Tiers and Relativized Locality Across Language Modules

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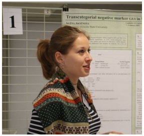
Parallels Between Phonology & Syntax
Amsterdam, July 9, 2018

The Subregular Group @ SBU

Jeff Heinz

Thomas Graf



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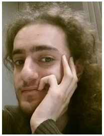

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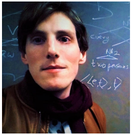

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The Elevator Pitch

Parallels between phonology and syntax?

- What would a computational linguist tell you?
  Probably none!

- What will I show you today?
  They are fundamentally similar!

The Take-Home Message

- **Two kind of dependencies**: local and non-local
- The core mechanisms are **the same** cross-domain, over the respective **structural representations**.
- **Relativized locality** plays a major role

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A methodological note:

- Only phonotactics considered (no input-output mappings)
- Minimalist Grammars (Stabler 1997) as a model of syntax
- Formal language theory as a tool to assess parallelisms

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Local Dependencies in Phonology

1. **Word-final devoicing**
   Forbid voiced segments at the end of a word

(1) a. * rad
    b. rat

1. **Intervocalic voicing**
   Forbid voiceless segments in between two vowels

(2) a. * faser
    b. fazer

These patters can be described by **strictly local** (SL) constraints.

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Local Dependencies in Phonology are SL

Example: Word-final devoicing

- Forbid voiced segments at the end of a word: *[+voice]$
- **German**: *z$, *v$,*d$ ($ = word edge).

$ r a d $ $ r a t $

Example: Intervocalic voicing

- Forbid voicess segments in-between two vowels: *V[-voice]V
- **German**: *ase, *ise, *ese, *isi, . . .

$ f a s e r $ $ f a z e r $

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* $ f [a **s** e] r $ *ok* $ f [a z e] r $

What about Syntax?

We need a model for syntax ...

- 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

Local dependencies in syntax

- Merge is a **feature-driven** operation:
  category feature N^-, D^-, ...
  selector feature N^+, D^+, ...
- Subcategorization as formalized by Merge is **strictly local**.

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Local Dependencies in Syntax

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’s	cat
N^+ D^+ D^-	N^-

Local Dependencies in Syntax

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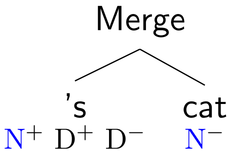

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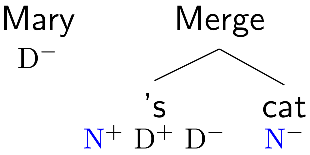

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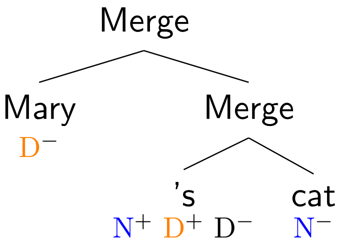
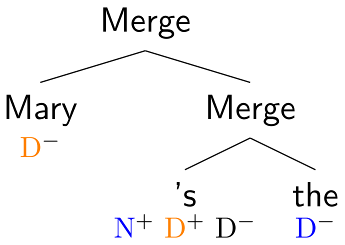
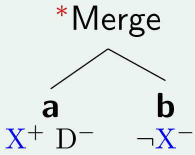


Merge is SL (Graf 2012a)



SL constraints on Merge

- We lift constraints from string n-grams to tree n-grams
- We get SL constraints over subtrees.



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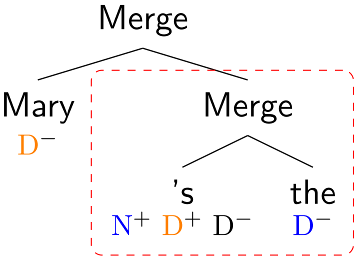

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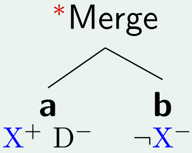

Interim Summary

	Local	Data Structure
Phonology	?	?
Syntax	?	?

Local phenomena modeled by n-grams of bounded size:

- computationally very simple
- learnable from positive examples of strings/trees
- plausible cognitive requirements

Interim Summary

	Local	Data Structure
Phonology	SL	Strings
Syntax	SL	Trees

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Interim Summary

	Local	Non-local	Data Structure
Phonology	**SL**	?	**Strings**
Syntax	**SL**	?	**Trees**

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Unbounded Dependencies in Phonology

- **Samala Sibilant Harmony**
  Sibilants must not disagree in anteriority.
  (Applegate 1972)

(3) a. * hasxintilawaʃ
 b. * haʃxintilawas
 c. haʃxintilawaʃ

- **Unbounded Tone Plateauing in Luganda** (UTP)
  No L may occur within an interval spanned by H.
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(4) a. **LHLLLL**
 b. **LLLLHL**
 c. * **LHLLHL**
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Unbounded Dependencies Are Not SL

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Example: Samala

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- **But:** Sibilants can be arbitrarily far away from each other!

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Locality Over Tiers

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Tier-based Strictly Local (TSL) Grammars (Heinz et al. 2011)

- Projection of selected segments on a tier T;
- Strictly local constraints over T determine wellformedness;
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- What do we need to project? [+strident]
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  I.E. ***sʃ**, ***sʒ**, ***zʃ**, ***zʒ**, ***ʃs**, ***ʒs**, ***ʃz**, ***ʒz**

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Example: TSL Samala

*	ok
Tier: s ʃ	Tier: ʃ ʃ
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TSL Phonology: Accounting for Context

- **Unbounded Tone Plateauing in Luganda** (UTP)
  No L may occur within an interval spanned by H.
  (Hyman 2011)

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Accounting for Context [cont.]

