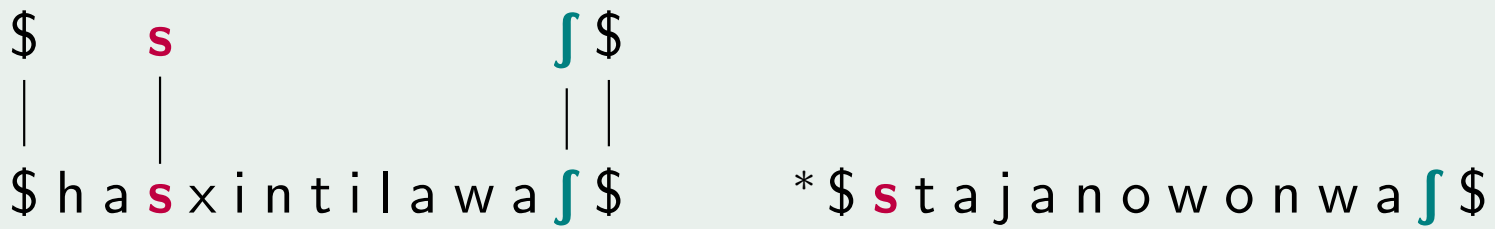

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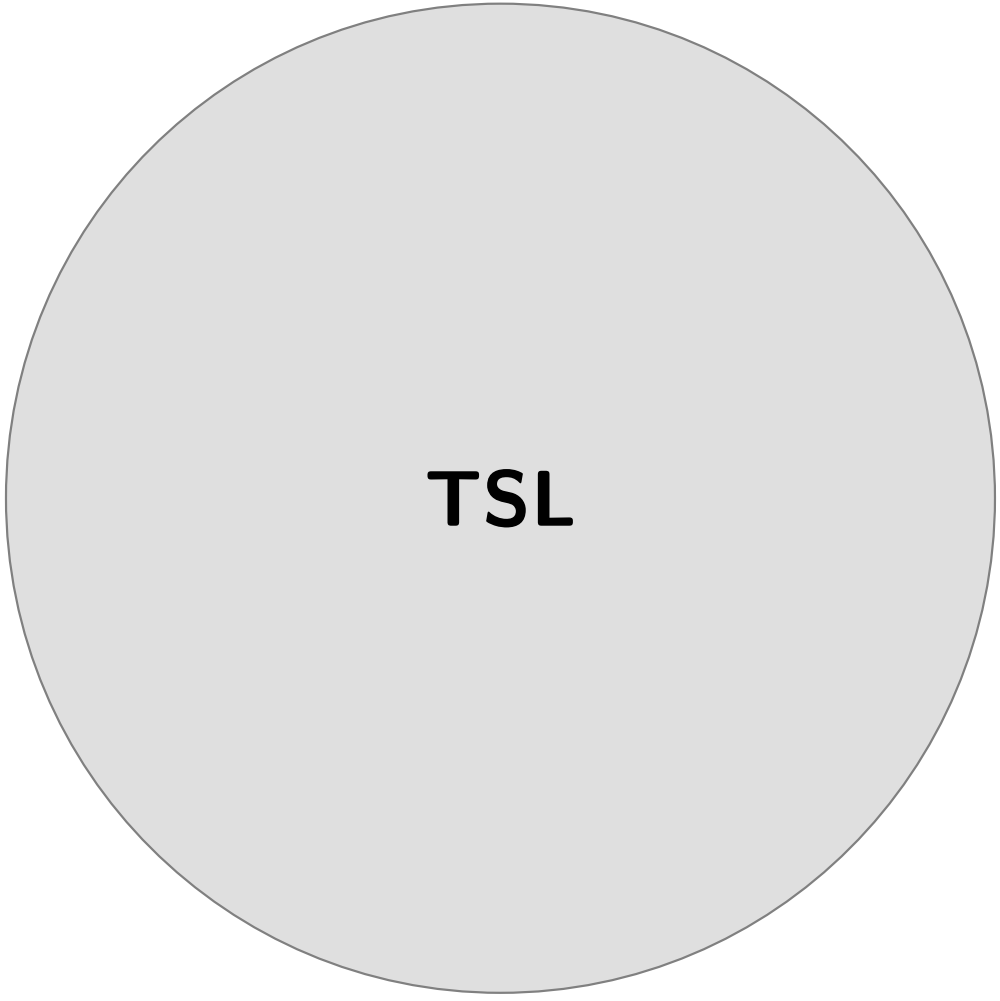

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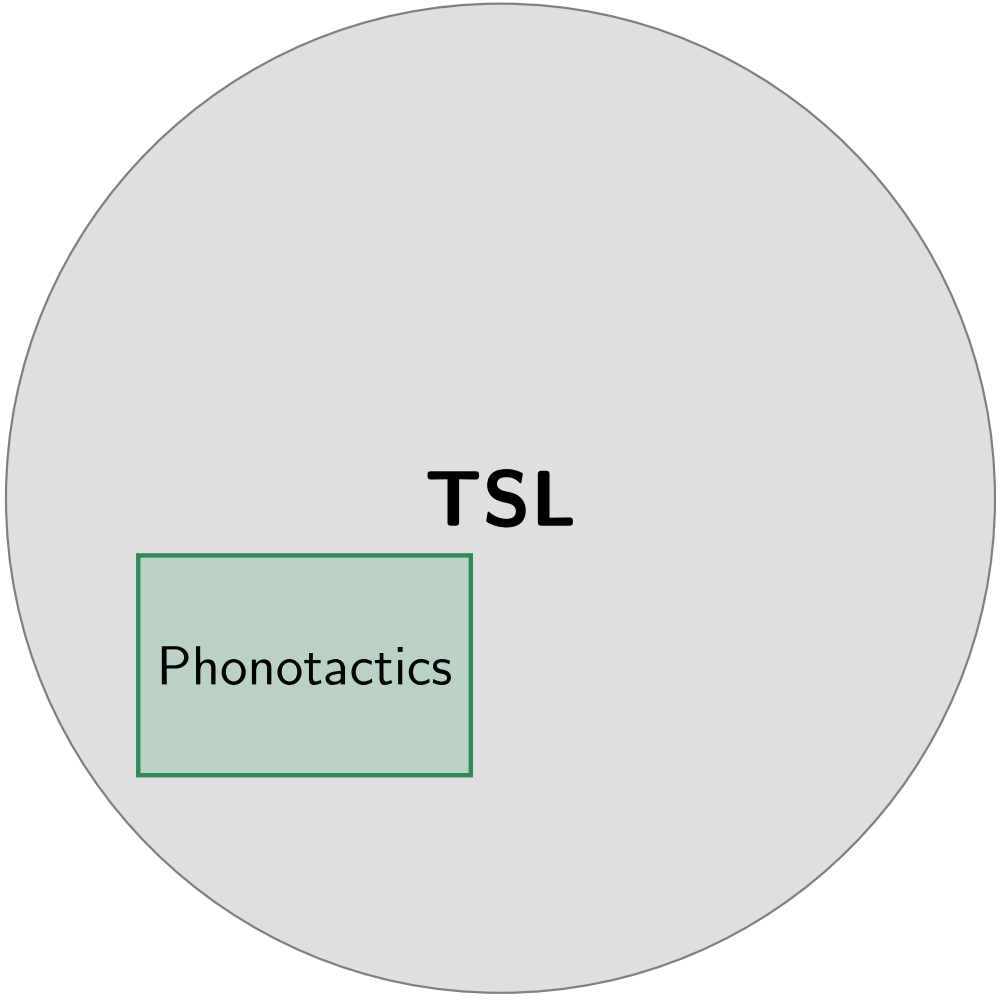

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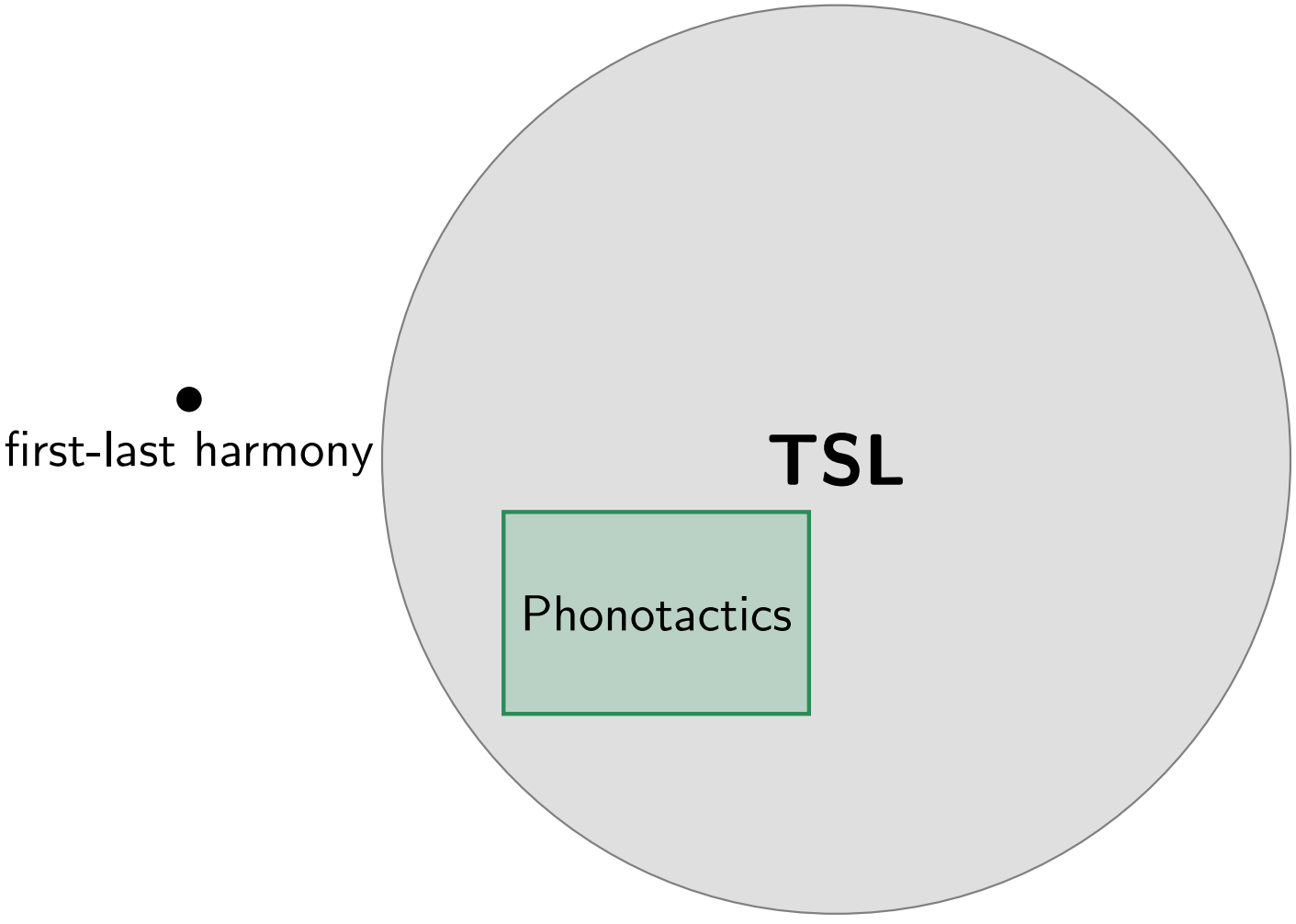

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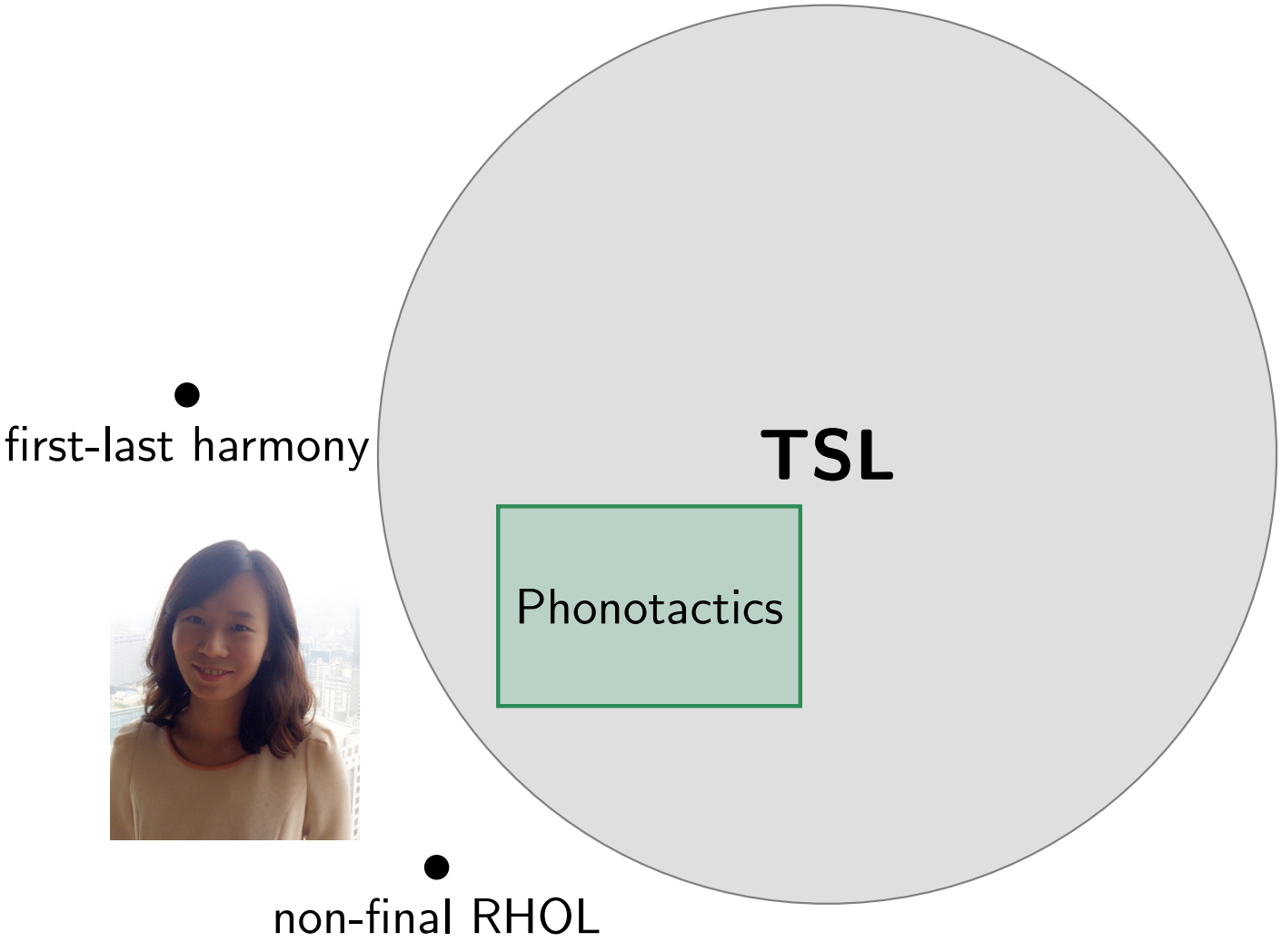

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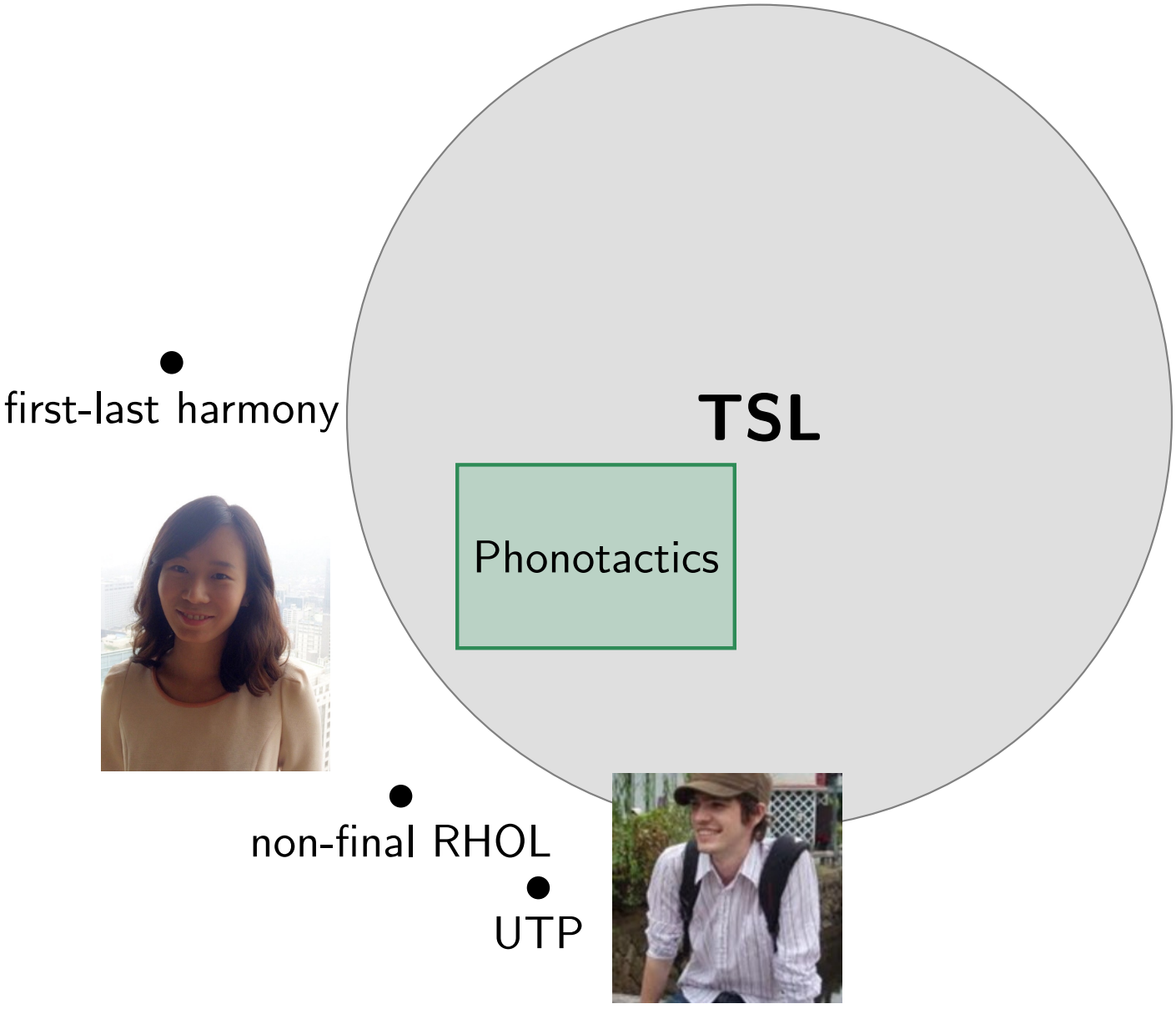

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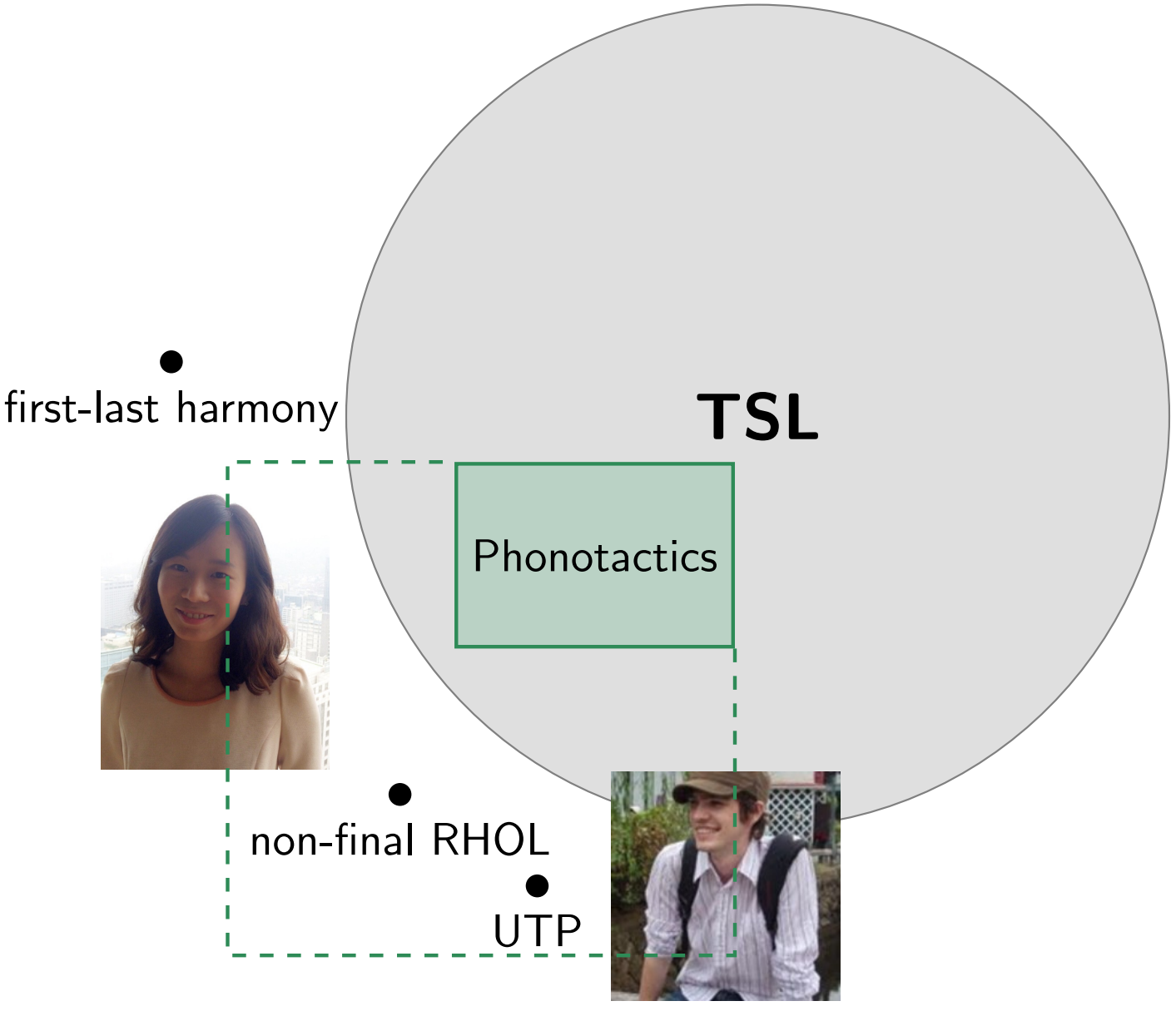

Going Beyond Phonology

TSL provides a good fit for phonological dependencies.

The $\$10^6$ Question

Is TSL also a good fit for other linguistic structures?

- Morphology?
- (Morpho-)Semantics?
- Syntax?

TSL Morphology

Alëna Aksënova

Sophie Moradi

- Joint work with Alëna Aksënova and Sophie Moradi.
- It seems that **morphotactics is also TSL**.
  (Aksënova et al. 2016)

Example: Unbounded *the day after*-Prefixation in German

- German has a prefix **über**.
- This prefix can be freely combined with *morgen* 'tomorrow'.

Example

morgen	tomorrow
über+*morgen*	the day after tomorrow
(**über**+)$^{\mathbf{n}}$*morgen*	(the day after)^{n} tomorrow

TSL Description

Tier: **über**, stem boundary +

Constraint	**Bigrams**
über must be prefix	*+ **über**

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$ **über** **über** + + **über** $
| | | | | | | |
$ **über** **über** + *morgen* + **über** $

Example: Bounded *the day after*-Circumfixation in Ilocano

- Ilocano has a circumfix **ka- -an**.
- This prefix can be combined once with *bigát* 'tomorrow'.

Example

bigát	tomorrow
ka+*bigát*+**an**	the day after tomorrow
*(**ka**)$^{\mathbf{n}}$+*bigát*+(**an**)$^{\mathbf{n}}$	(the day after)^n tomorrow

TSL Description

Tier: *ka*, *an*, stem boundary +

Constraint	Bigrams
ka must be prefix	*+ **ka**
an must be suffix	***an** +
ka before **an**	***an ka**
no iteration	***ka ka**, ***an an**
no lonely affix	***ka** ++ $, *$++ **an**

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$ **an ka ka** + + $
| | | | | | | |
$ **an ka ka** + *bigát* + $

Typological Gap: No Unbounded Circumfixation

- There seems to be no language with an affix that is
  - freely iterable like German **über**, and
  - a circumfix like **ka- -an** in Ilocano.
- Why this gap? Because the **result would not be TSL**!

Explanation

- The pattern would be **ka**^{n}+*bigát*+**an**^{n}.
- TSL cannot memorize exact numbers.
- All affixes would have to be visible in the same search window.
- But the window's size is bounded, while the pattern is not.