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Example

^{ok}**L H L L L L** $\quad$ ***L H L L H L**

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- **What about syntax?**

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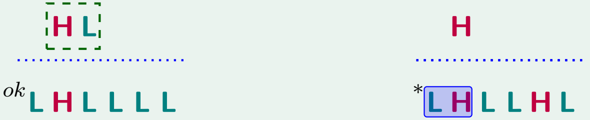

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Non-Local Dependencies in Syntax

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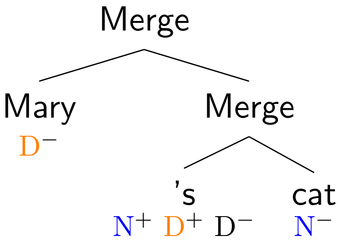
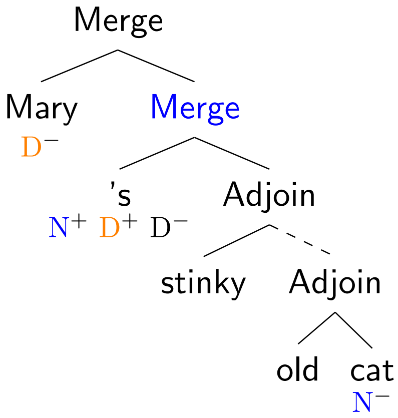


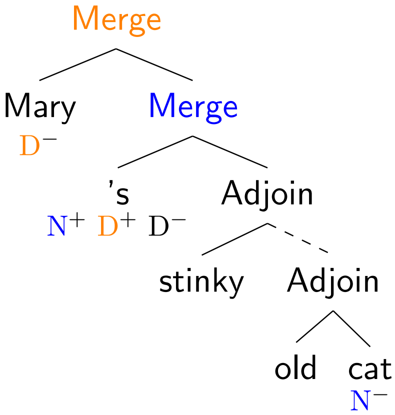
Non-Local Dependencies in Syntax

Let's stick to core operations:

- Move
- **Merge**: Unbounded adjunction
  Frey and Gärtner (2002); Graf (2017b)



TSL over Trees: Projecting Tiers



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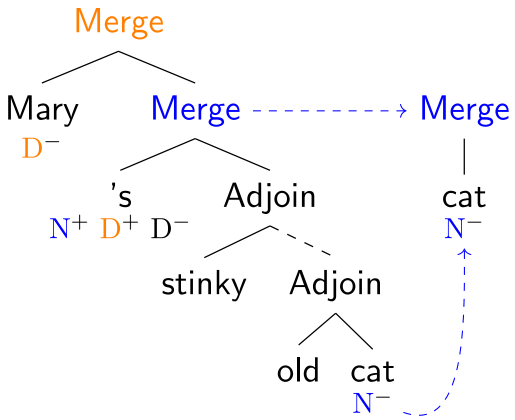

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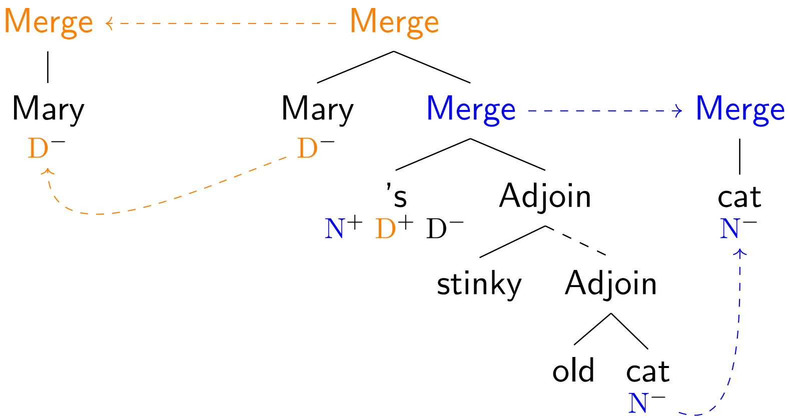
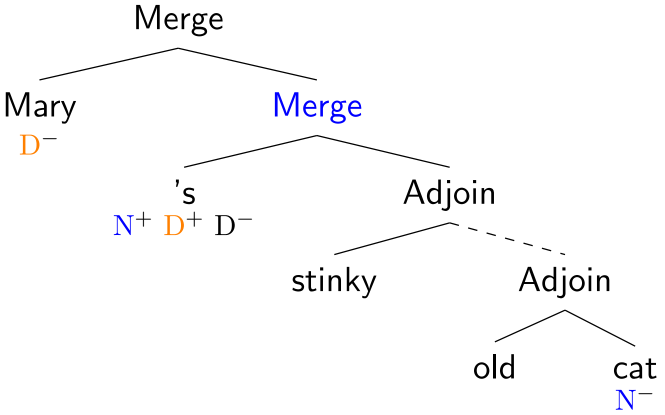


Merge with Adjunction is TSL



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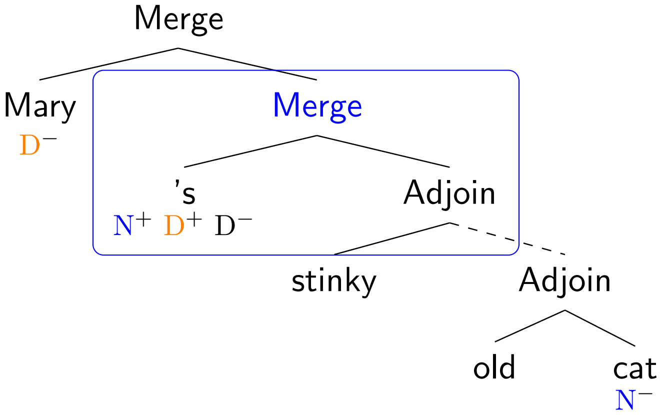

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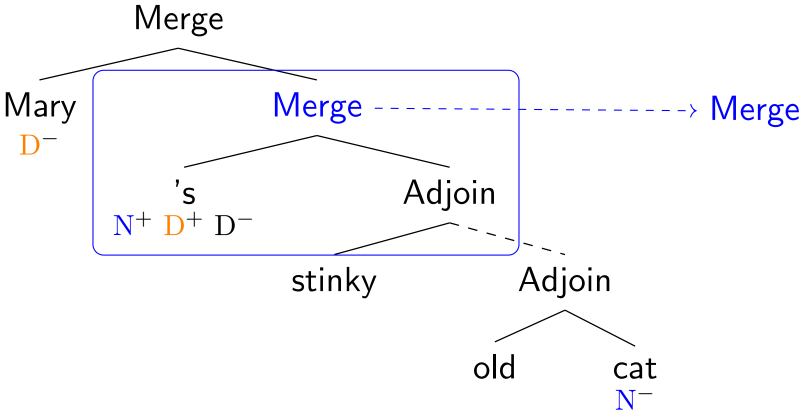

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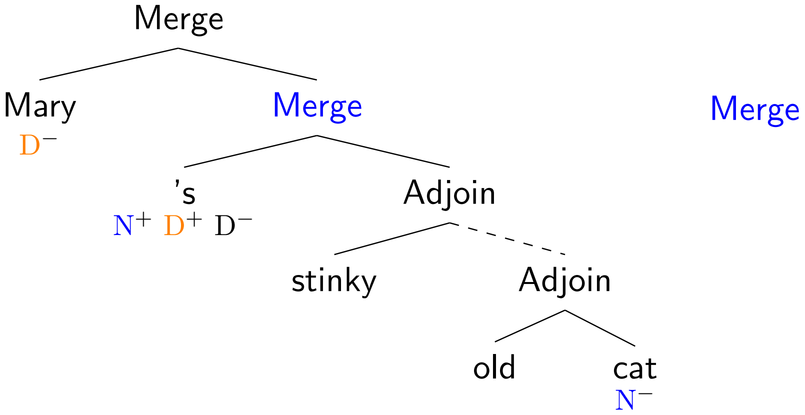

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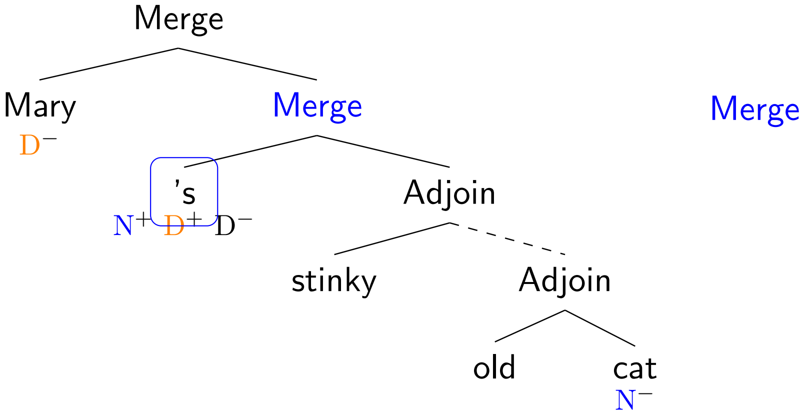

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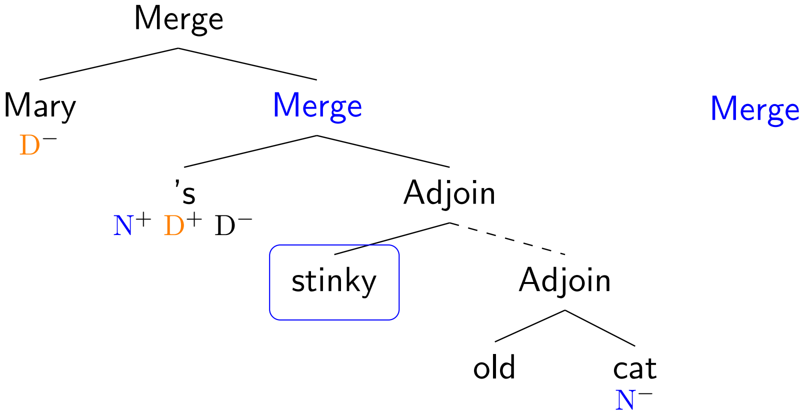

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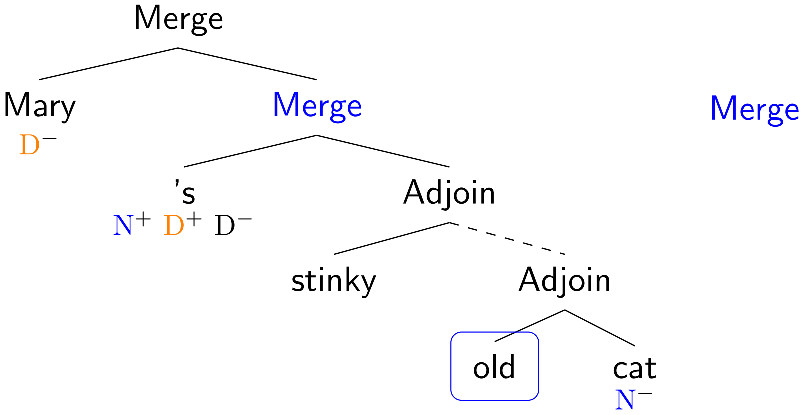

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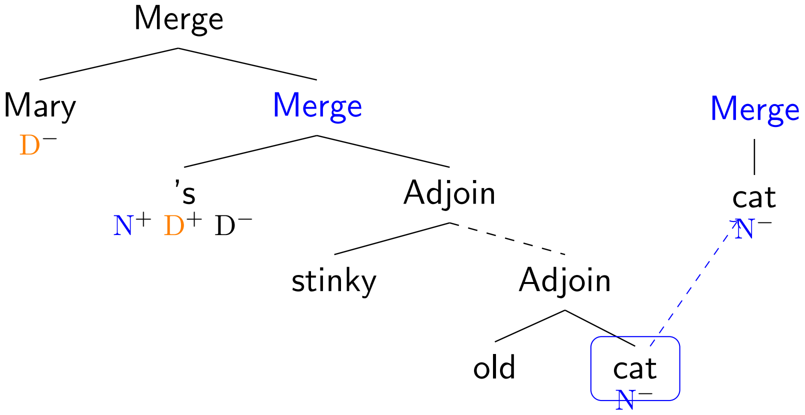