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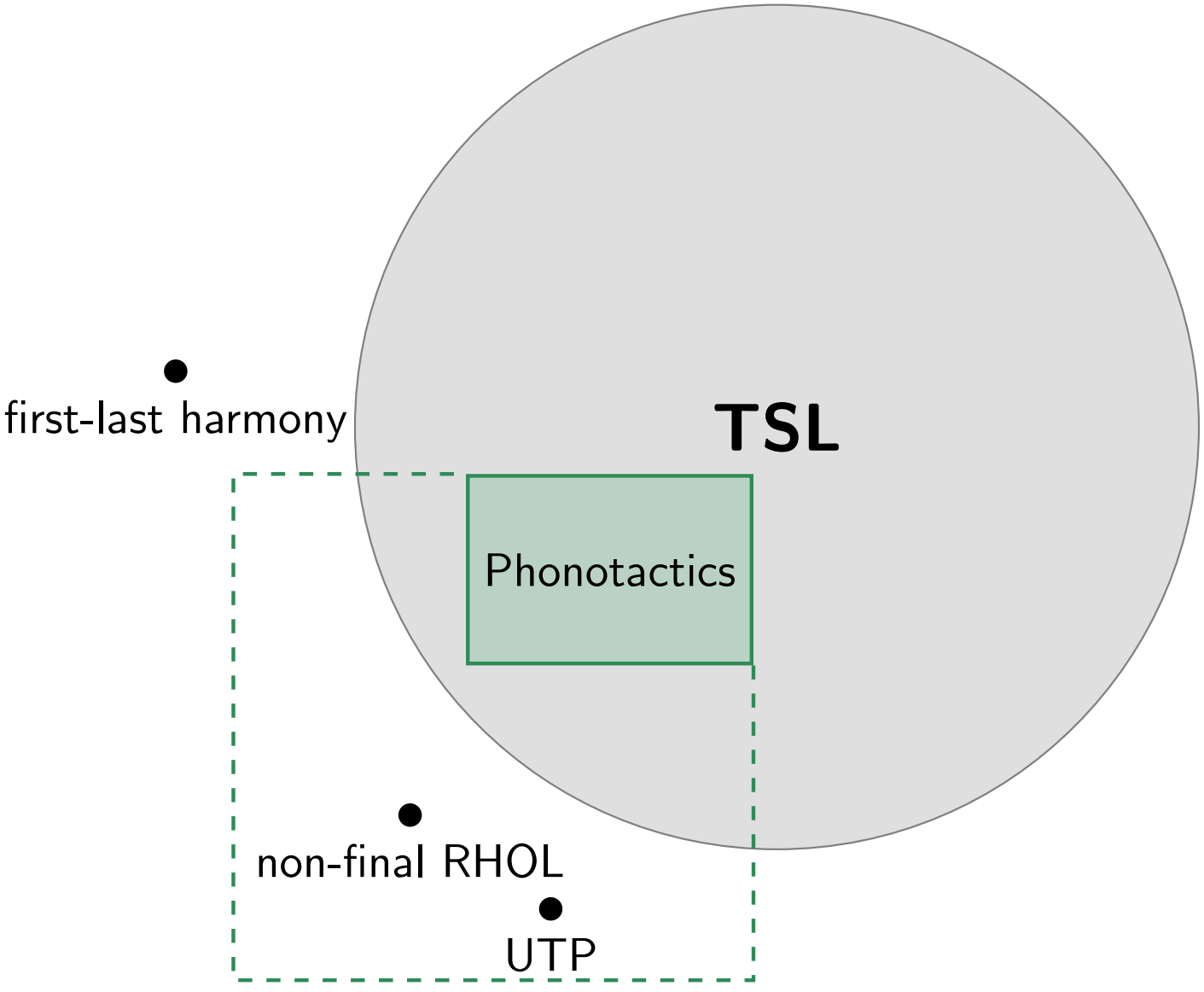

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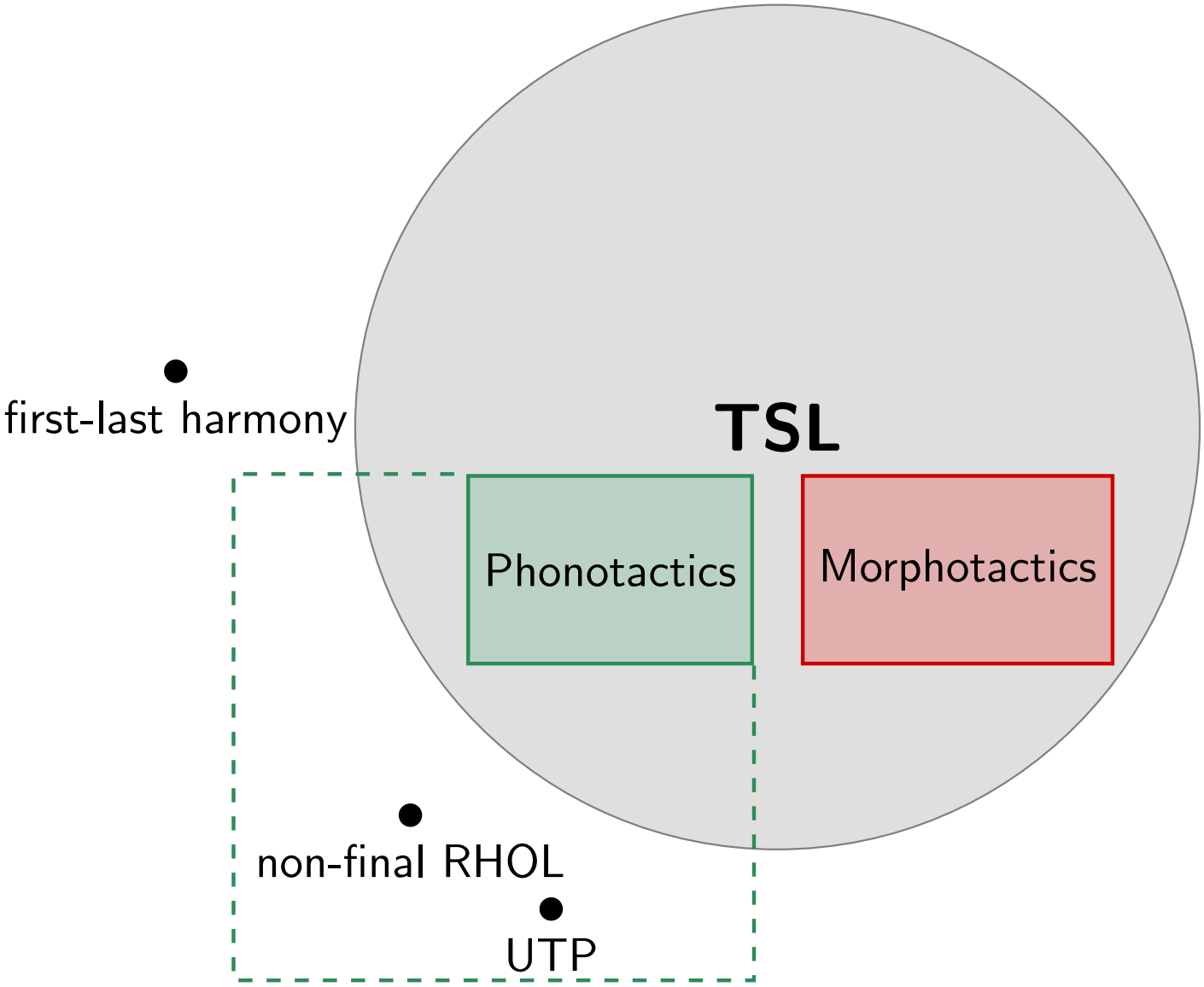

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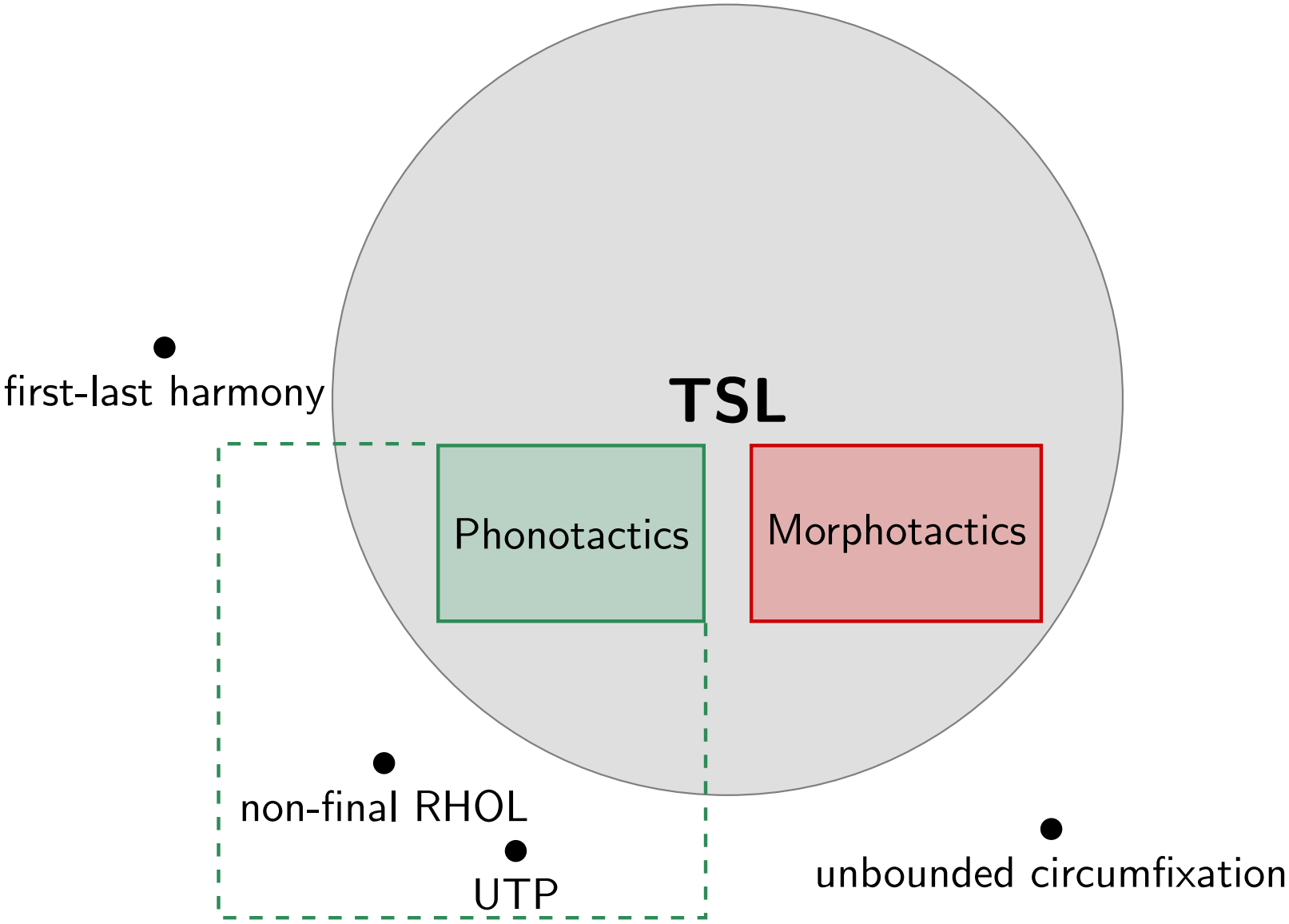

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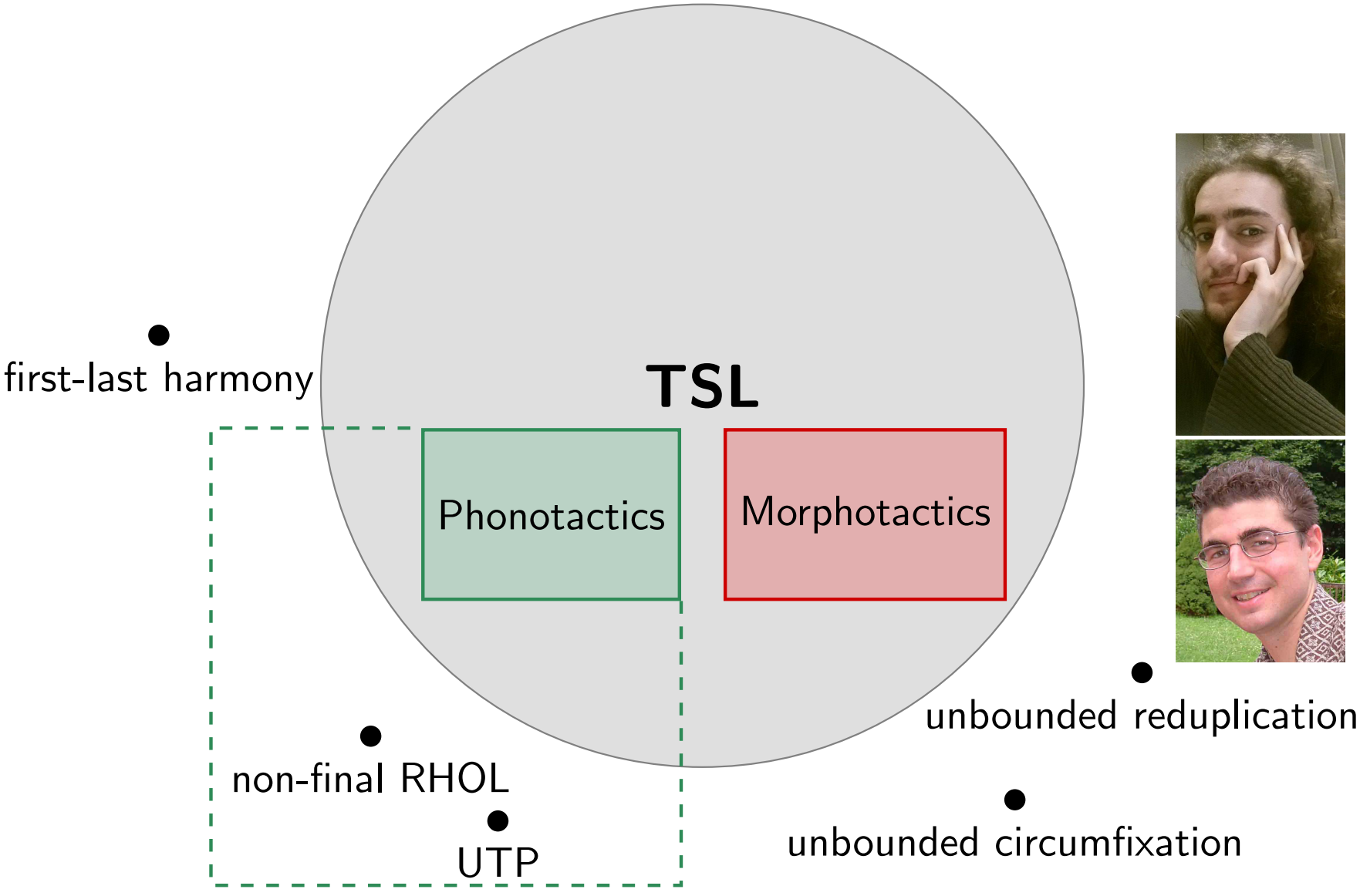

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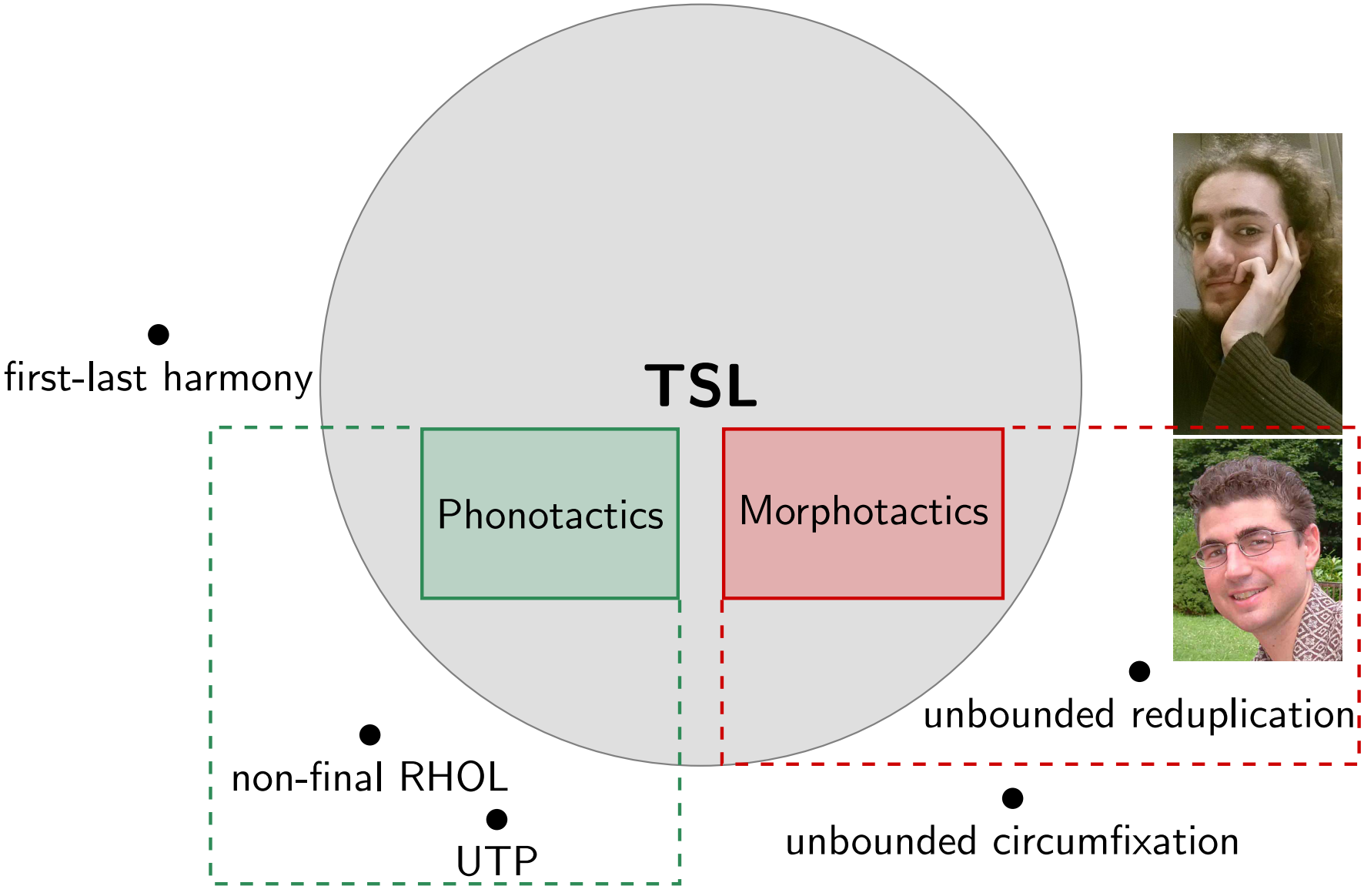

TSL Morpho-Semantics?

The importance of TSL for word structure seems to extend even into semantics.

Case Study: Generalized Quantifiers (Graf 2017d)

A generalized quantifier may have a monomorphemic realization only if its quantifier language is TSL.

Quantifier Languages (van Benthem 1986)

(1) a. Every student cheated.
b. No student cheated.
c. Some student cheated.
d. Three students cheated.

students	John	Mary	Sue
cheated	yes	no	yes
string	Y	N	Y

- (1a): **False**, because the string contains a N
- (1b): **False**, because the string contains a Y
- (1c): **True**, because the string contains a Y
- (1d): **False**, because the string does not contain three Ys

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TSL Grammars for Quantifier Languages

Quantifier	Constraint	n-grams	Tier
every	$\lvert \mathsf{N} \rvert = 0$	*N	none
no	$\lvert \mathsf{Y} \rvert = 0$	*Y	none
some	$\lvert \mathsf{Y} \rvert \geq 1$	*$$	Y
at least **n**	$\lvert \mathsf{Y} \rvert \geq \mathbf{n}$	*1^{\mathbf{m}}$$ ($\mathbf{m} < \mathbf{n}$)	Y
at most **n**	$\lvert \mathsf{Y} \rvert \leq \mathbf{n}$	*Y$^{\mathbf{n}+1}$	Y

Example

$	Y		Y	$
|	|		|	|
$	Y	N	Y	$

some	*$$	**True**
at least 2	*$$, *Y	**True**
at least 3	*$$, *Y, *YY	**False**
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Overview of Quantifier Languages

If a quantifier language is **not TSL**,
then its quantifier **cannot be monomorphemic** in any language.

(Paperno 2011)

Quantifier	TSL?	Tier	Mono.
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no	yes	none	yes
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(at least) two	yes	Y	yes
(at most) two	yes	Y	yes
not all	yes	N	no
all but one	yes	N	no
even number	no		no
prime number	no		no
infinitely many	no		no
most	no		???

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The Case of *most*

There is good semantic evidence that "most" is internally complex and hence **not monomorphemic**. (Hackl 2009)

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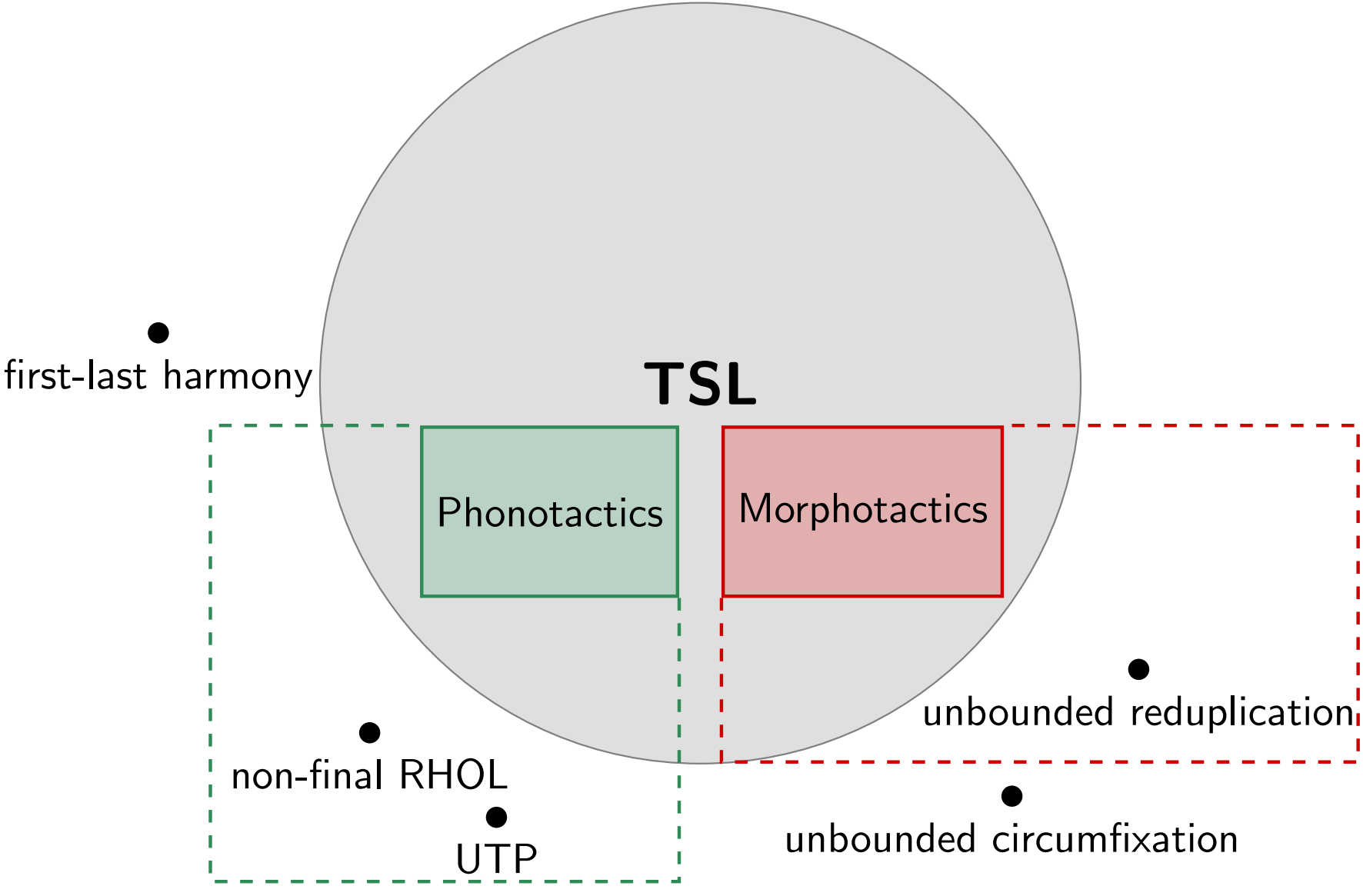