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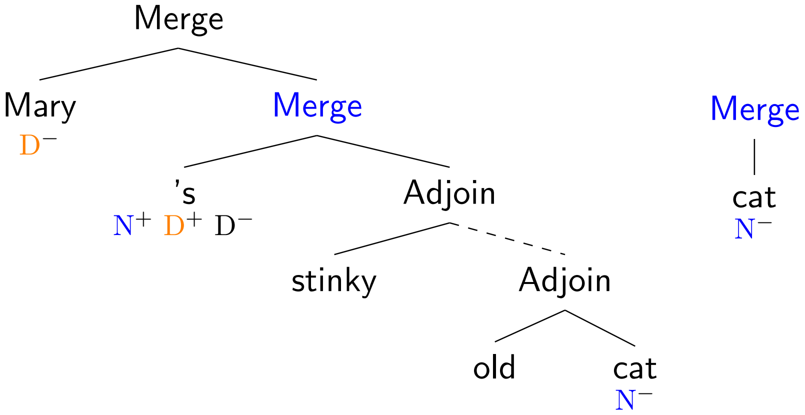

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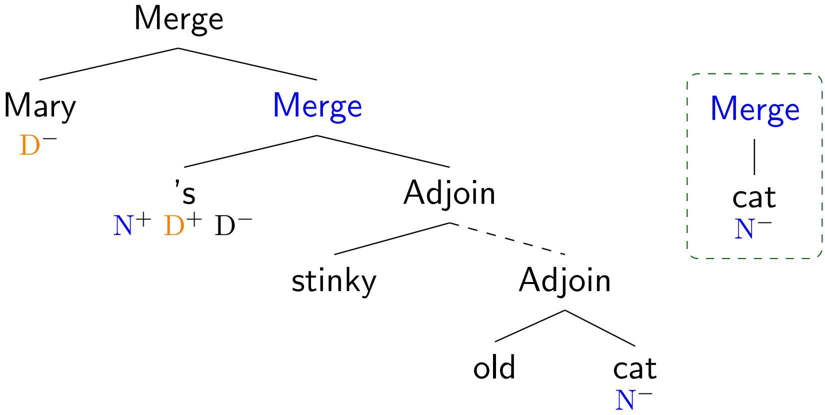

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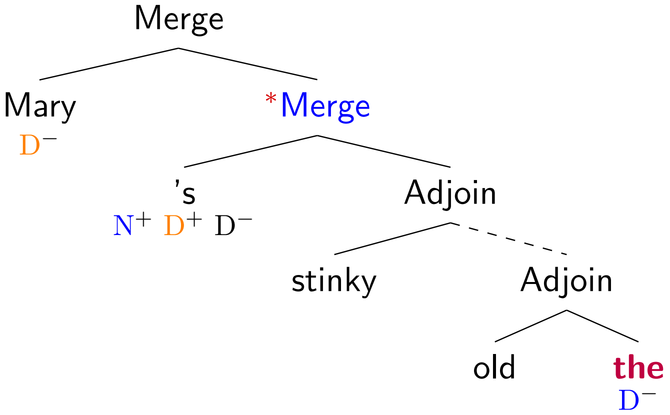

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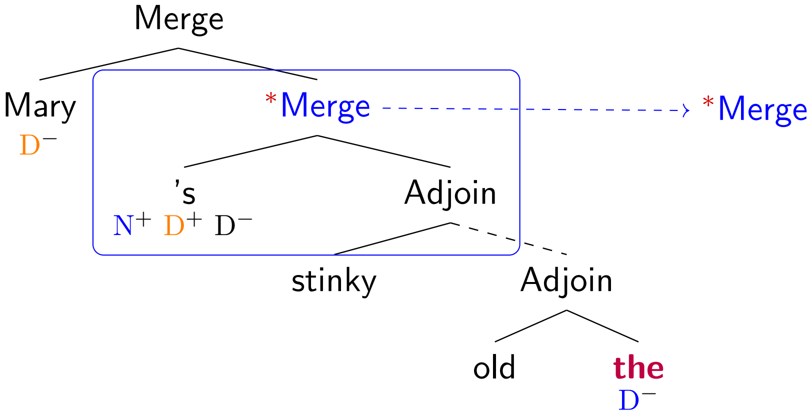

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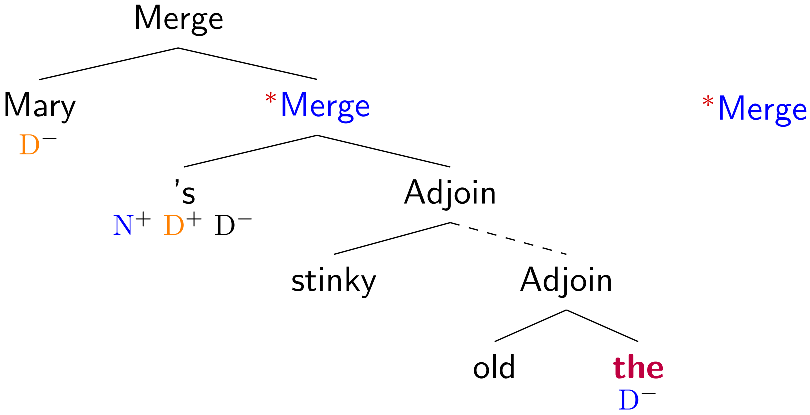

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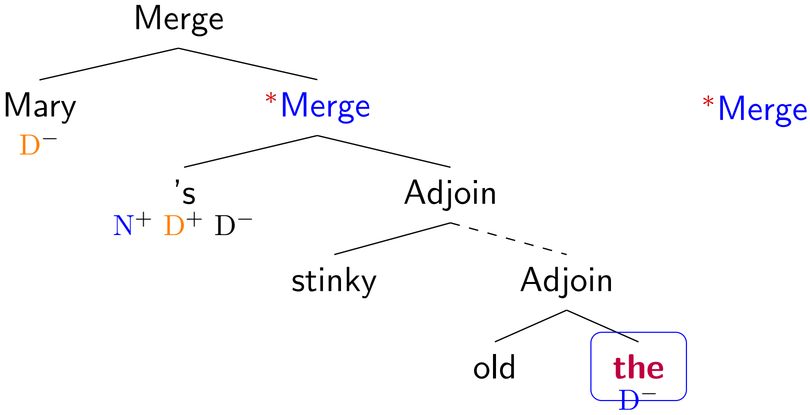