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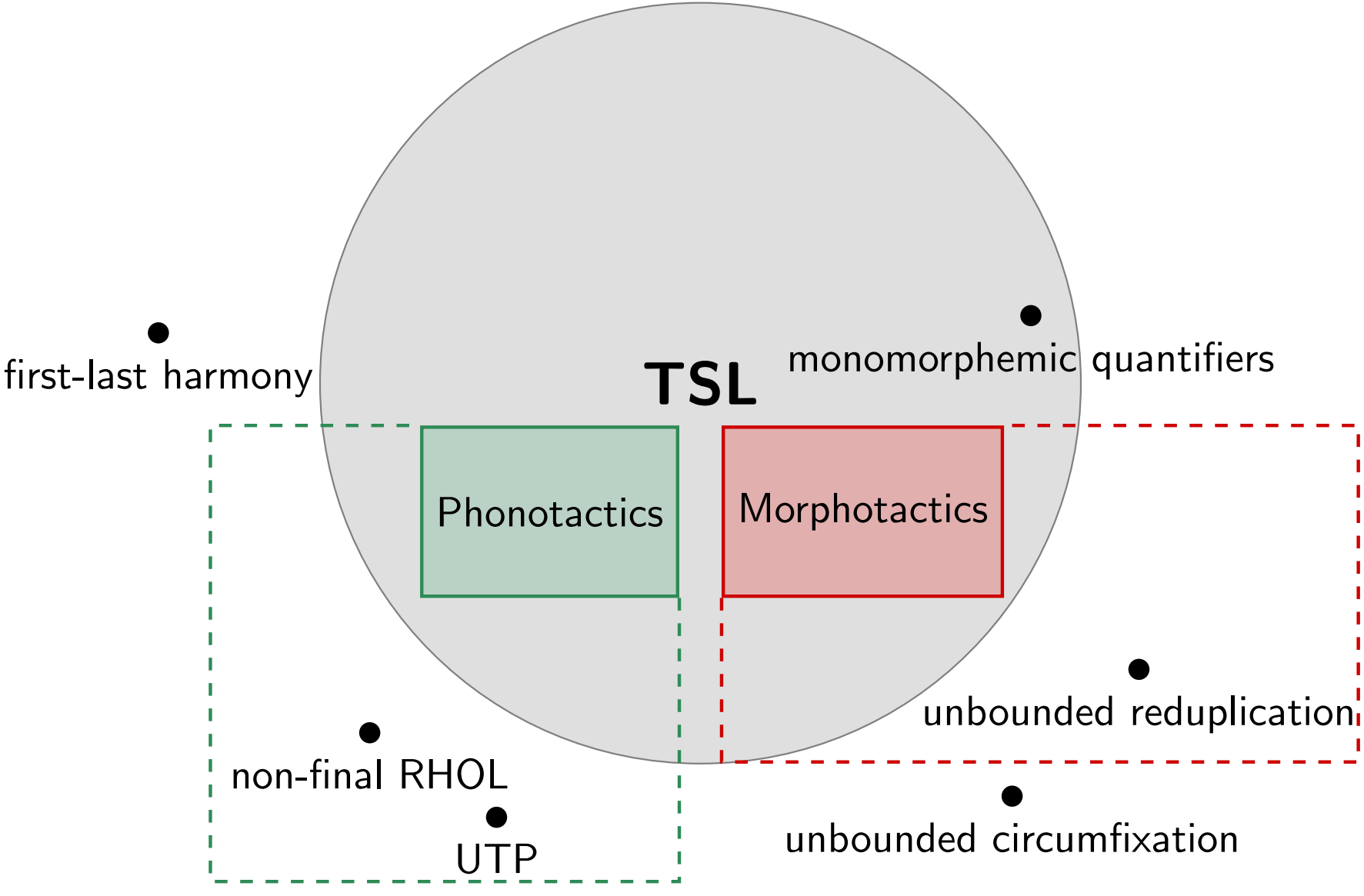

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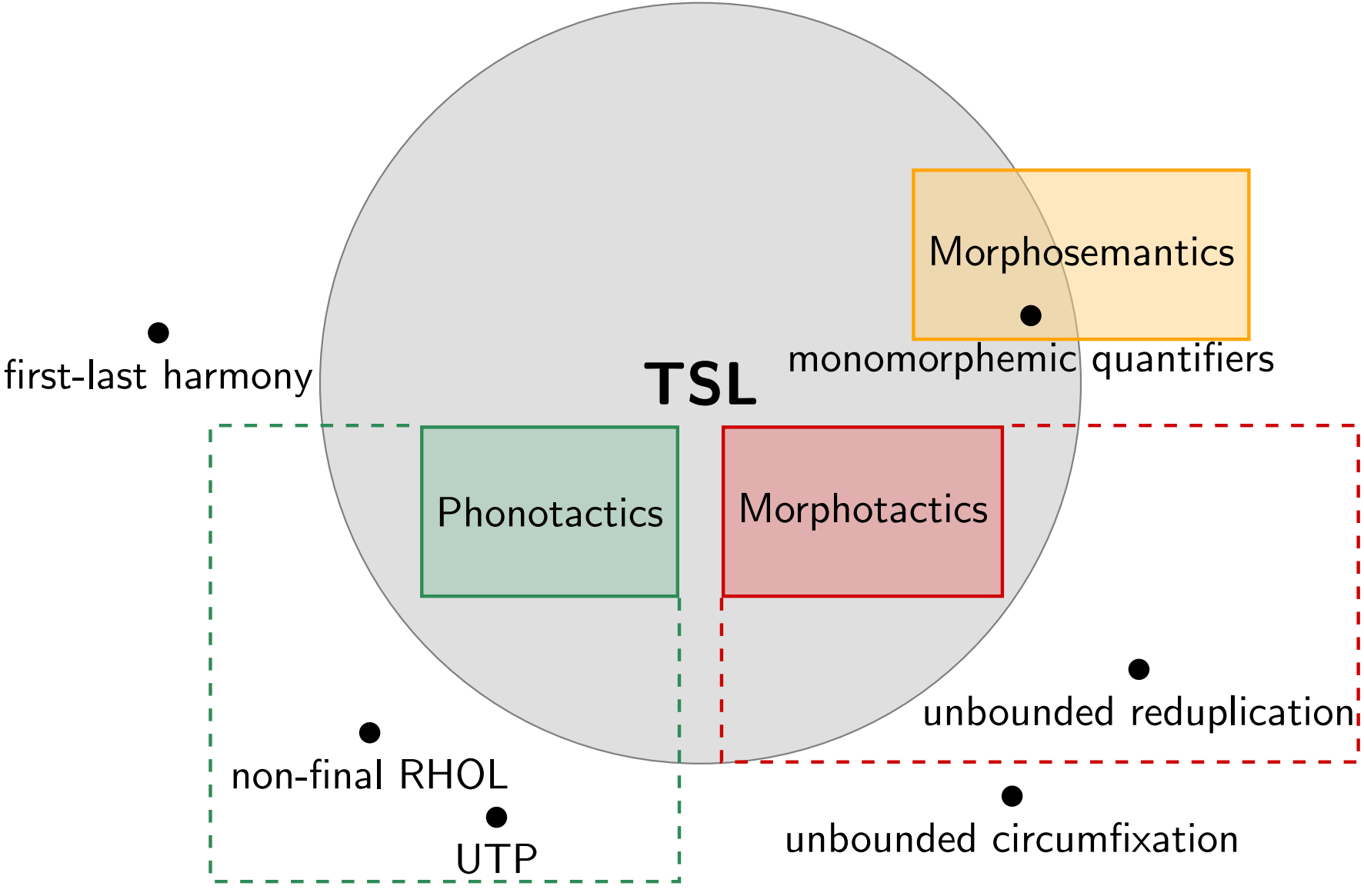
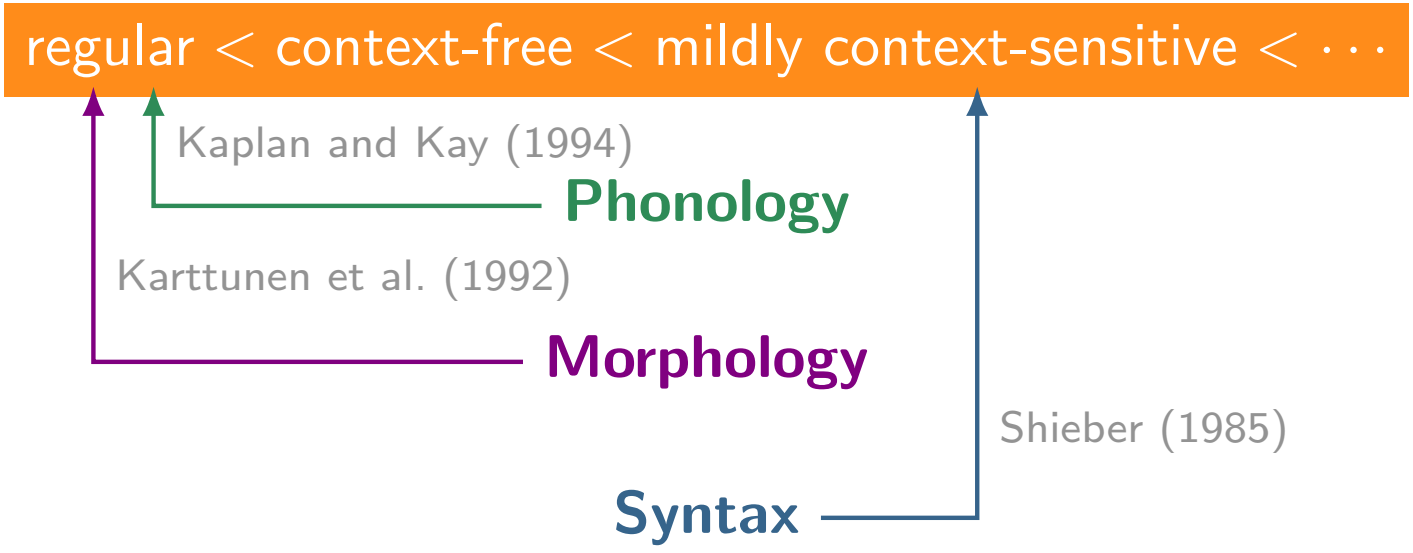


Against the Received View



- This is about strings.
- Syntax is about **trees**!

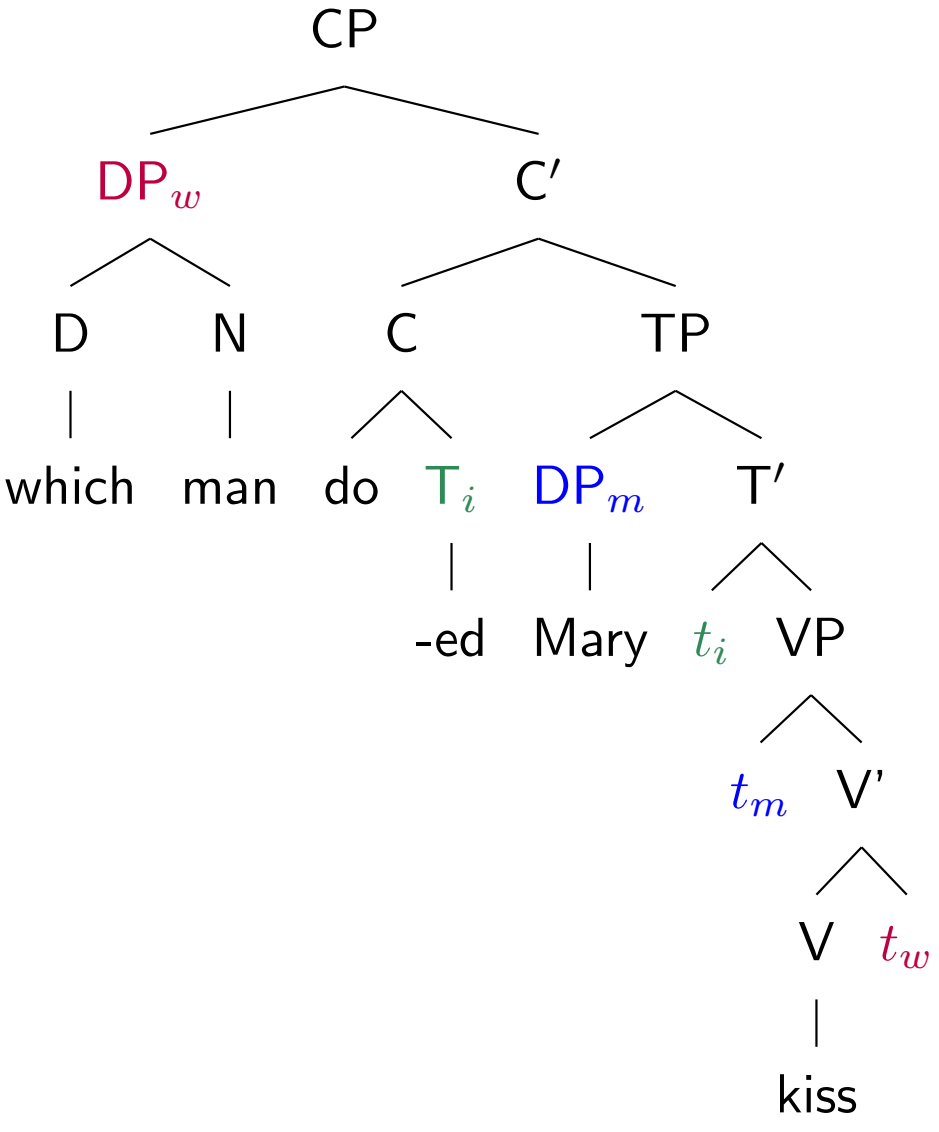
Minimalist Grammars

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

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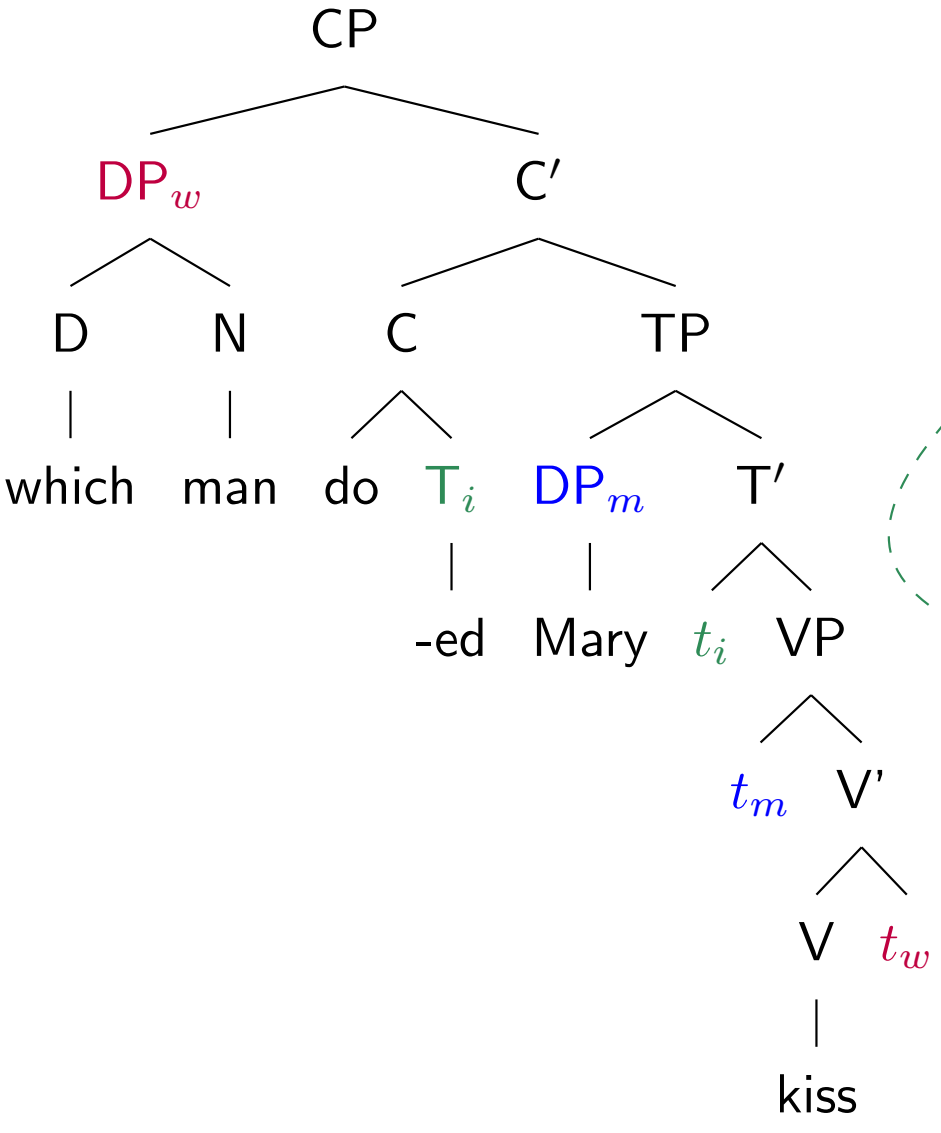

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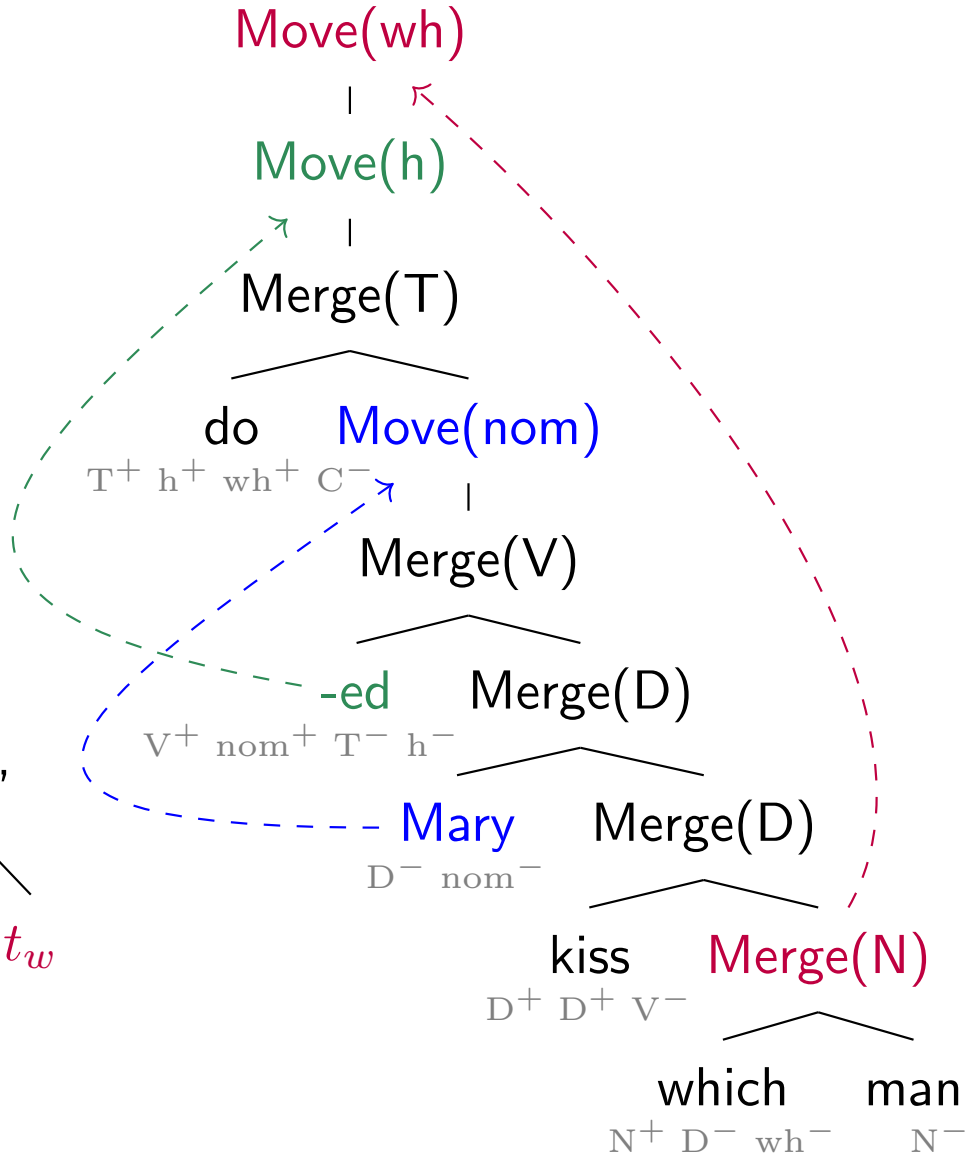
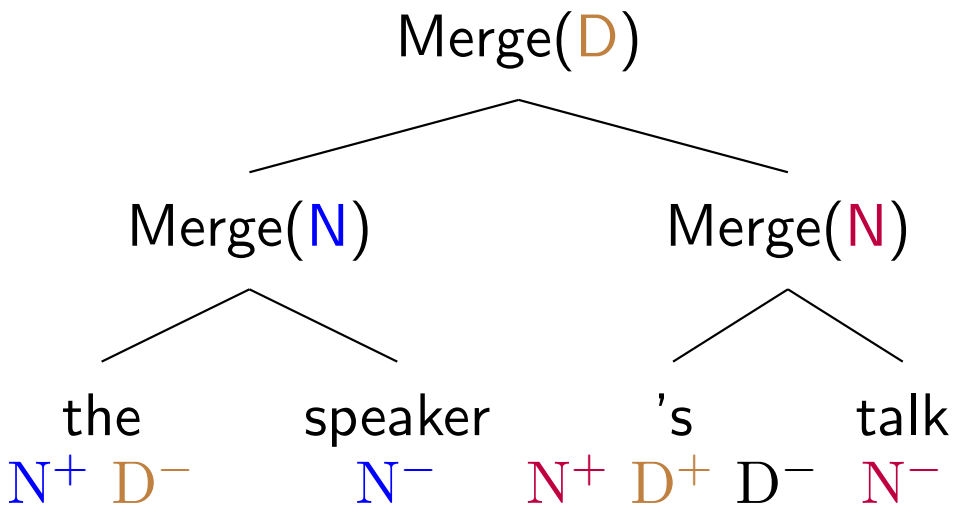


Derivation Tree

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

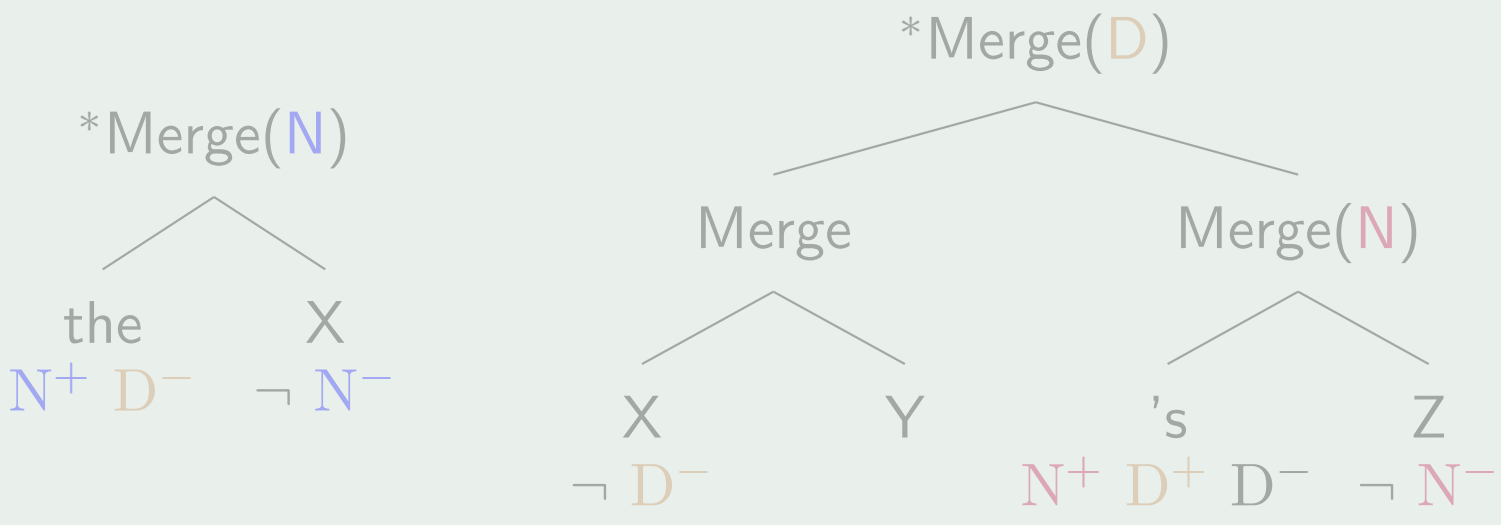


- The selector features of the head have to match the category features of the arguments.
- Since every head has a bounded number of arguments, the **distance between those features is bounded**.
- So Merge establishes only local dependencies.

SL Grammar for Merge

- We need to lift string n-grams to **tree n-grams**.
- Instead of strings of length n, use subtrees of depth n.
- Each subtree encodes a constraint on the derivation.

Example



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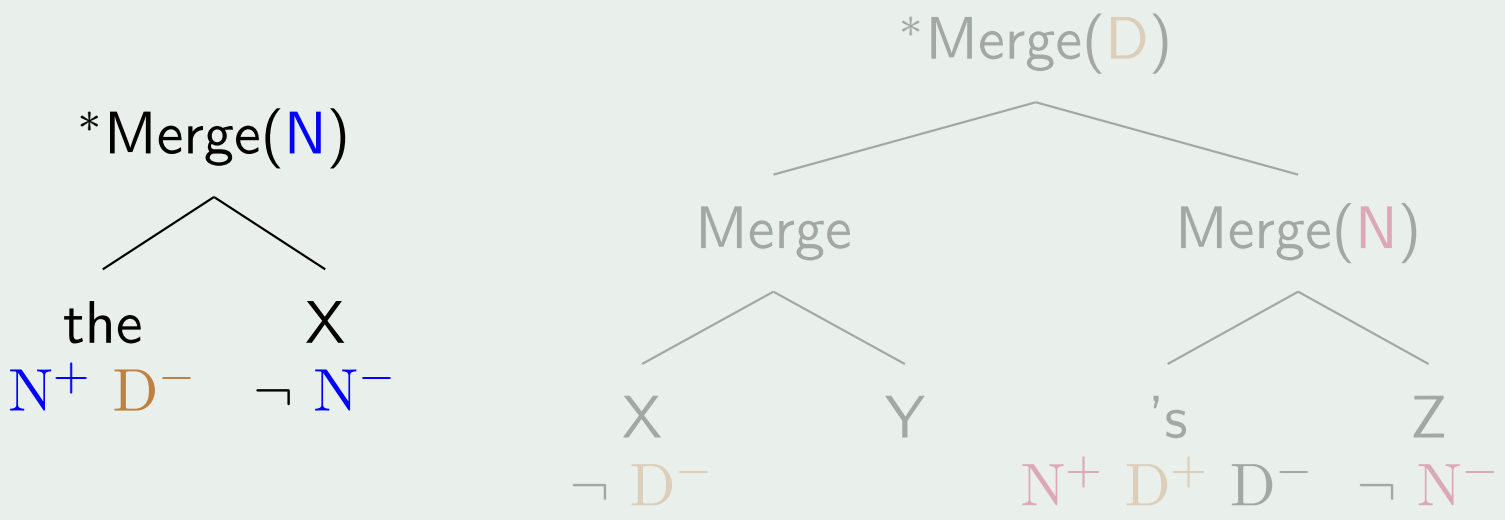

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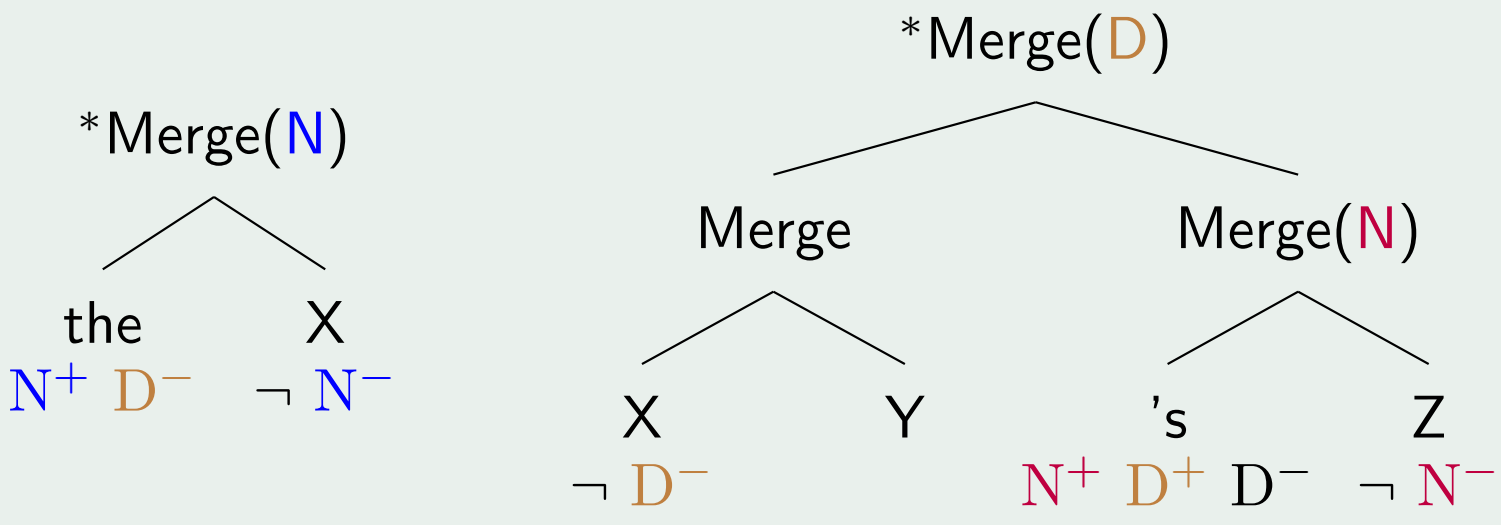
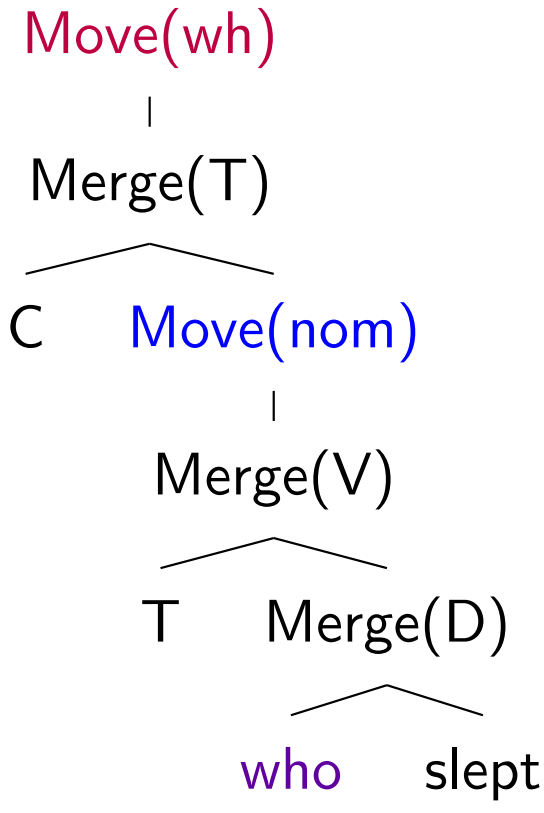


Move: Single Movement Normal Form

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



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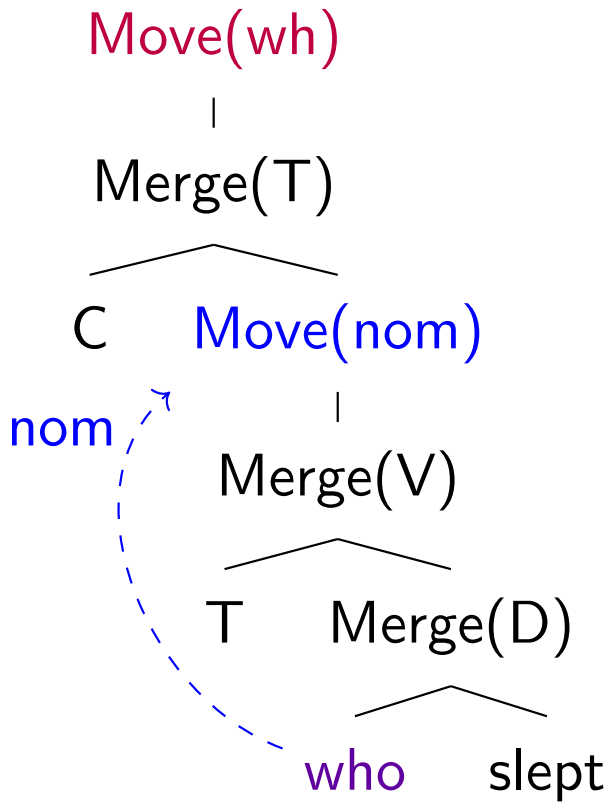

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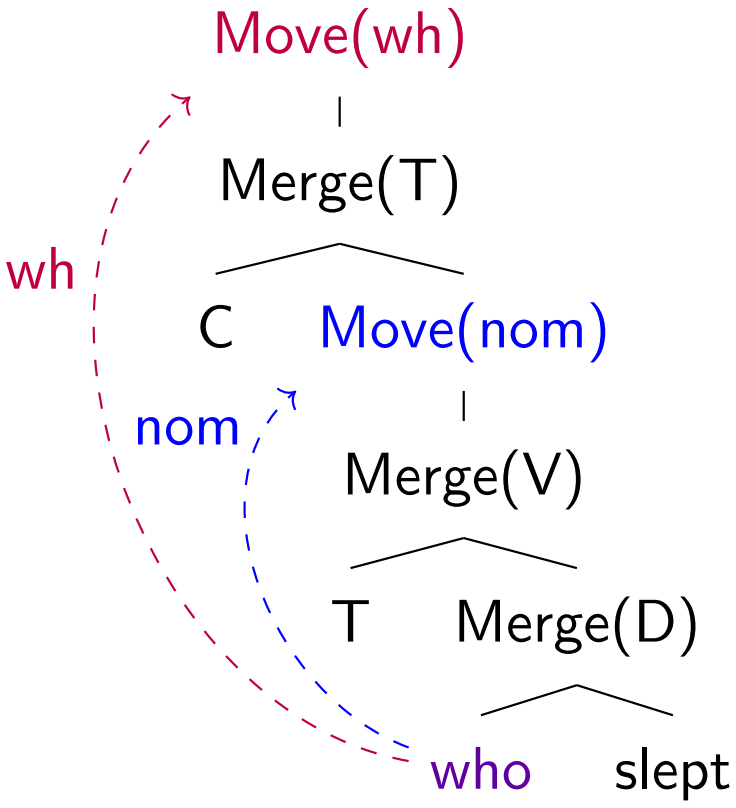

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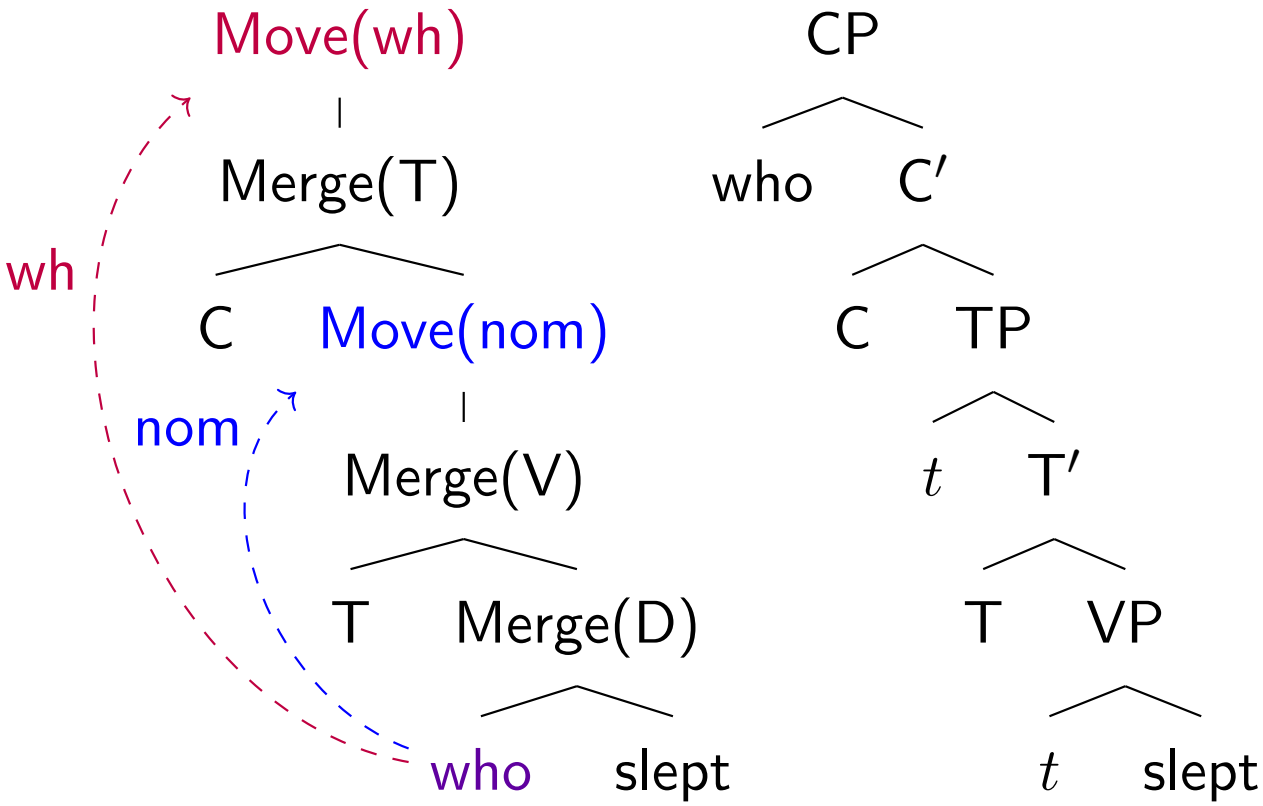

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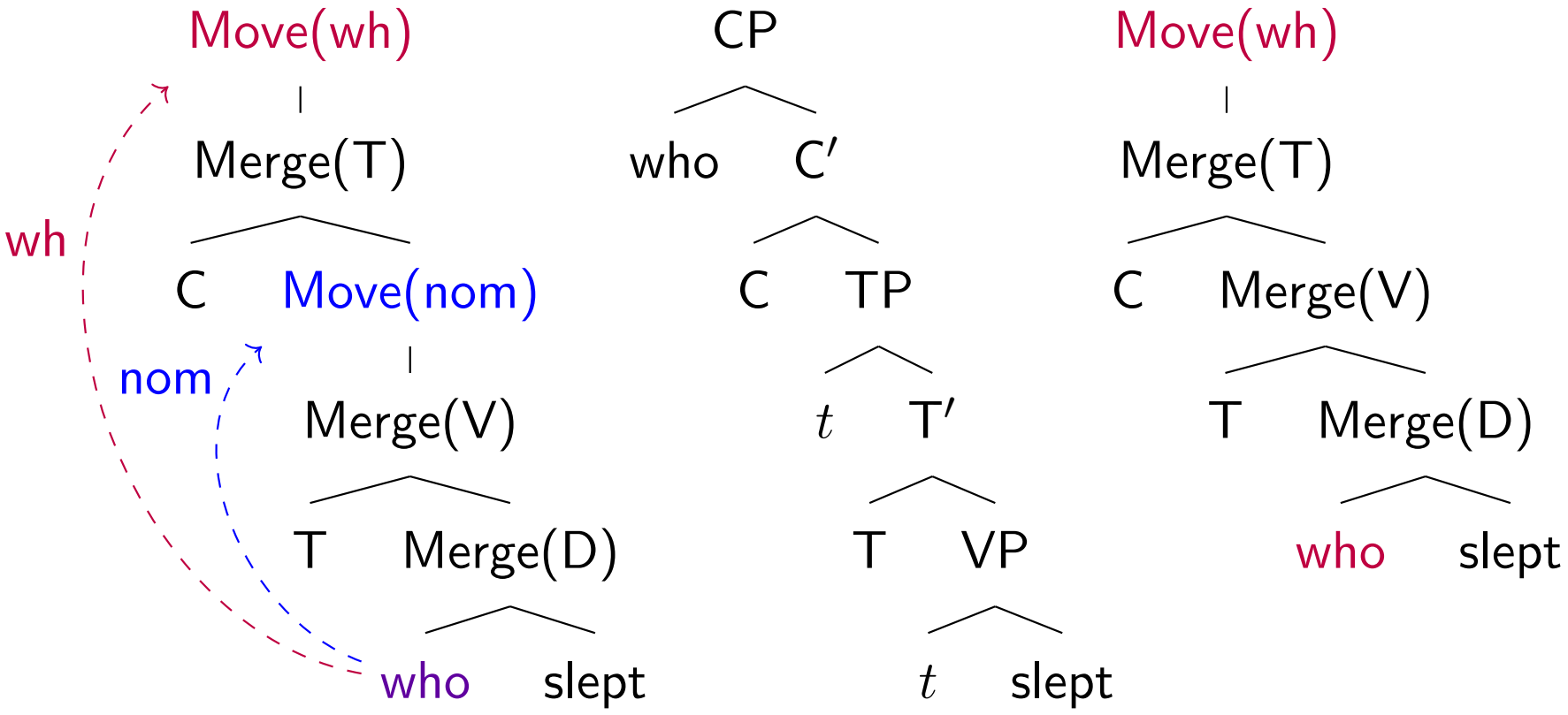

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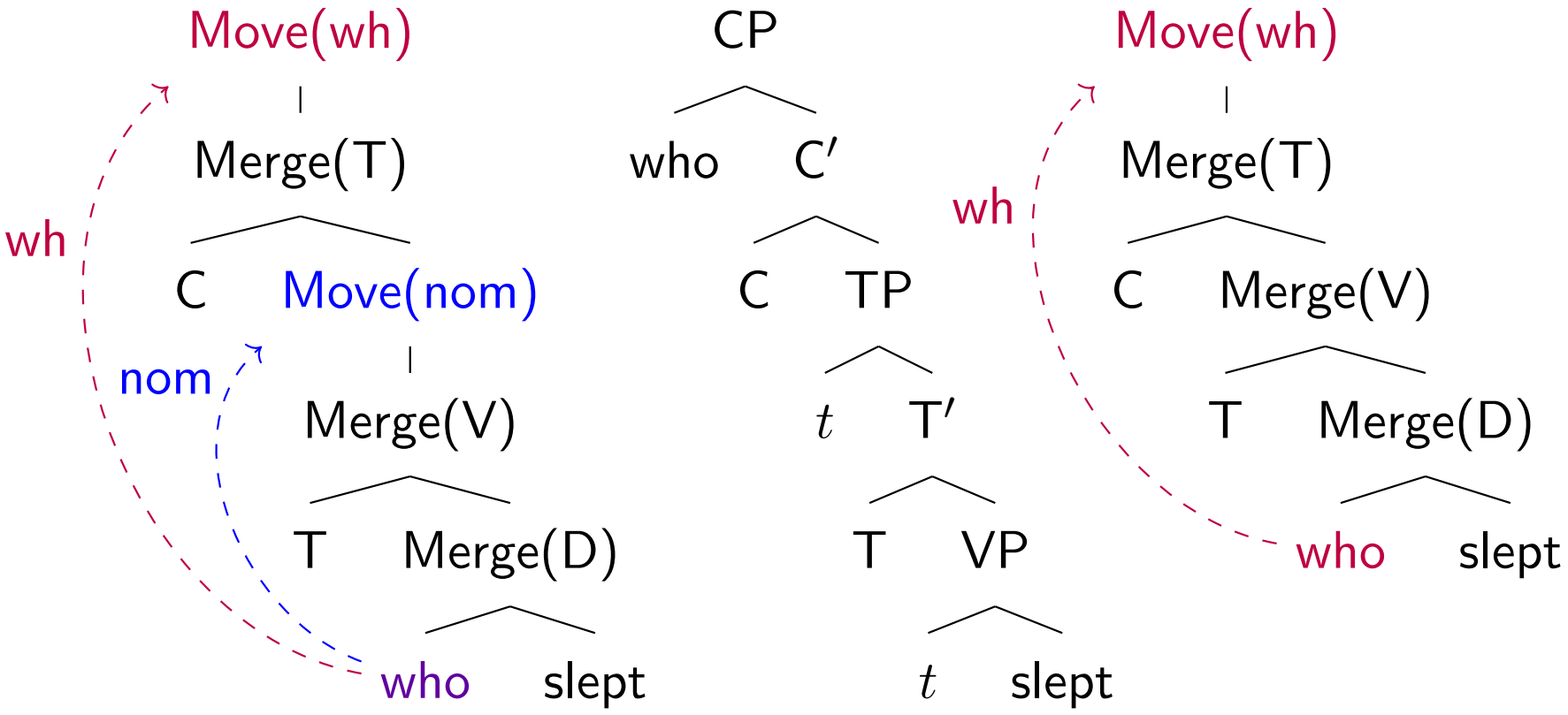

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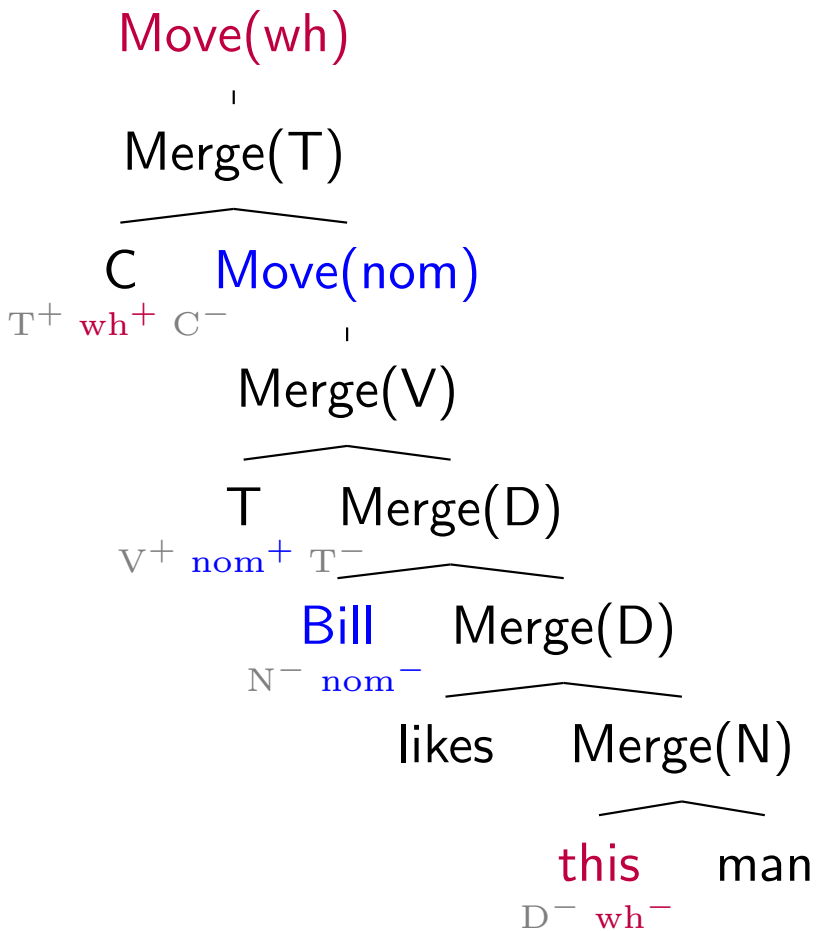
- But maybe it is still TSL?



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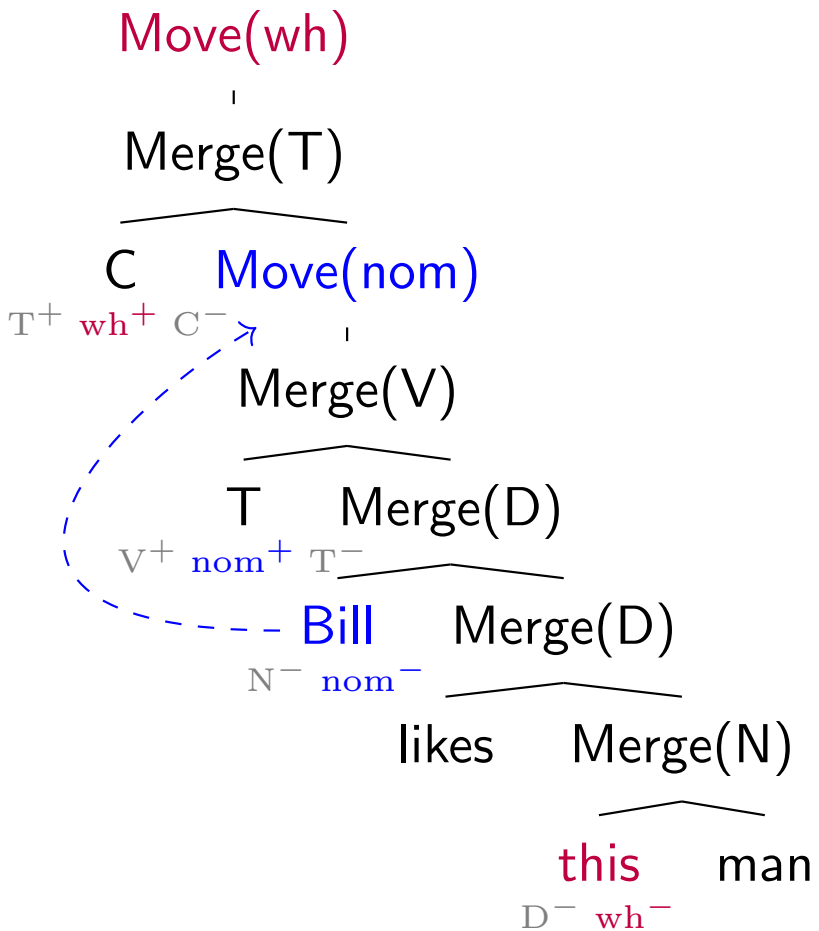

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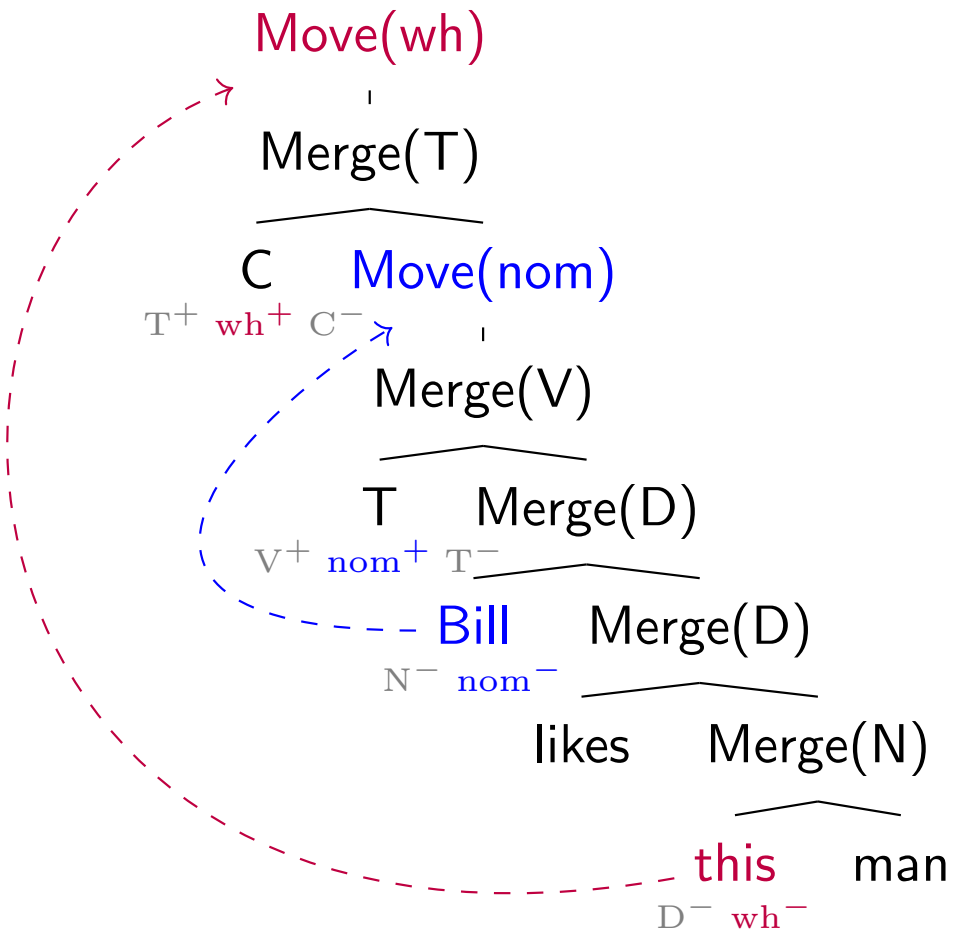