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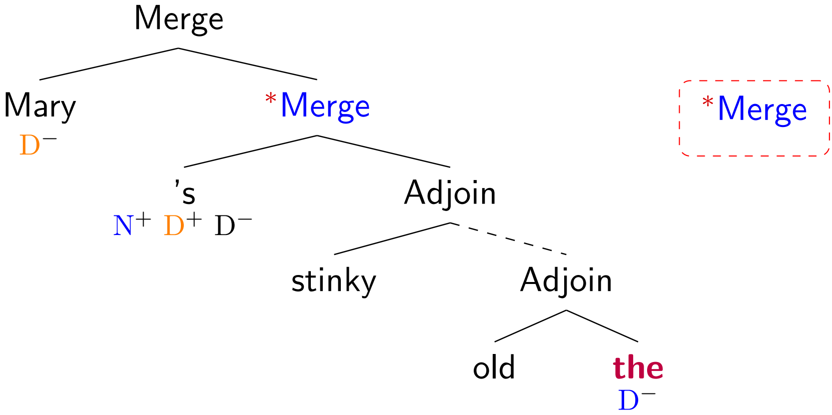

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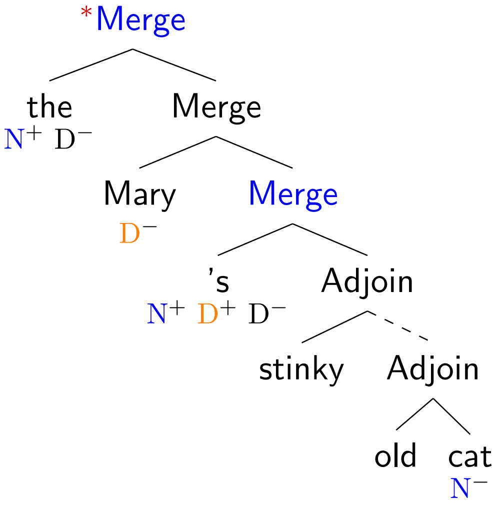

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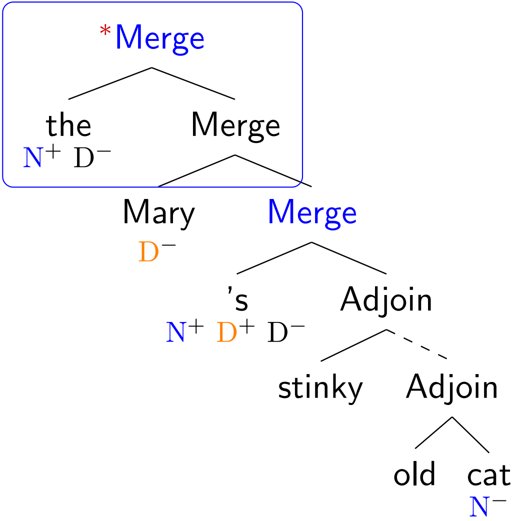

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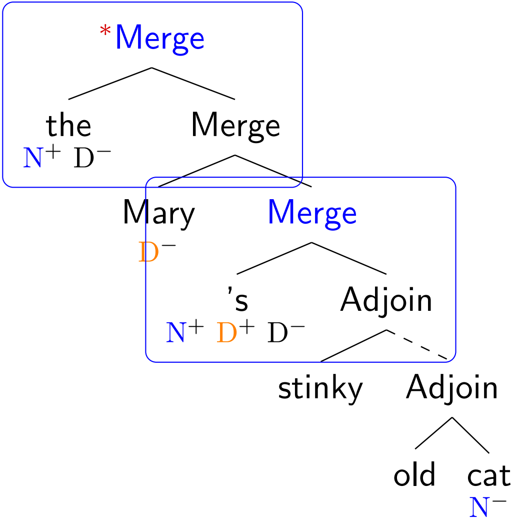

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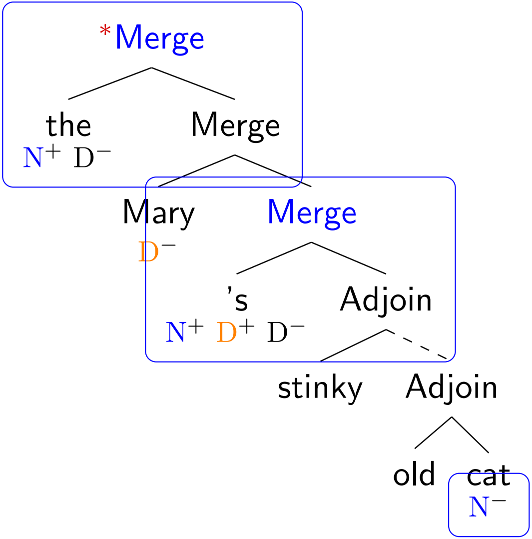

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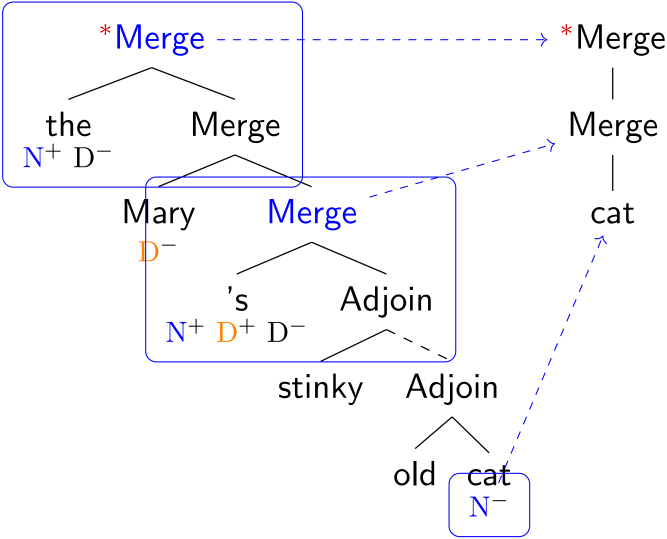

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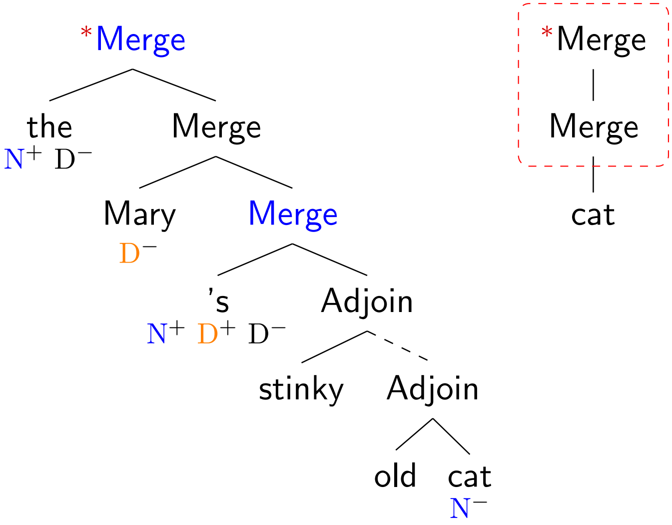

Parallels Between Phonology And Syntax

	Local	Non-local
Phonology	?	?
Syntax	?	?