Move Tiers

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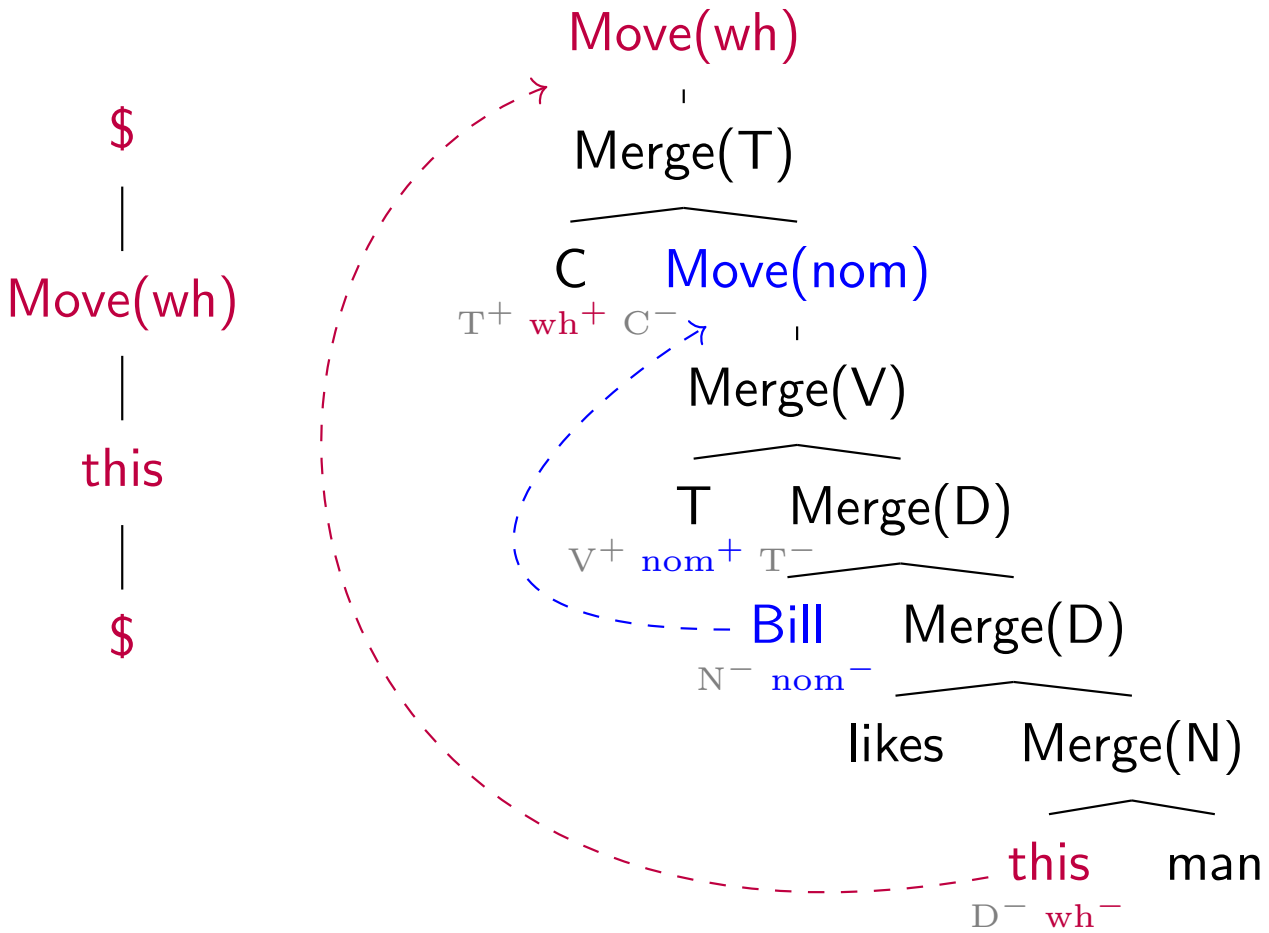

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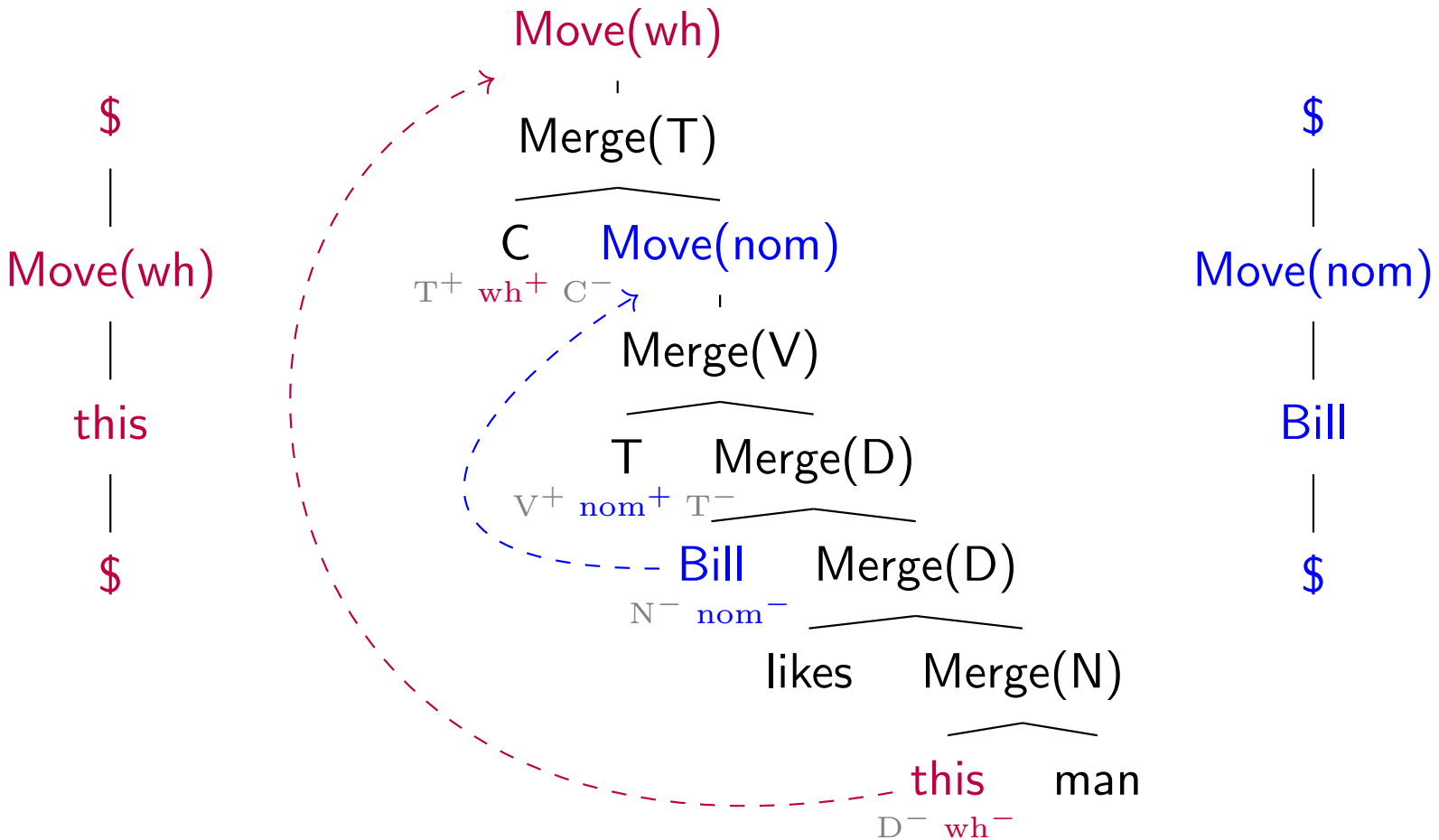
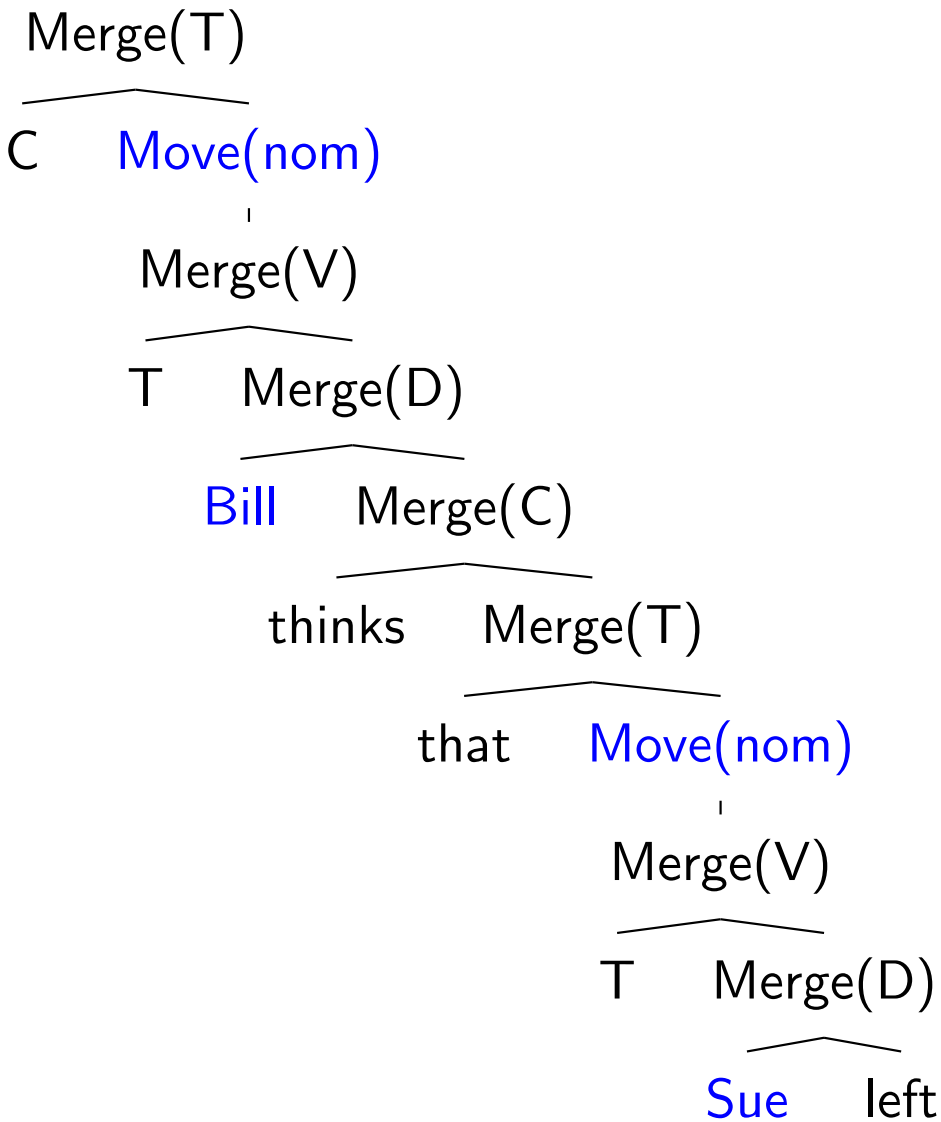


A Tier With Multiple Movers



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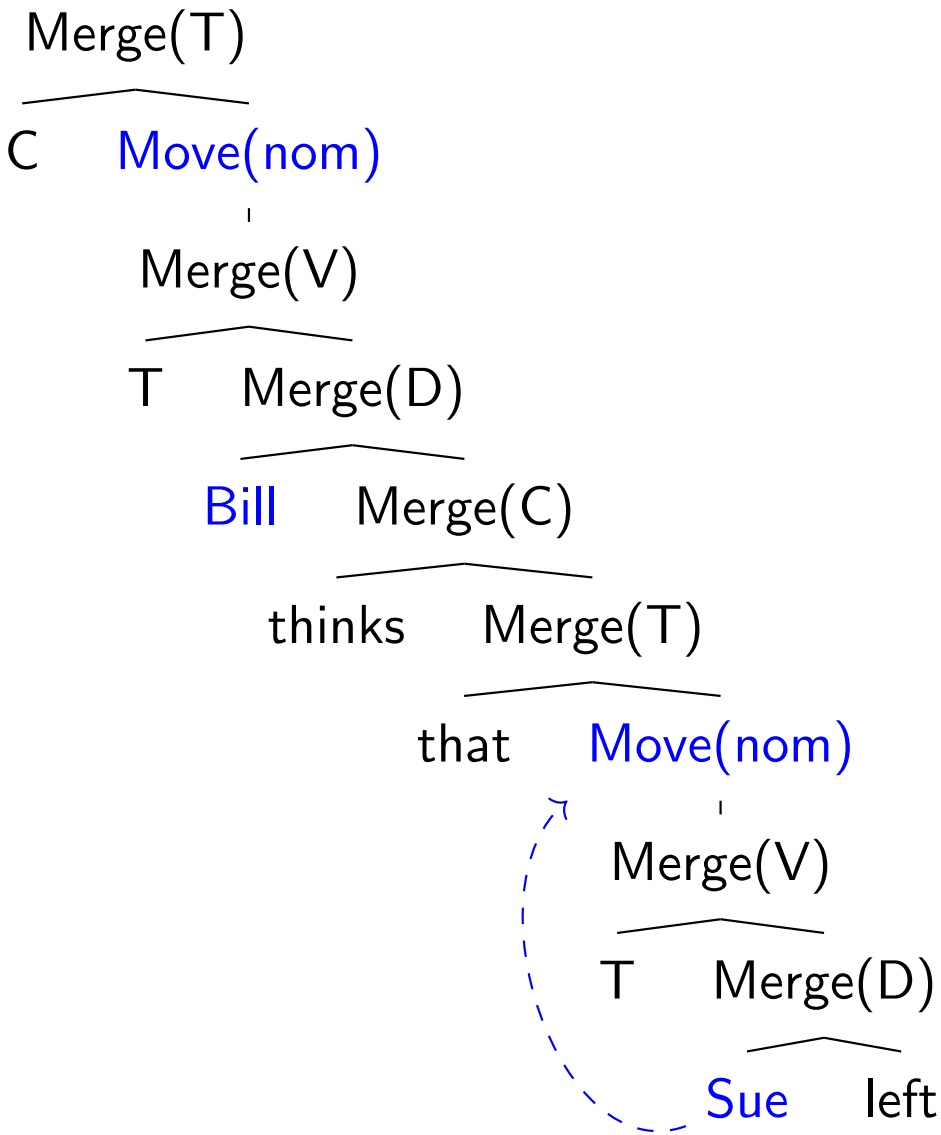

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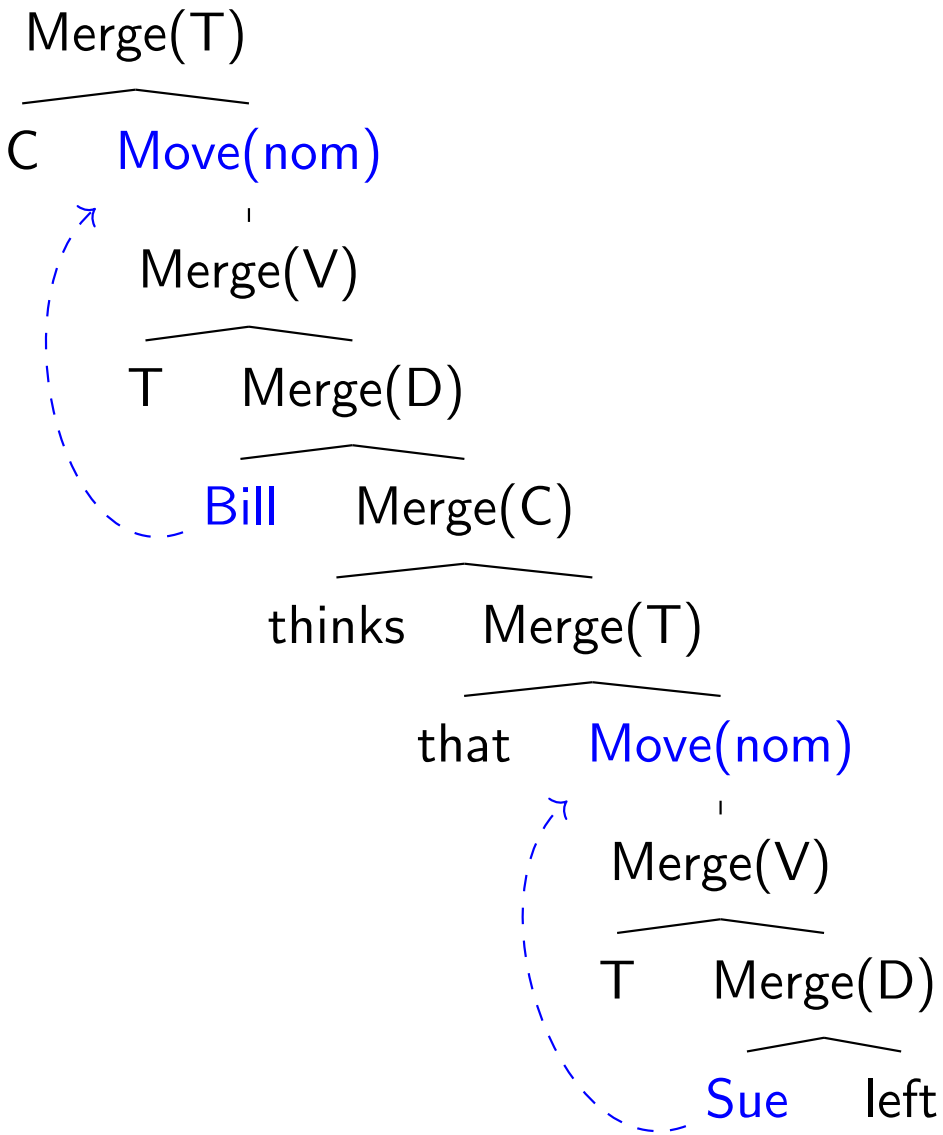

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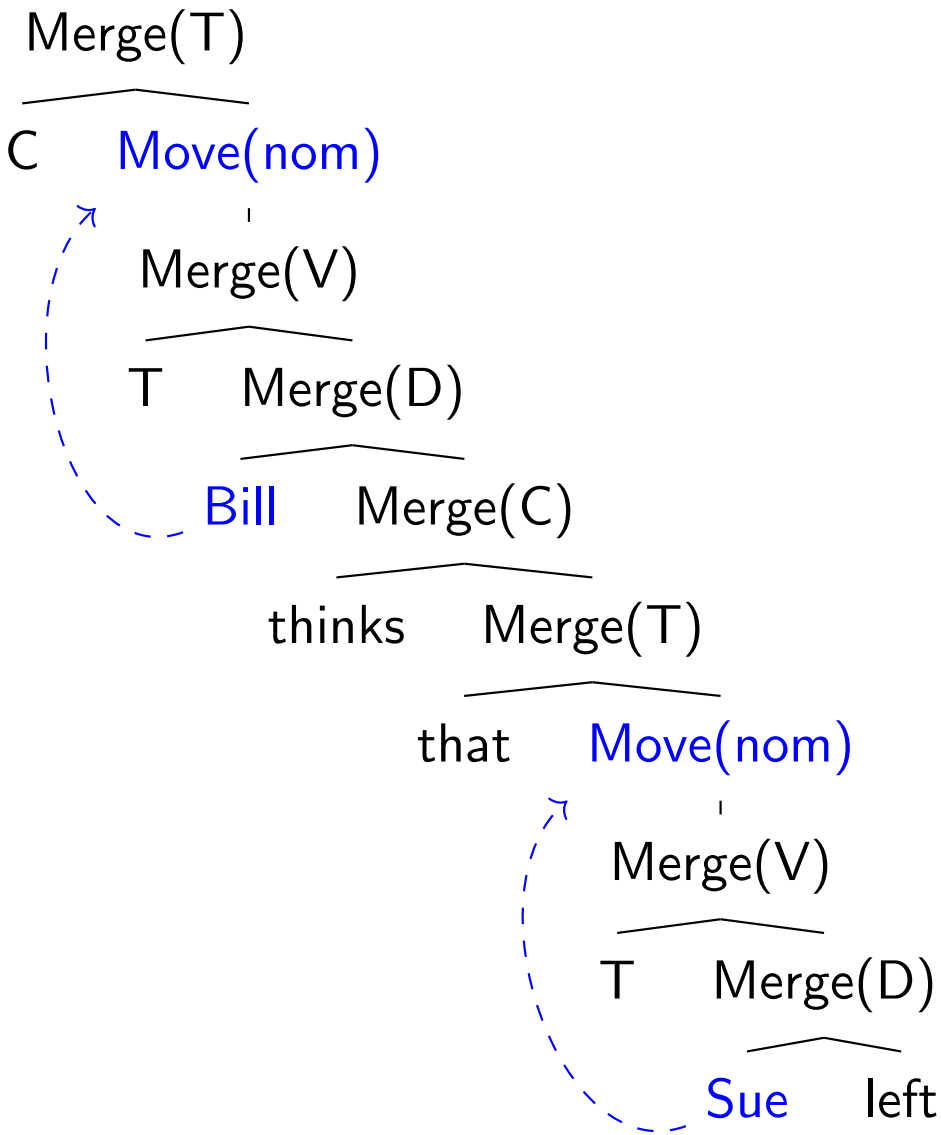
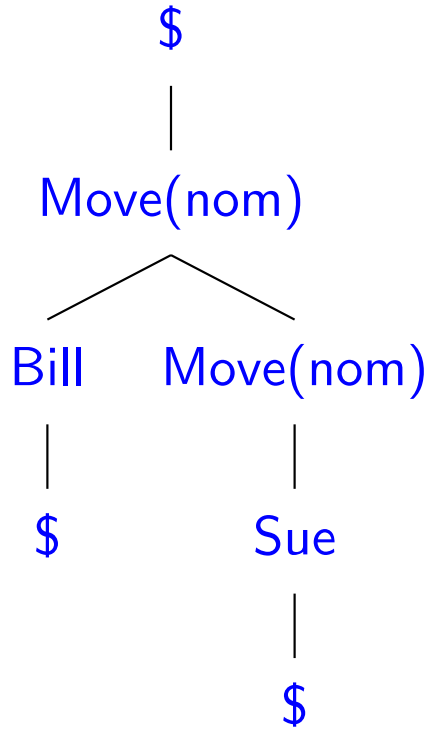
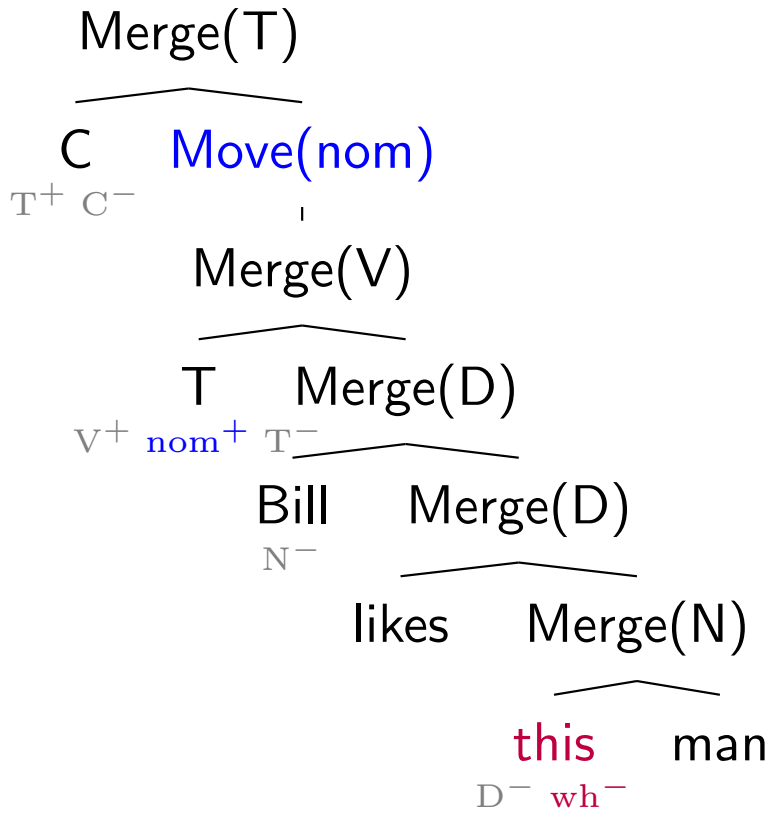




Blocking Simple Cases of Illicit Movement



TSL Grammar for Move

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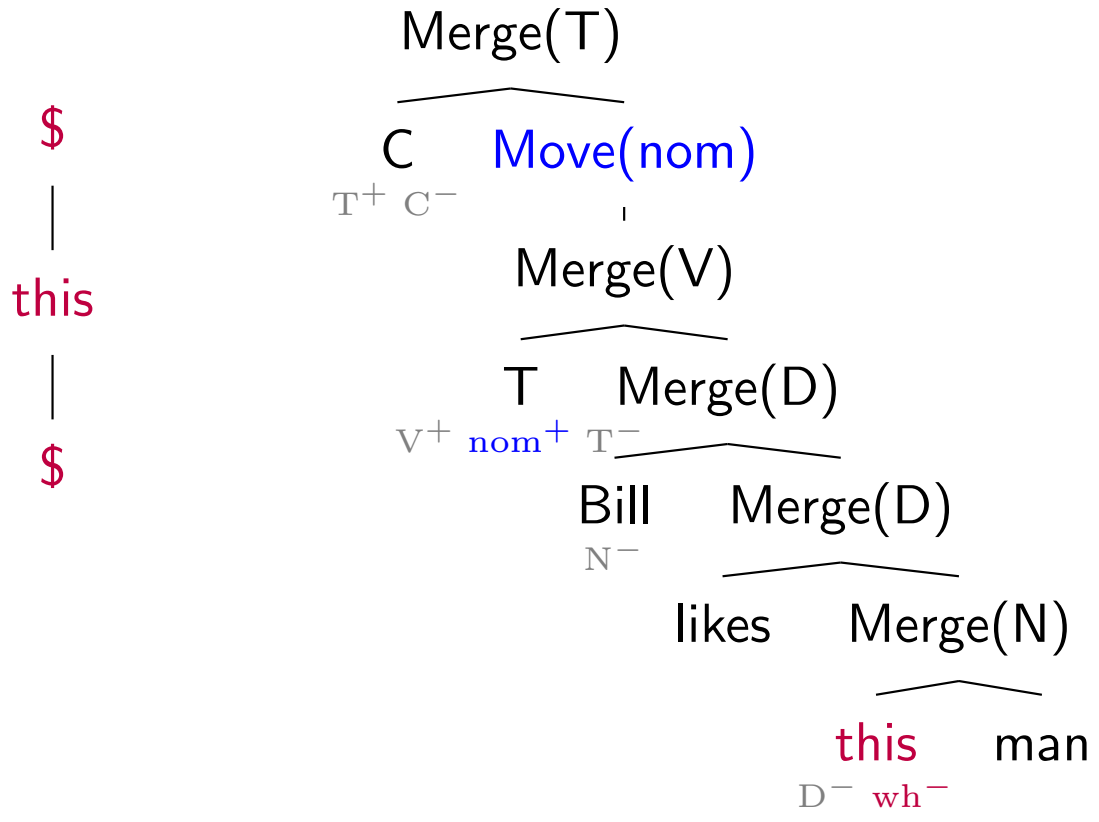

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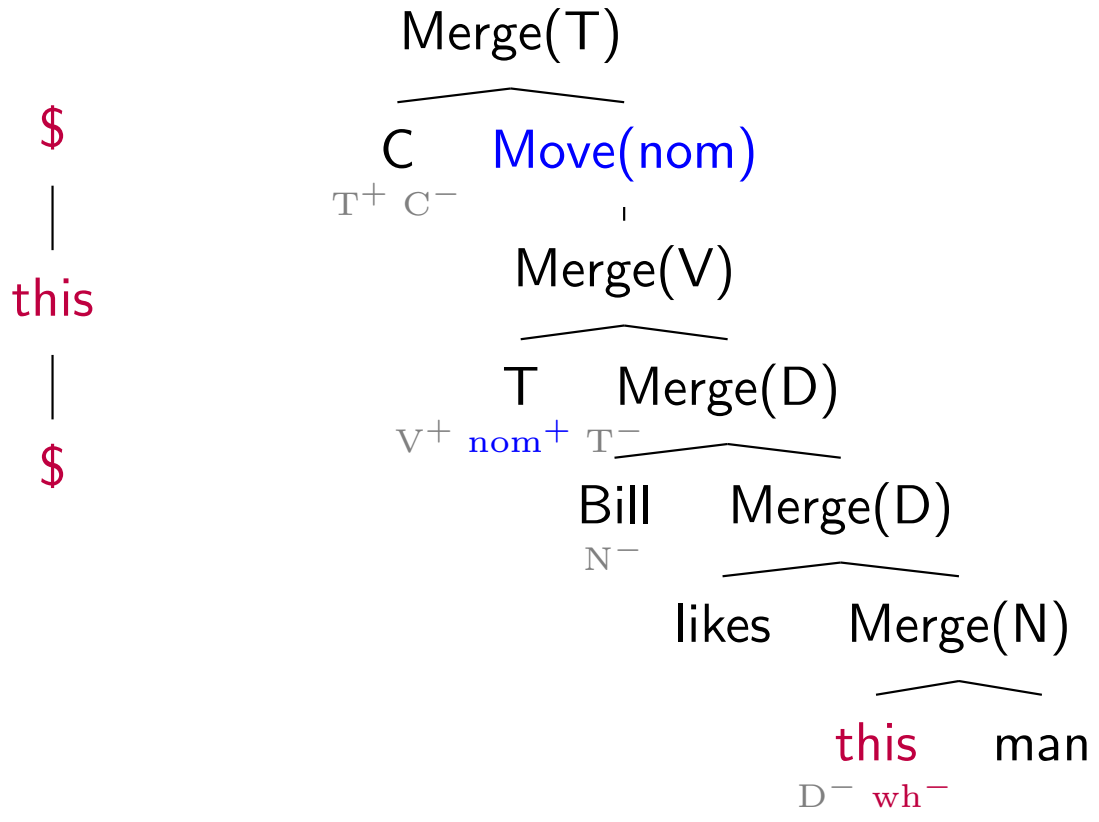

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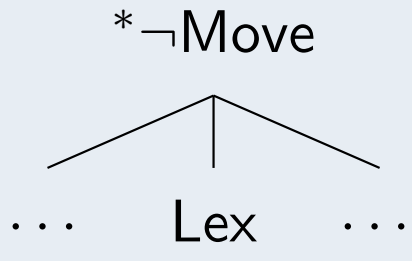

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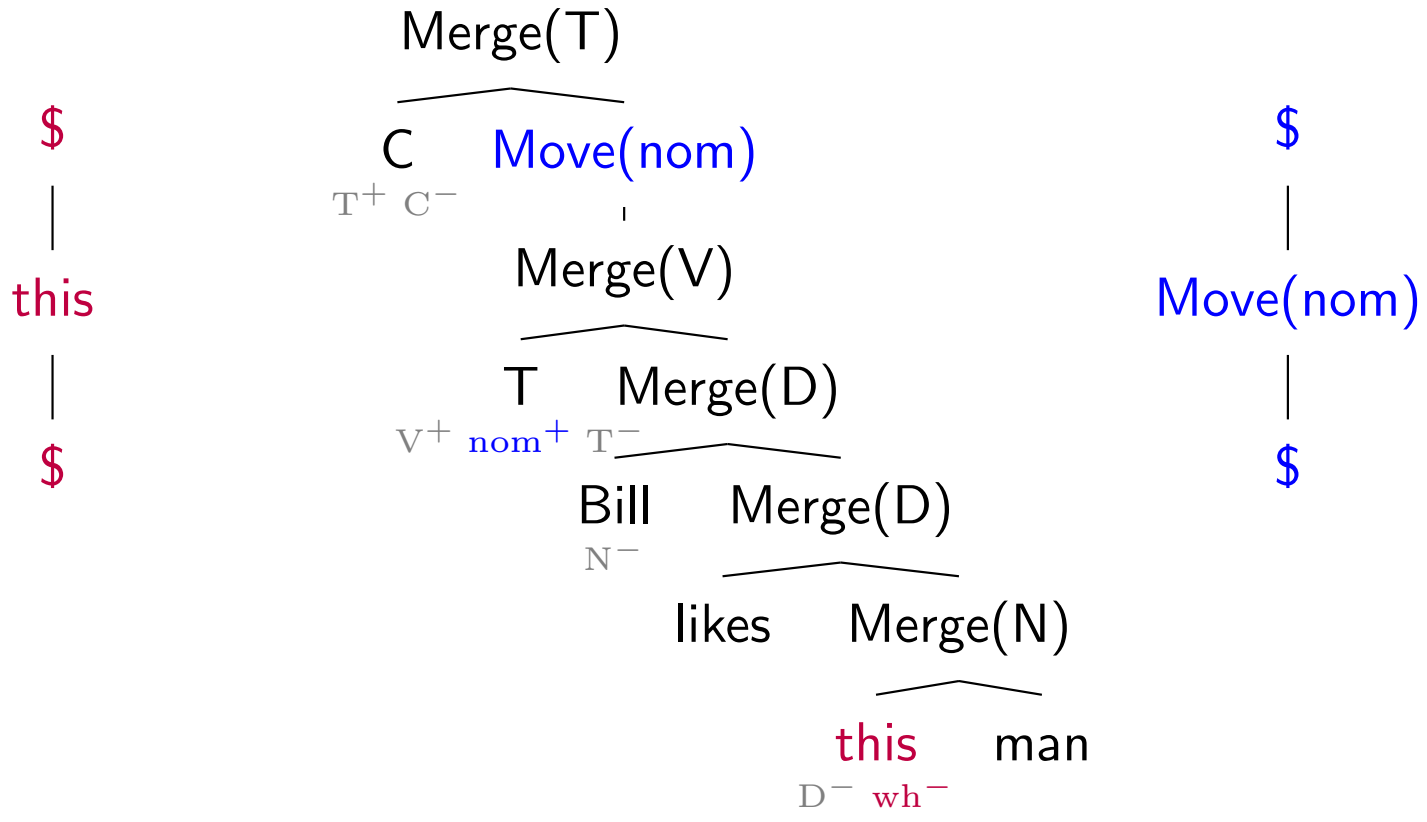

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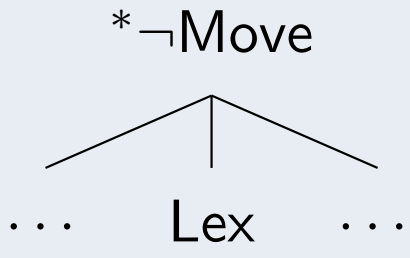

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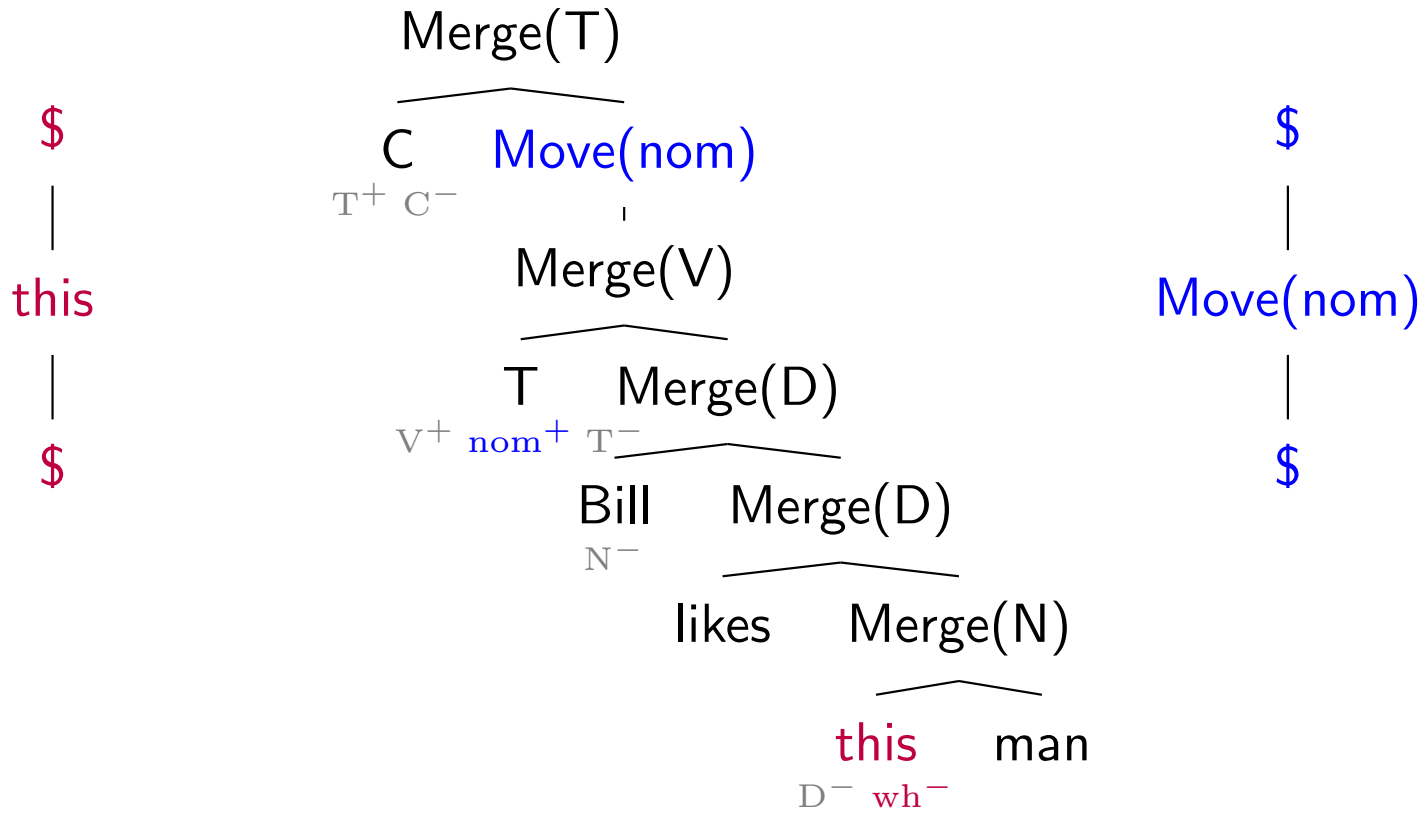

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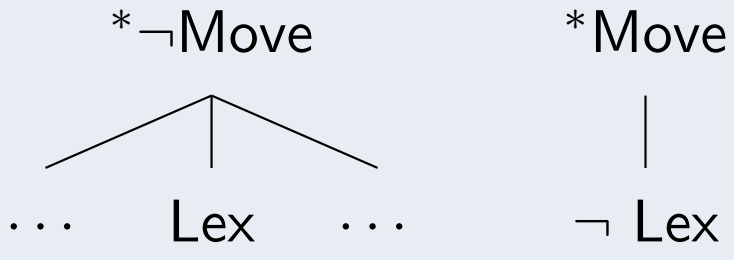

Shortest Move Constraint

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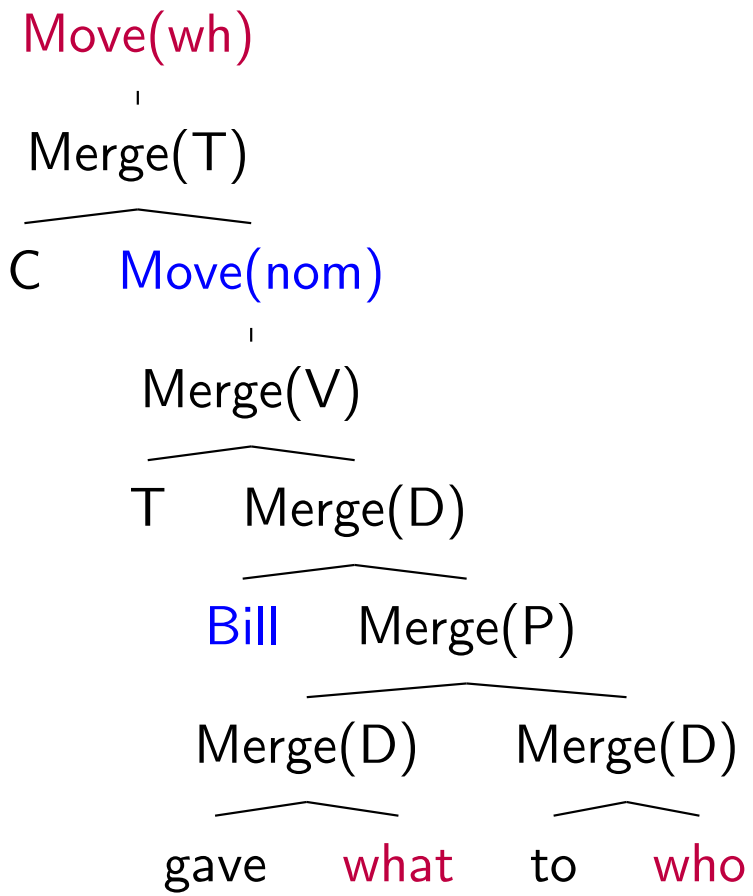

SMC Movers must not target the same position.

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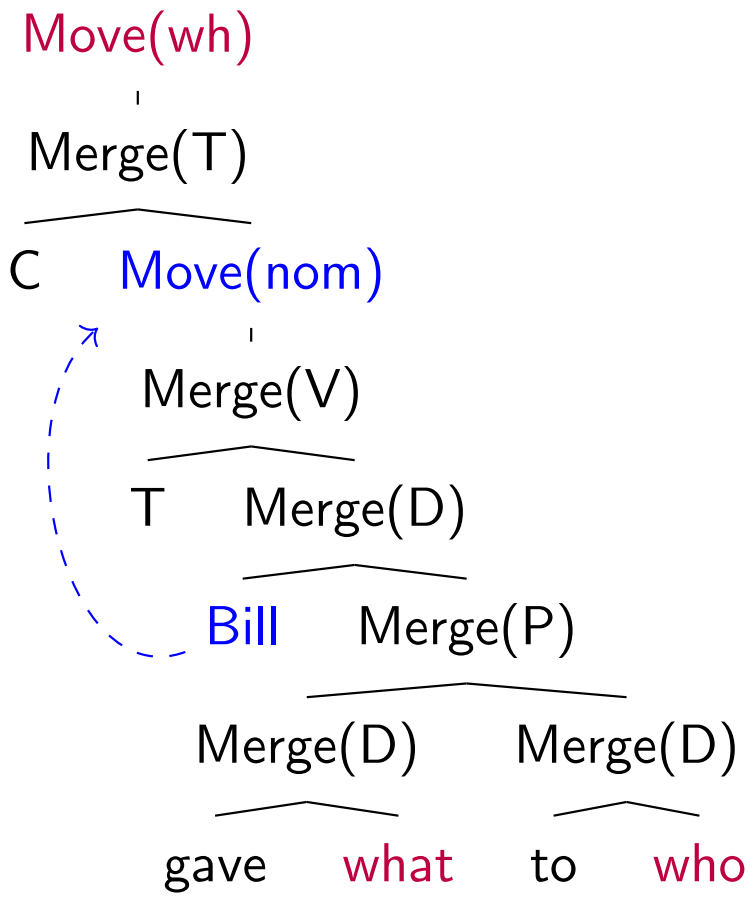

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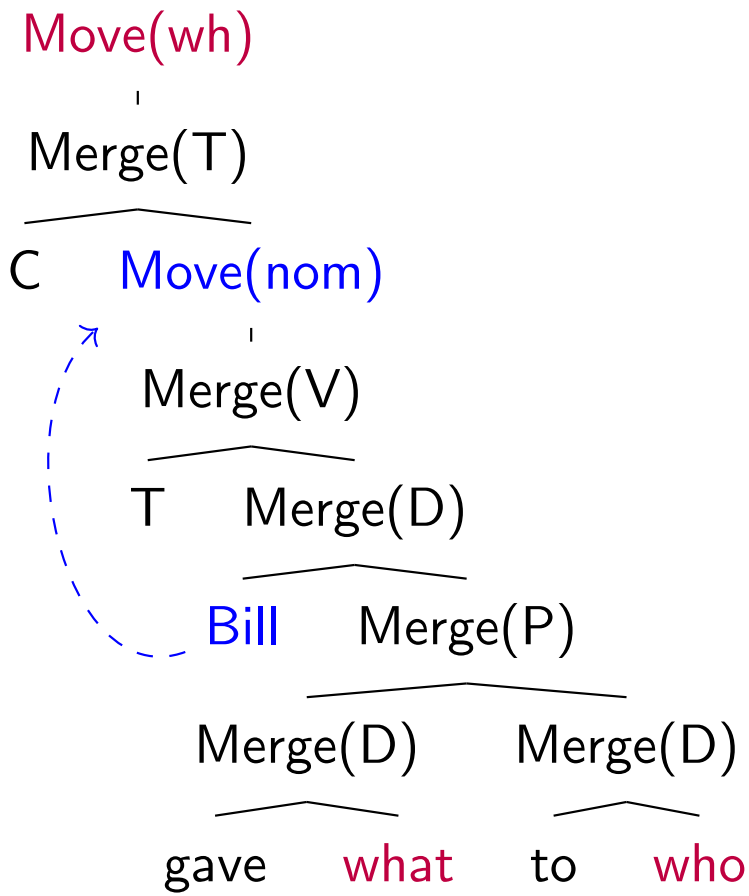

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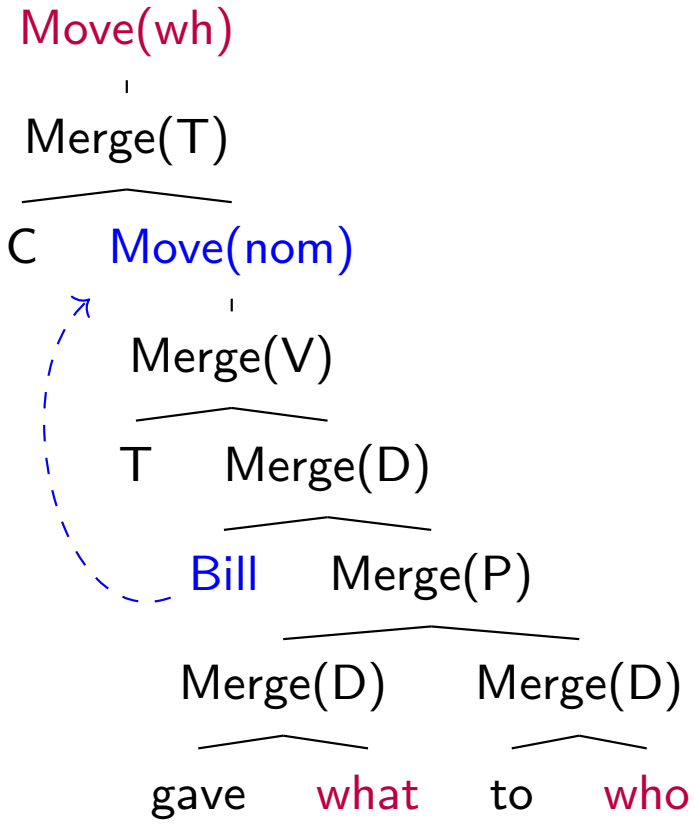

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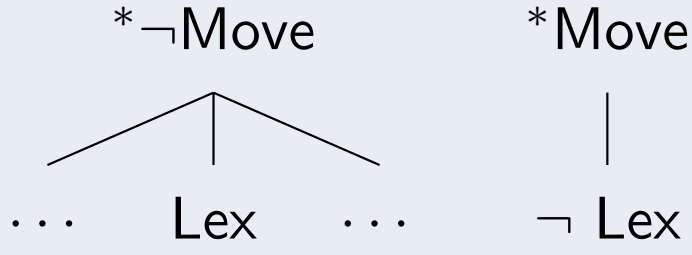

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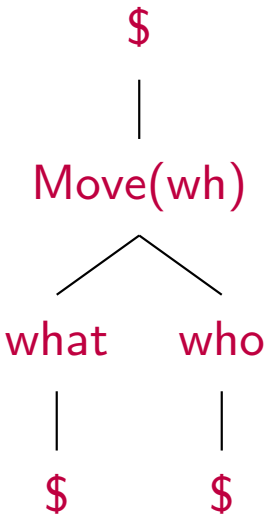

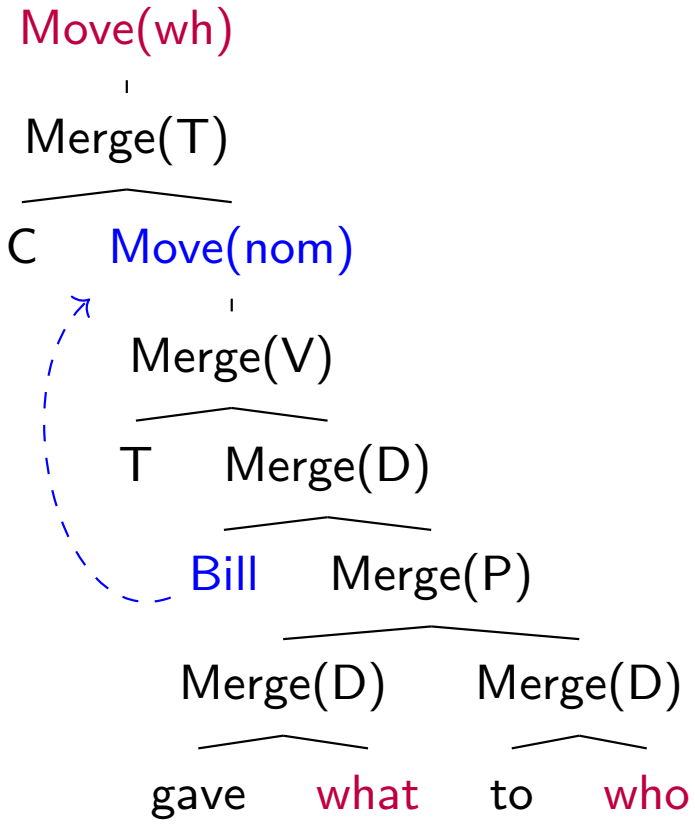

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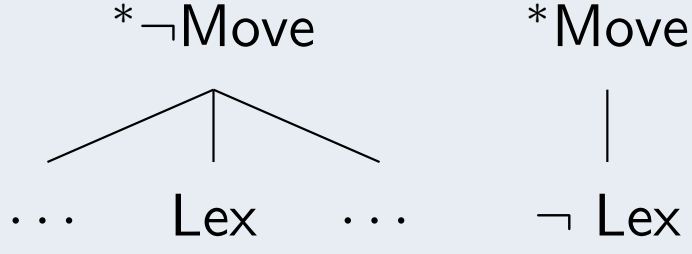

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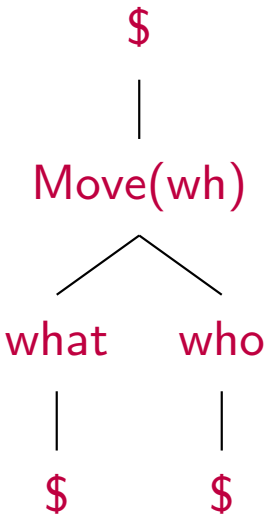