- **Relativized Locality:**
  Non-local dependencies are local over a simple relativization domain.

Strong Cognitive Parallelism Hypothesis

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

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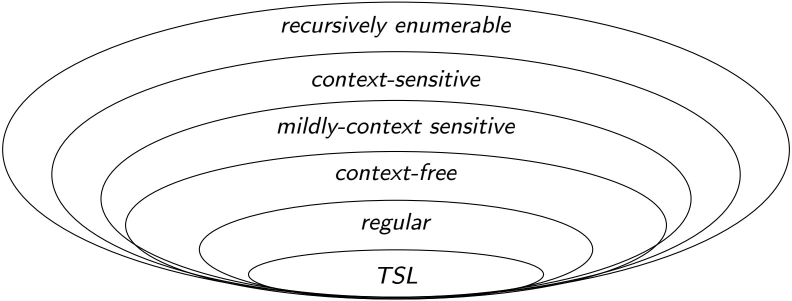

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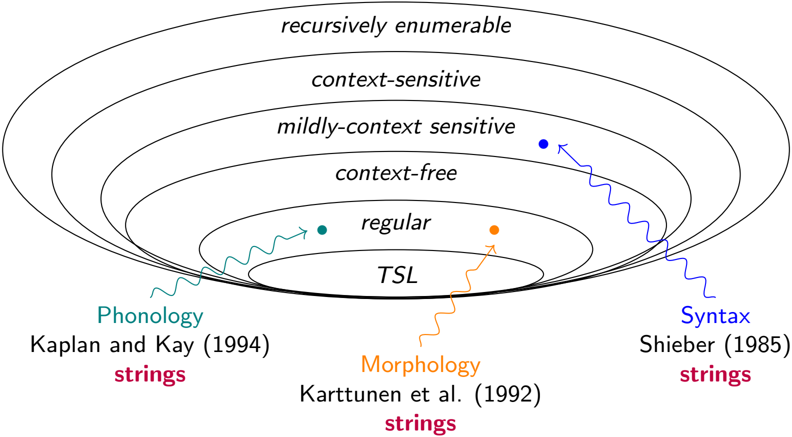

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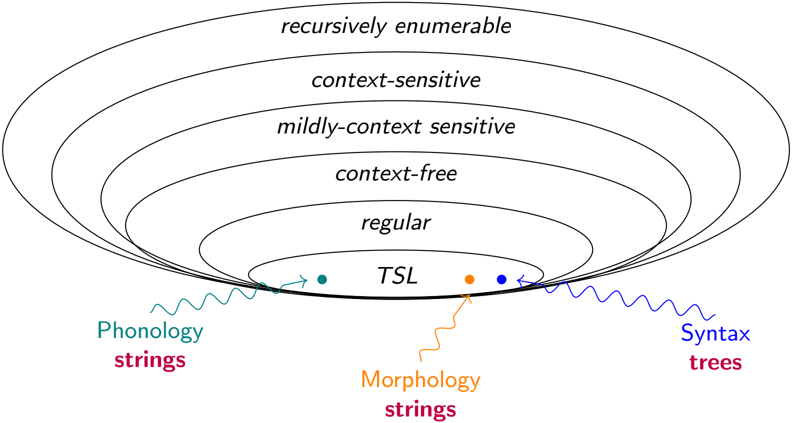

Conclusion

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  Finite, flat memory

Future Work

We are just getting started:

- autosegmental structures (Jardine 2017:i.a)
- morphological derivations (Chandlee 2017; Aksënova and De Santo 2017)
- mappings (Chandlee 2014; Chandlee and Heinz 2018:i.a.)
- syntax beyond Merge and Move (Graf 2017b; Vu 2018)

Join the Enterprise!

- typological universals/gaps
- TSL-analyses of phenomena/counterexamples
- artificial language learning experiments
- new formal results
- and much more ...

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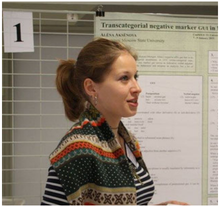
Tier-Based Strictly Local Morphology



- Work by Alëna Aksënova, Thomas Graf, and Sophie Moradi.
- It seems that **morphology is also TSL**.
  (Aksënova et al. 2016)
- Morphology $\equiv$ Morphotactics of underlying forms
  but see (Aksënova and De Santo 2017) on derivations
- We are unaware of any non-TSL patterns in this realm.
- Tight typology, explains gaps

Example: Circumfixation in Indonesian

- Indonesian has circumfixation with no upper bound on the distance between the two parts of the circumfix.

(8) maha siswa
big pupil
'student'

(9) *(ke-) maha siswa *(-an)
NMN- big pupil -NMN
'student affairs'

- Requirements: exactly one *ke-* and exactly one *-an*

Tier$_1$	contains all NMN affixes
Tier$_0$	contains all morphemes
n-**grams**	**\$an**, **ke\$**, **keke**, **anan**

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Tier$_1$	contains all NMN affixes	$	an			ke	ke	$
Tier$_0$	contains all morphemes							
n**-grams**	**$an**, **ke$**, **keke**, **anan**	$	an	m	s	ke	ke	$

Example: Swahili *vyo*

Swahili *vyo* is **either a prefix or a suffix**,
depending on presence of negation. (?)