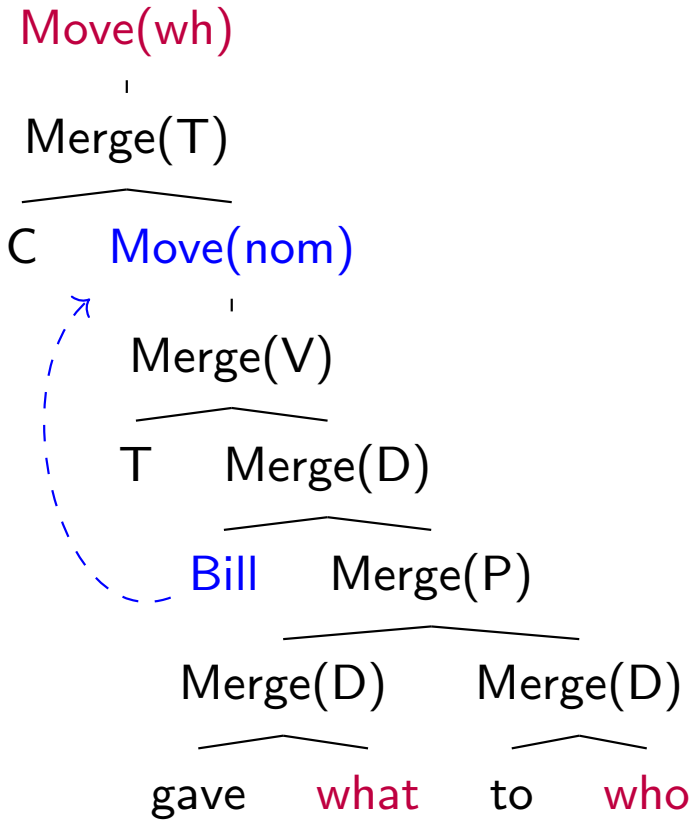

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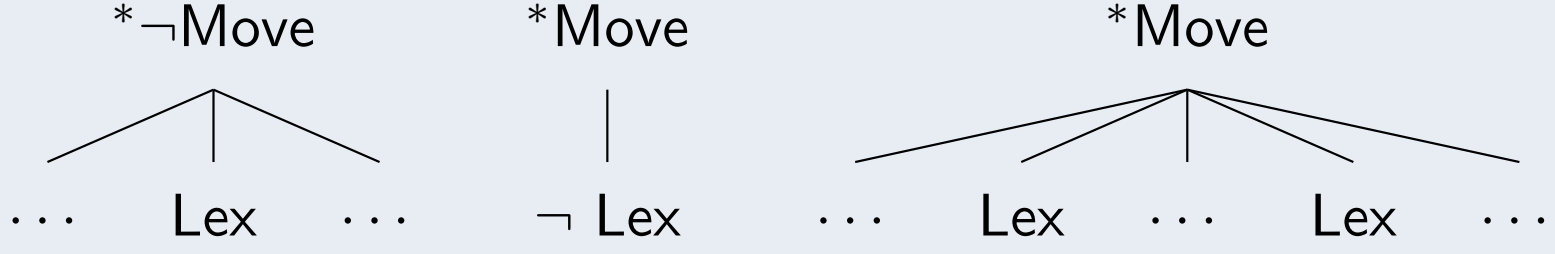

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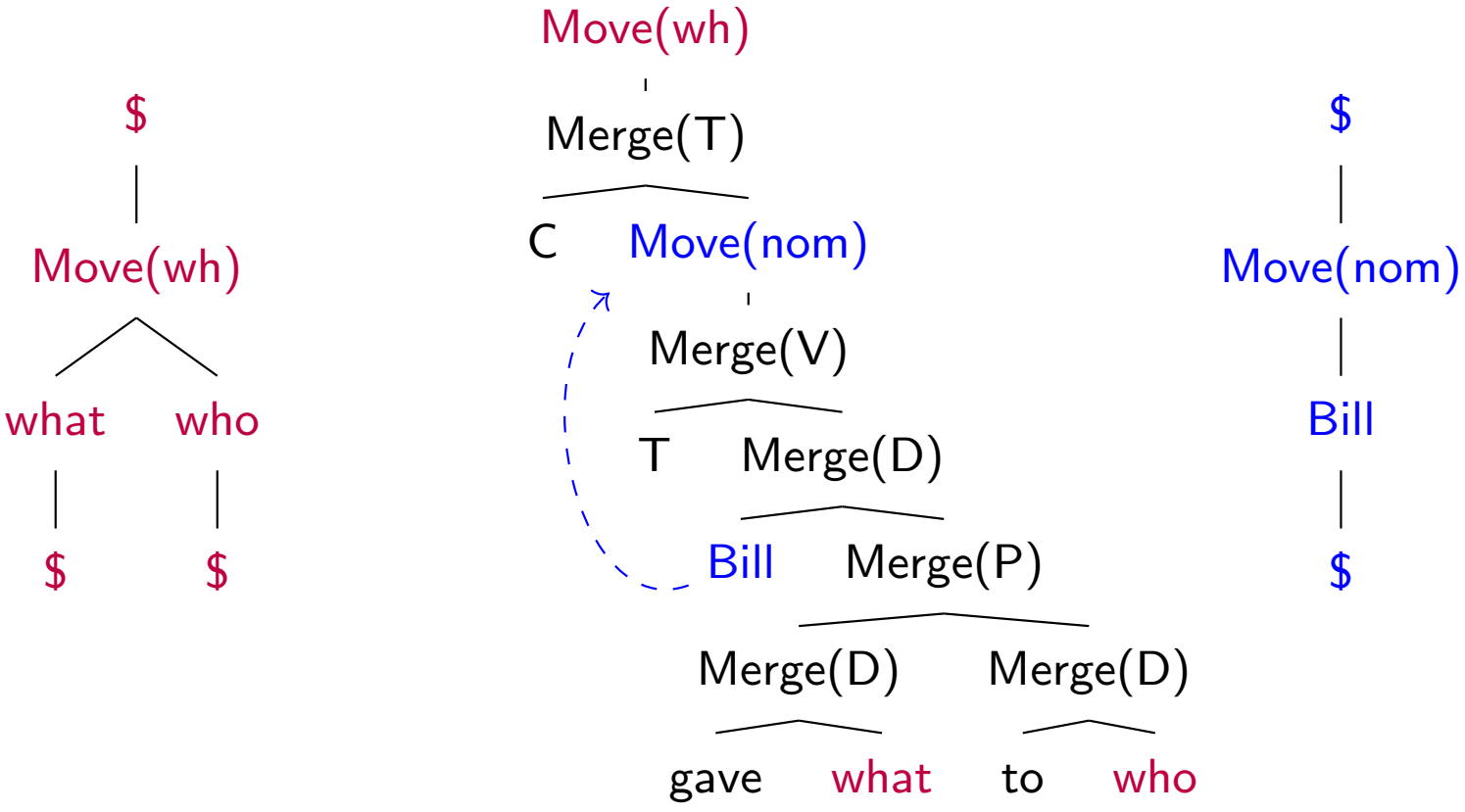

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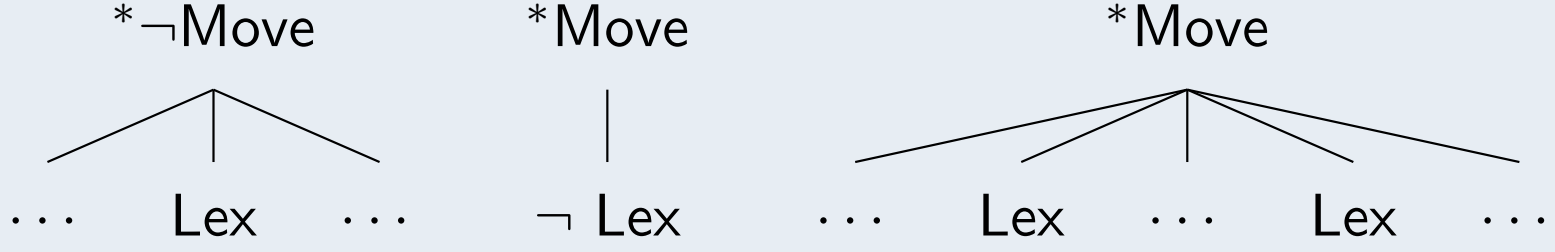

Upward versus Downward Movement

- Without intermediate movement, **upward movement is TSL**.
- Nice and dandy, but what does it tell us about syntax?

Why is There No Downward Movement?

Downward = movement to c-commanded position

Usually ruled out by Extension Condition, but...

- Head movement
- Affix hopping
- Late adjunction
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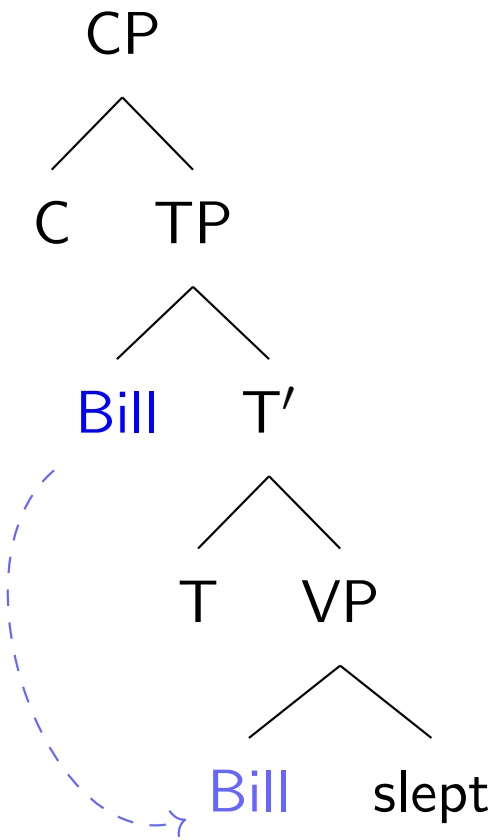
Downward Movement in MGs (Graf 2012b, 2014a)



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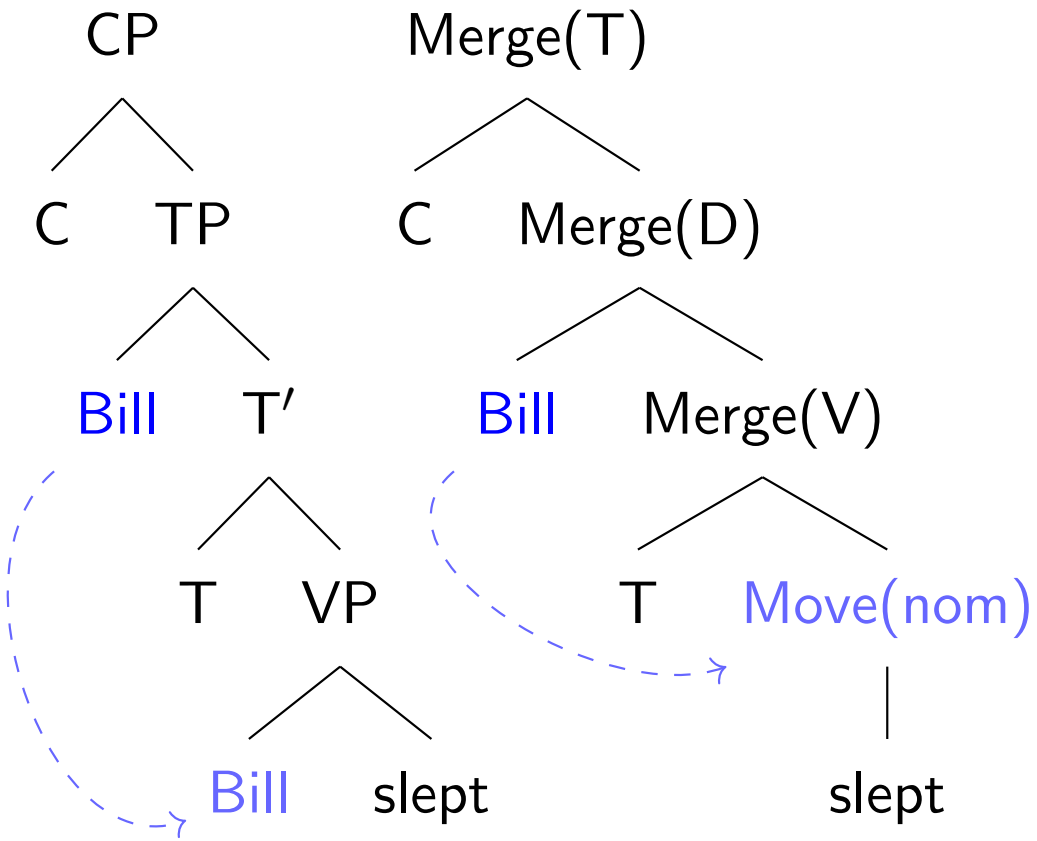

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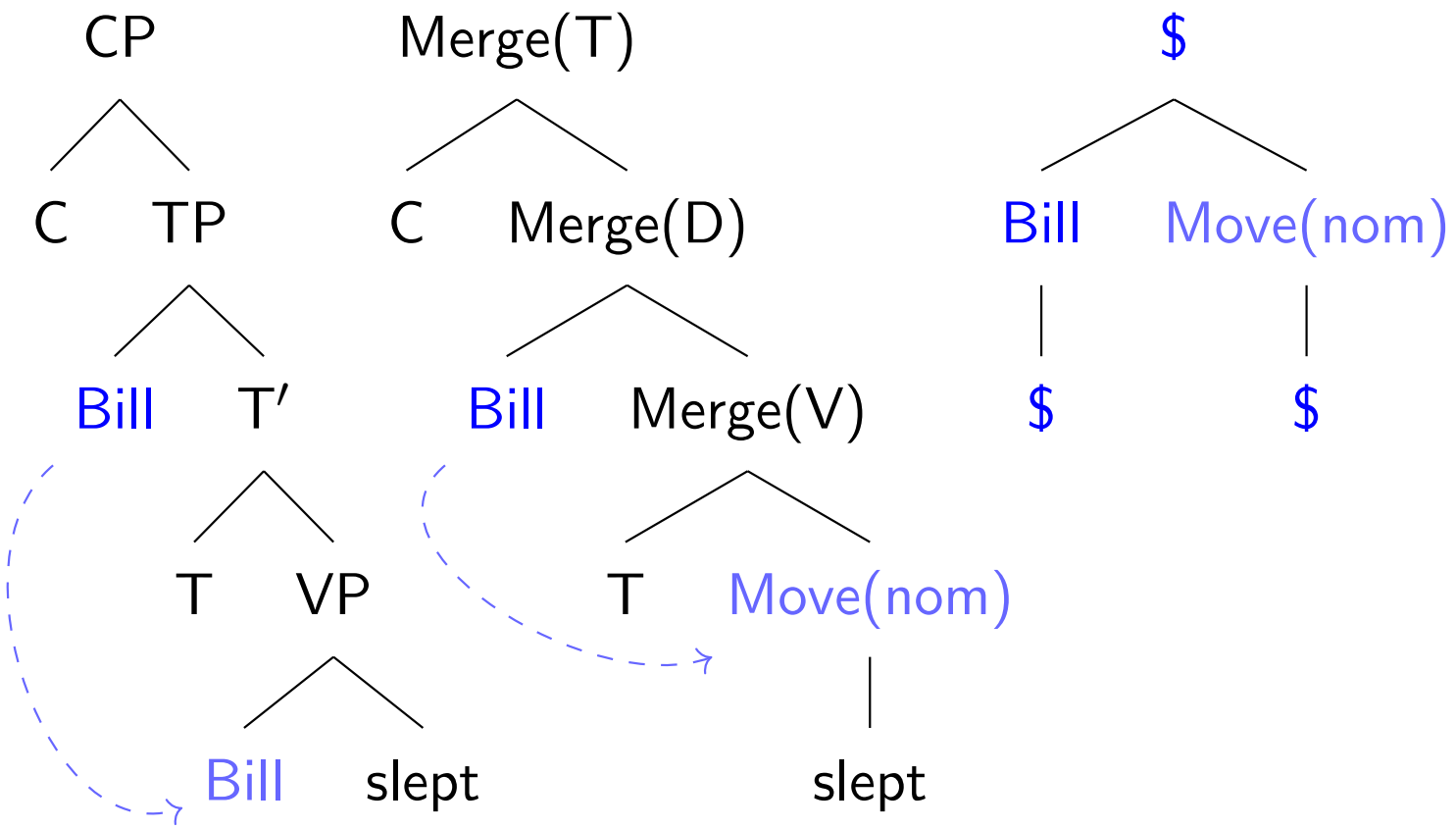

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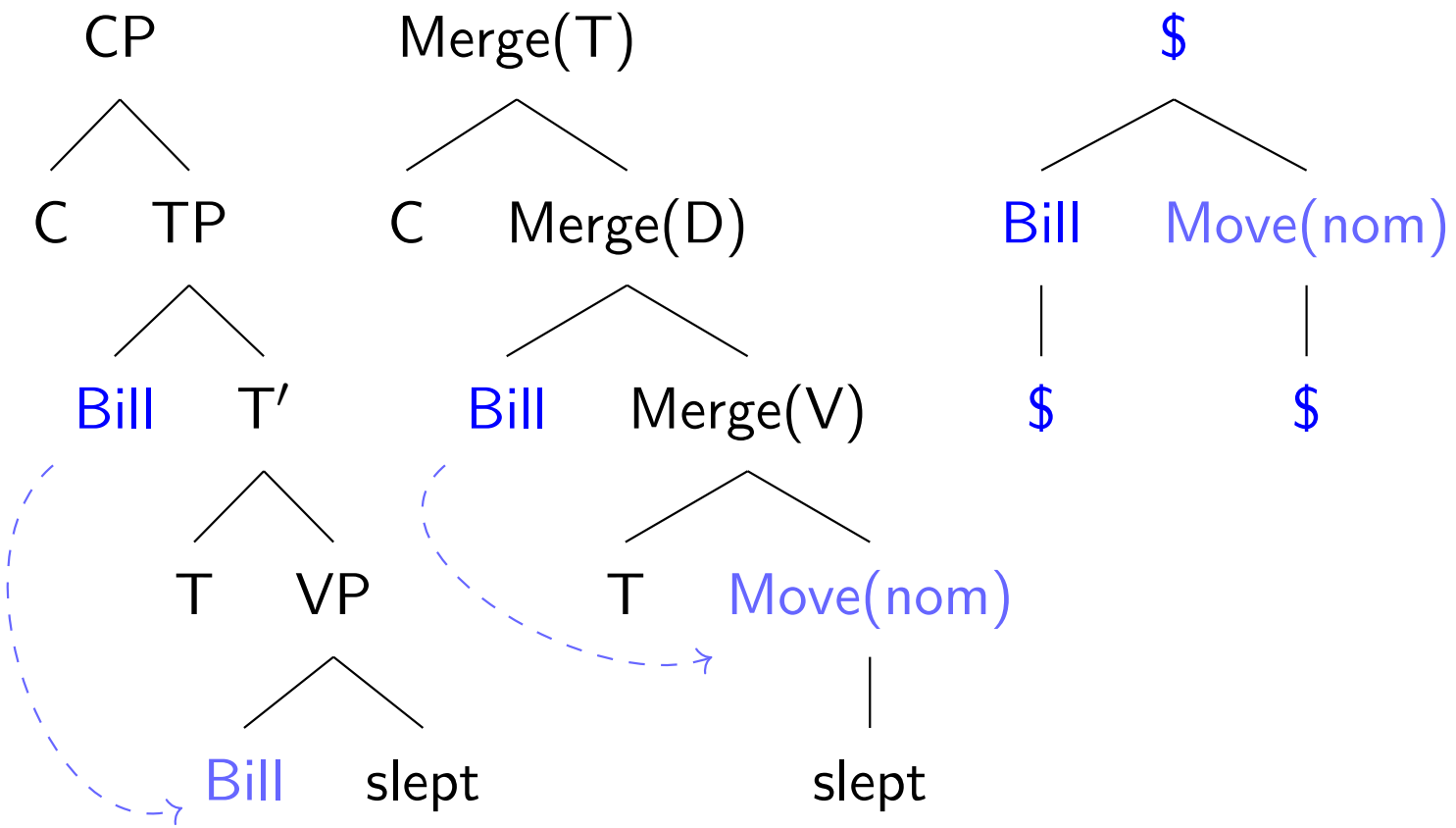
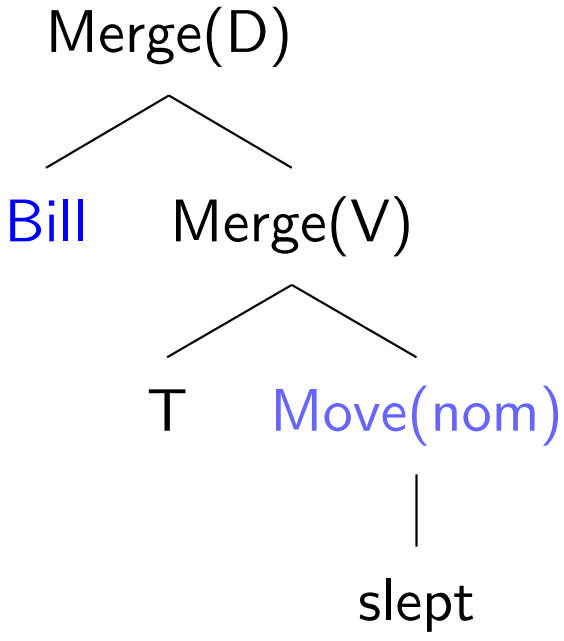


Downward movement is **not TSL**, because . . .

C-Command is not TSL



Important Questions

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- movement : constraints = segmental : suprasegmental?
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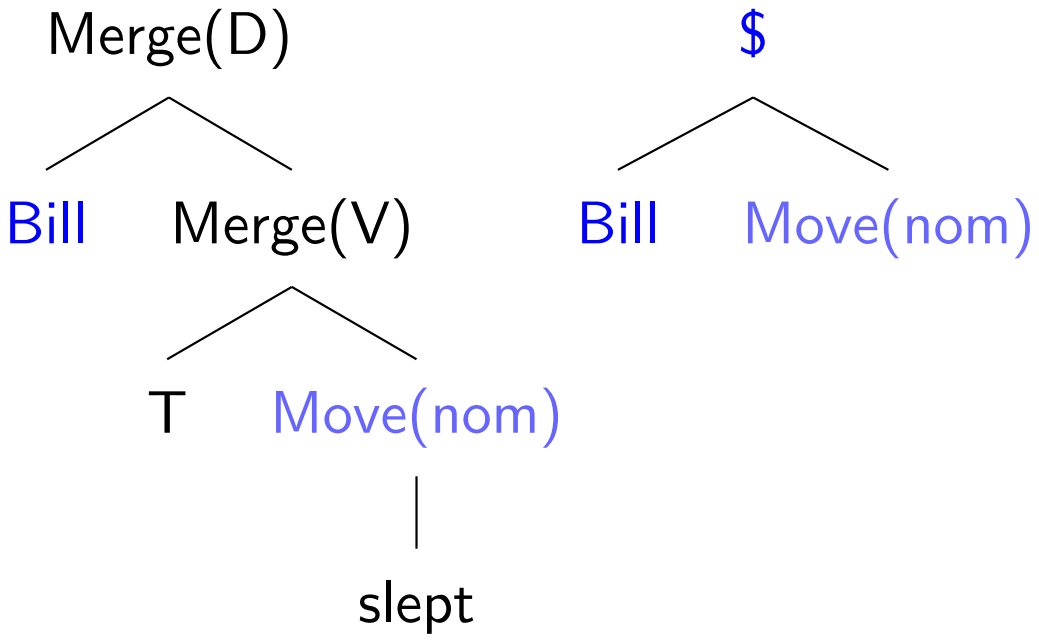

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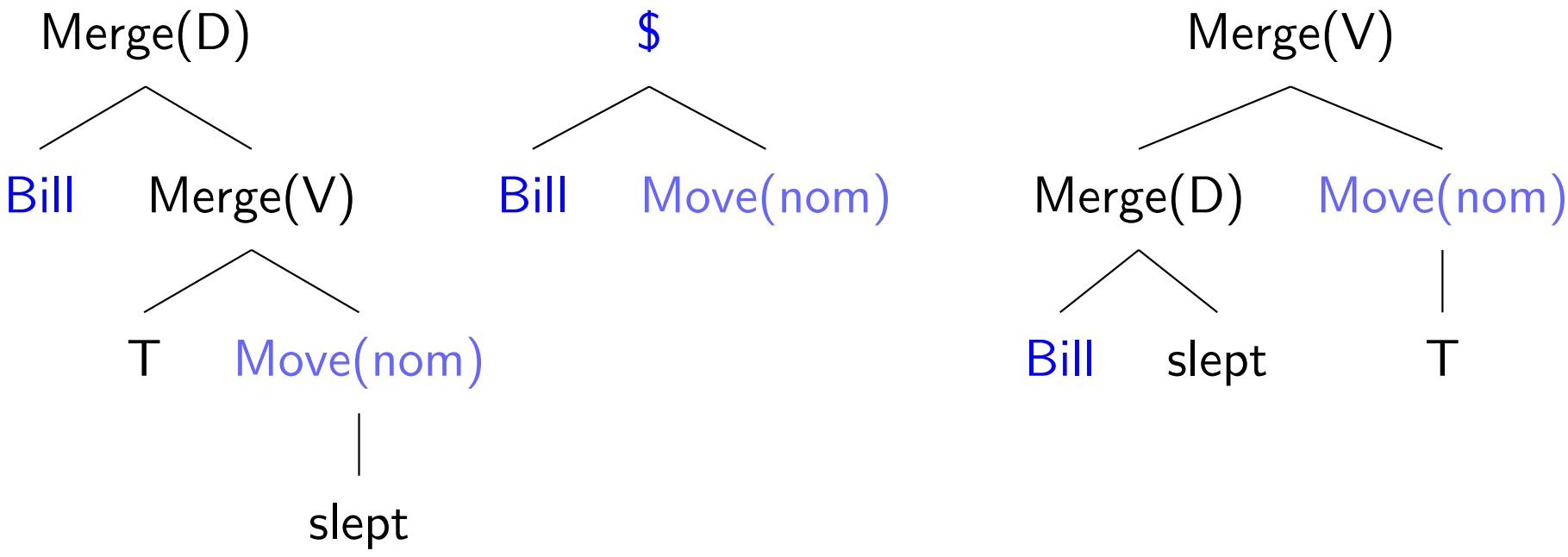