(10) a.

a-	vi-	**soma**	**-vyo**
SBJ:CL.1-	OBJ:CL.8-	read	-REL:CL.8

‘reads’

b.

a-	si-	**vyo-**	vi-	**soma**
SBJ:CL.1-	NEG-	REL:CL.8-	read	-OBJ:CL.8

‘doesn’t read’

Example: Swahili *vyo* [cont.]

(11)

a. * a- **vyo-** vi- **soma**
SBJ:CL.1- REL:CL.8- OBJ:CL.8- read

b. * a- **vyo-** vi- **soma** **-vyo**
SBJ:CL.1- REL:CL.8- OBJ:CL.8- read -REL:CL.8

c. * a- si- **vyo-** vi- **soma** **-vyo**
SBJ:CL.1- NEG- REL:CL.8- OBJ:CL.8- read REL:CL.8-

d. * a- si- vi- **soma** **-vyo**
SBJ:CL.1- NEG- OBJ:CL.8- read REL:CL.8-

Example: Swahili *vyo* [cont.]

Generalizations About *vyo*

- may occur at most once
- must follow negation prefix *si-* if present
- is a prefix iff *si-* is present

Tier$_1$	contains *vyo*, *si*, and stem edges #	
Tier$_0$	contains all morphemes	
n-**grams**	**vyovyo**, **vyo##vyo**	"at most one *vyo*"
	vyosi, **vyo##si**	"*vyo* follows *si*"
	si##vyo, **$vyo##**	"*vyo* is prefix iff *si* present"

Explaining Typological Gaps

Restriction to TSL can also explain some typological gaps.

General Strategy

- Attested patterns **A** and **B** are TSL.
- But combined pattern **A**+**B** is not attested.
- Show that **A**+**B** is not TSL.

Example: Compounding Markers

- Russian has an infix *-o-* that may occur between parts of compounds.
- Turkish has a single suffix *-sı* that occurs at end of compounds.

(12)	vod	**-o-**	voz	**-o-**	voz	
	water	-COMP-	carry	-COMP-	carry	

‘carrier of water-carriers’

(13)	türk	bahçe	kapı	**-sı**	(***-sı**)
	turkish	garden	gate	-COMP	(*-COMP)

‘Turkish garden gate’

- **New Universal**
  If a language allows unboundedly many compound affixes, they are **infixes**.

Example: Compounding Markers [cont.]

- Russian and Turkish are TSL.

Tier$_1$	COMP affix and stem edges #
Russian n-grams	**oo**, **$o**, **o$**
Turkish n-grams	**sisi**, **$si**, **si#**

- The combined pattern would yield Ruskish: stem^{n+1}-si^{n}
- This pattern is not regular and hence **not TSL either**.

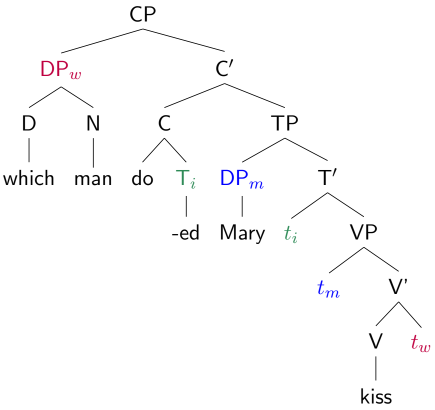
Interim Summary: Morphology

- While we know less about morphology than phonology at this point, it also seems to be TSL.
- Even complex patterns like Swahili *vyo* can be captured.
- At the same time, we get **new universals**:

Bounded Circumfixation No recursive process can be realized via circumfixation.

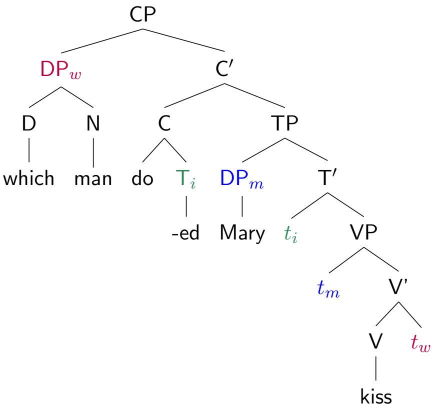
- We can reuse tools and techniques from TSL phonology, including learning algorithms.
- The cognitive resource requirements are also comparable.

MGs & Derivation Trees



Phrase Structure Tree

MGs & Derivation Trees



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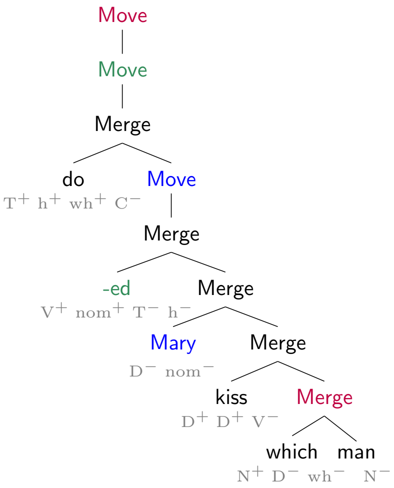

Derivation Tree

Constraints on Move

What about Move?

Suppose our MG is in **single movement normal form**,
i.e. every phrase moves at most once.
Then movement is regulated by two constraints. (Graf 2012a)

Constraints on Movement

Move	Every head with a negative Move feature is dominated by a matching Move node.
SMC	Every Move node is a closest dominating match for exactly one head.