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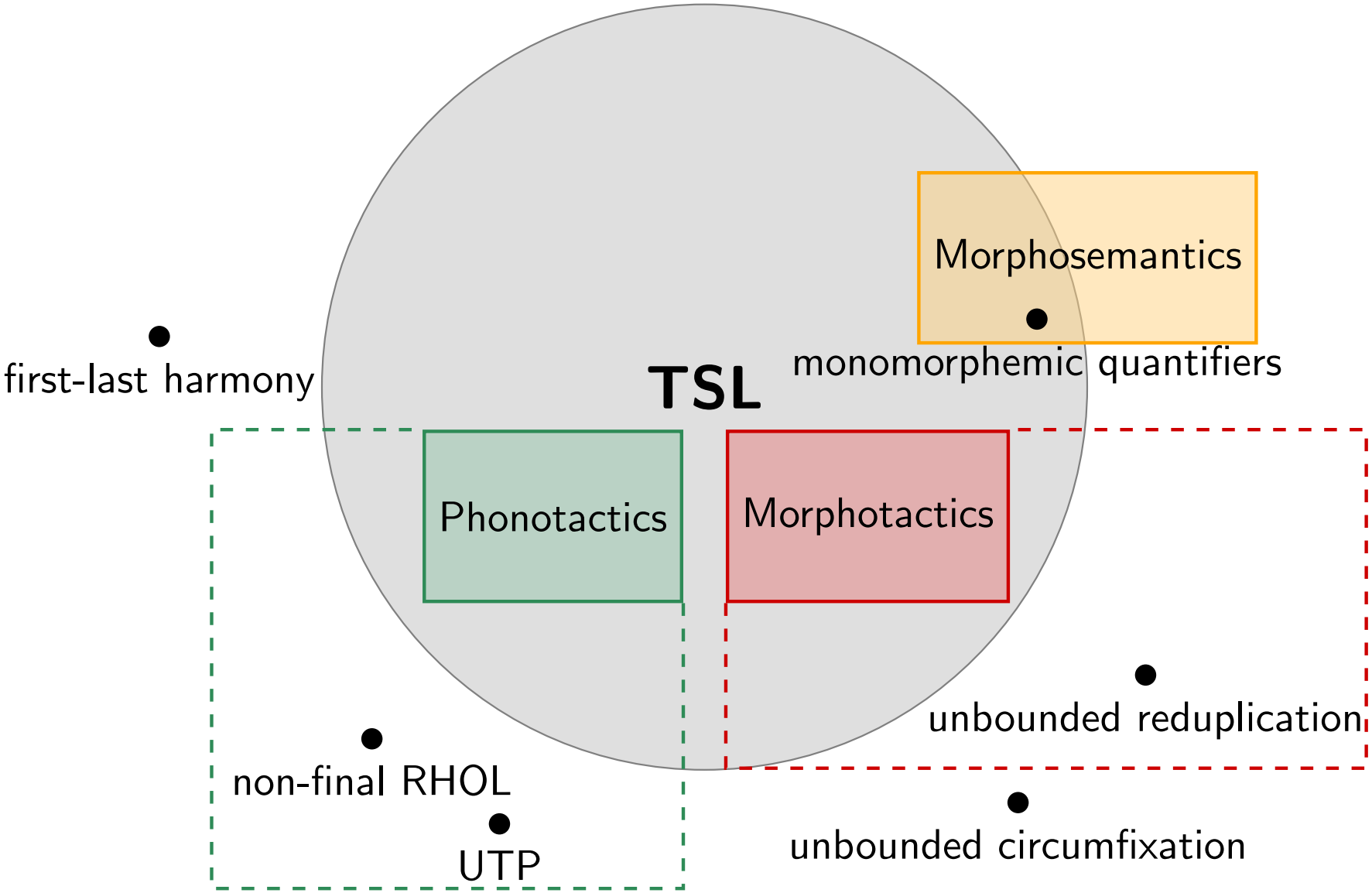

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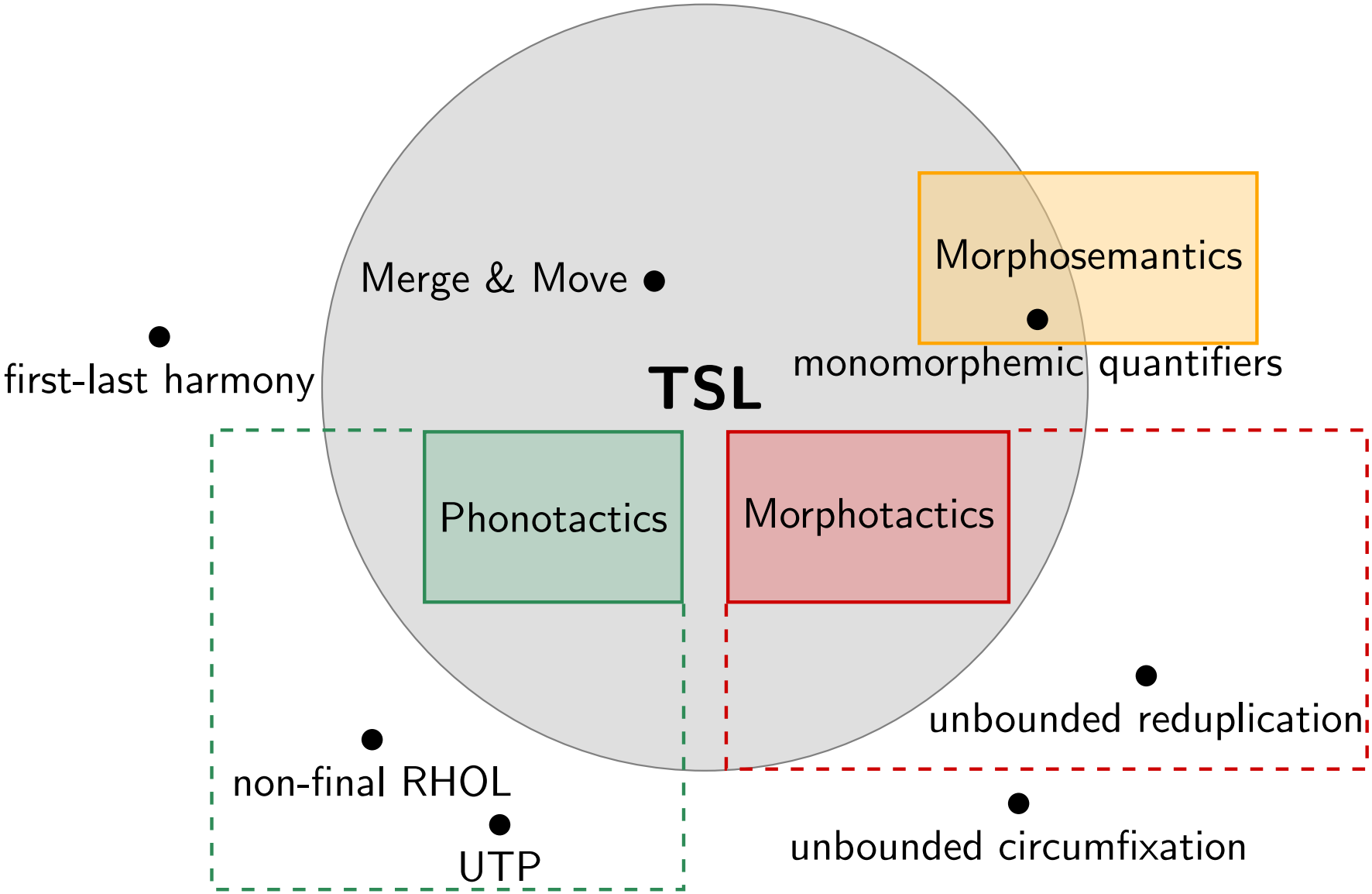

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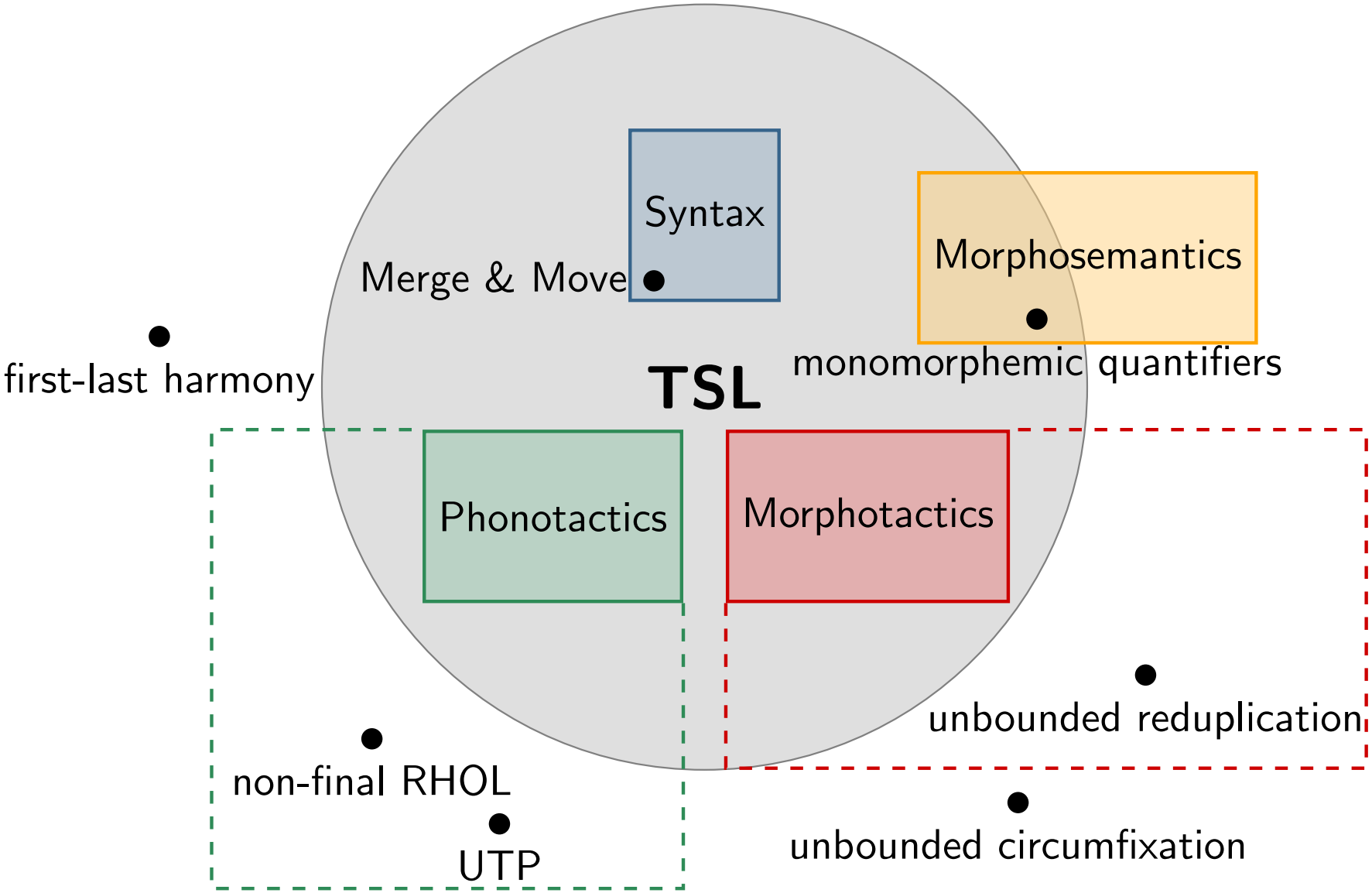

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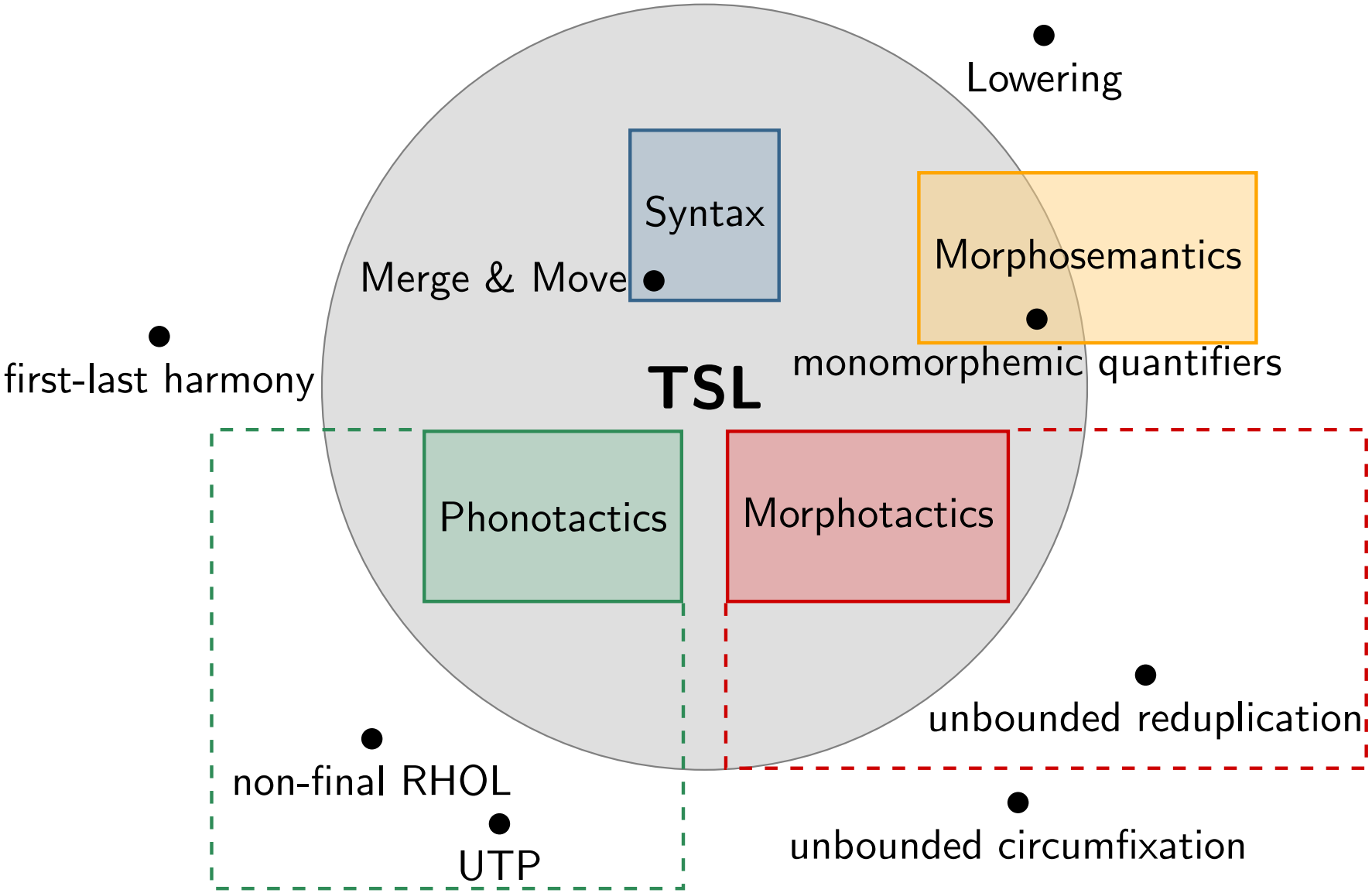

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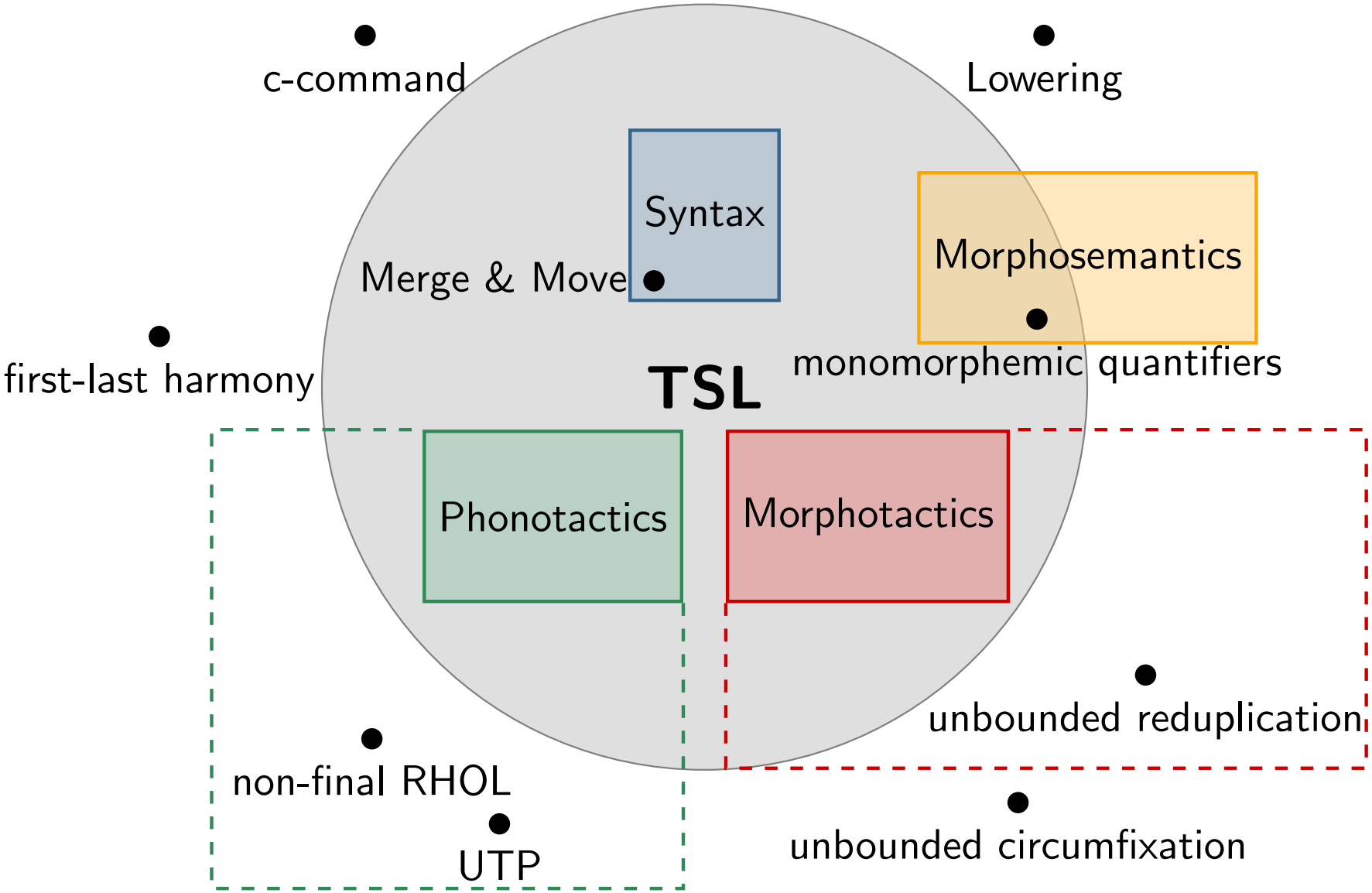

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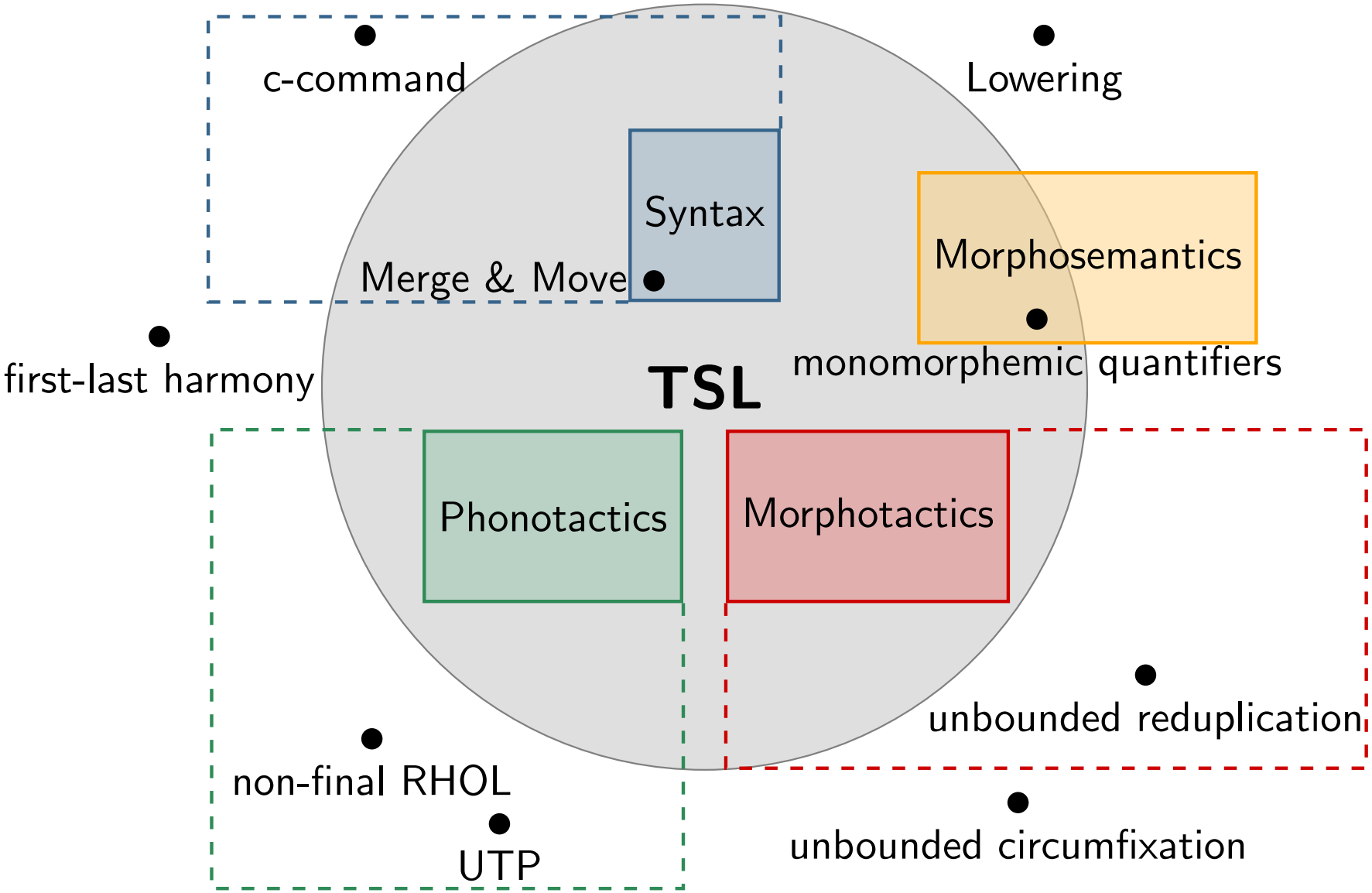

This is Just the Tip of the Iceberg

Mappings

Jane Chandlee

Representations

Adam Jardine
@3:15

Beyond TSL

Aniello De Santo

Sign language

Jon Rawski
@3:45

. . . and many open questions

What CompLing Can Do For You

- Computational linguistics is not a field, it is a **perspective**:
  - What patterns are truly complex?
  - How complex can dependencies be?
  - Are some analyses simpler than others?
- As in any formalism, interplay of theory and data:
  - new typological claims
  - deeper understanding of formalism through data
  - new empirical questions
  - unification of diverse data points
  - learnability
  - direct ties to cognition
- It's just another tool. The more tools, the better!

What You Can Do For CompLing

Everybody can contribute!

- Do you have data that contradicts our predictions?
- probe the status of c-command in syntax
- grammar fragments
- artificial language learning experiments
- processing experiments

Resources and Readings

1. **Survey papers:** Pullum and Rogers (2006); Heinz (2011a,b, 2015); 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)
3. **TSL morphology:** Aksënova et al. (2016); Graf (2017b)
4. **TSL morpho-semantics:** Graf (2017d)
5. **TSL syntax:** Graf (2012a); Graf and Heinz (2016)
6. **Mappings:** Courcelle and Engelfriet (2012); Chandlee (2014, 2016); 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. 2012)
  - crossing $<$ nested dependencies (Kobele et al. 2012)
  - 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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Long Story Short

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More on C-Command

- C-command-like relations can be added
- Useful for some phonological phenomena:
  - non-final RHOL
  - bounded harmony due to long-distance blocking in Copperbelt Bemba
  - long-distance blocking of local dissimilation in Samala

Sideward Movement

- Move anywhere except m-commanded positions

Relation	TSL?
move upward	yes
move anywhere	yes
m-command	no
sideward	no

- **But:** m-command is TSL over dependency graphs, because it reduces to dominance
  $\Rightarrow$ sideward movement can be TSL

References I

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