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Tiers for Movement

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- Consequently, **Move dependencies are not local**.
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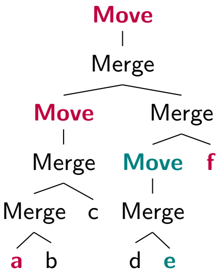

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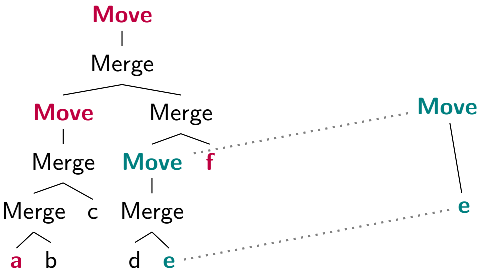

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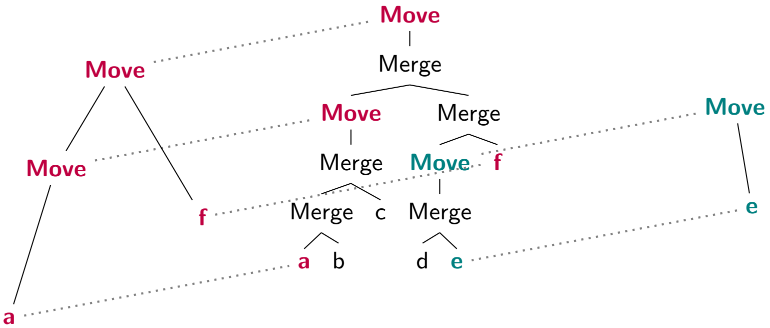
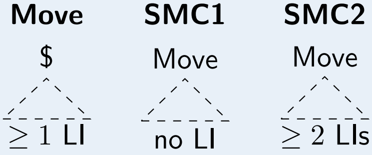


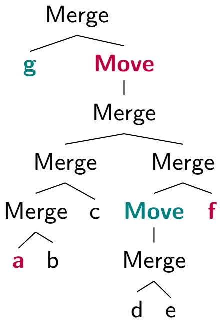
Move Constraints over Tiers

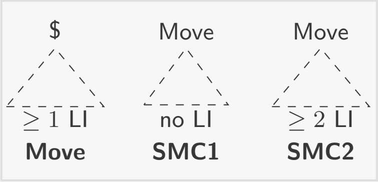
	Original	**Tier**
Move	Every head with a negative Move feature is dominated by a matching Move node.	Every lexical item has a **mother** labeled Move.
SMC	Every Move node is a closest dominating match for exactly one head.	Exactly one of a Move node's **daughters** is a lexical item.

Tree n-gram Templates



Example of Ill-Formed Derivation





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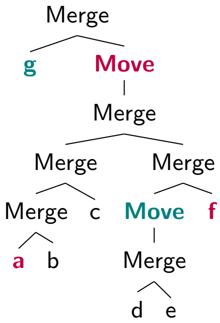

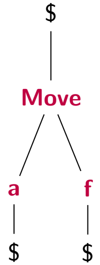

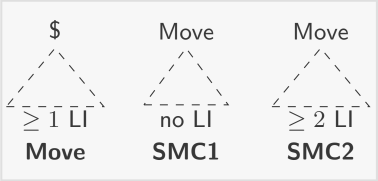

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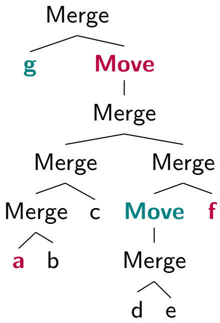

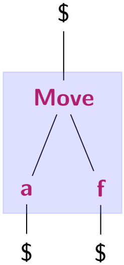

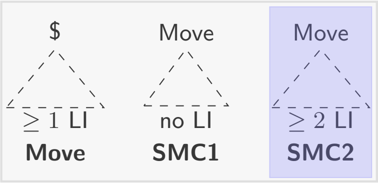

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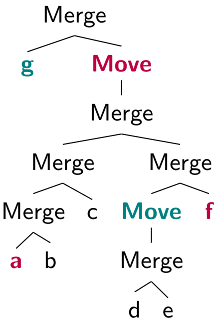

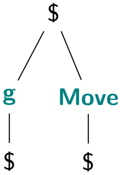

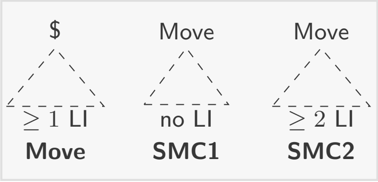

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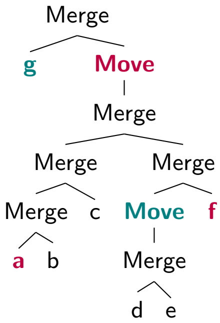

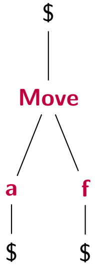

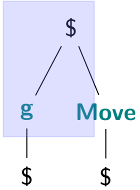

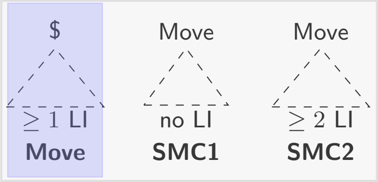

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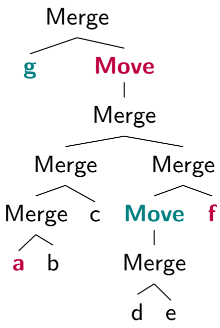

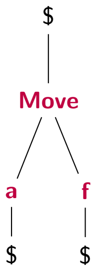

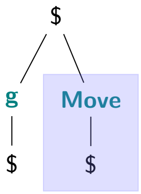

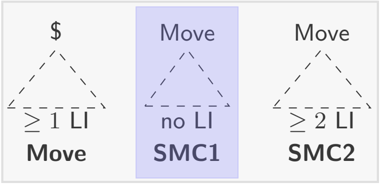

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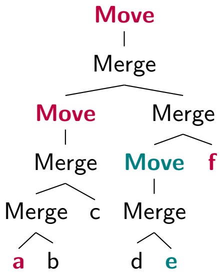

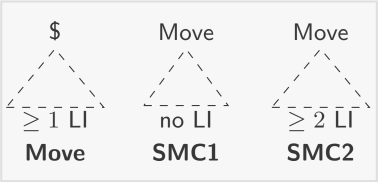

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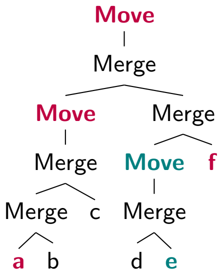

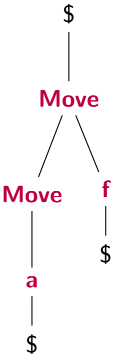

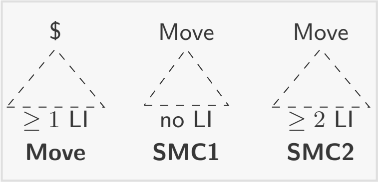

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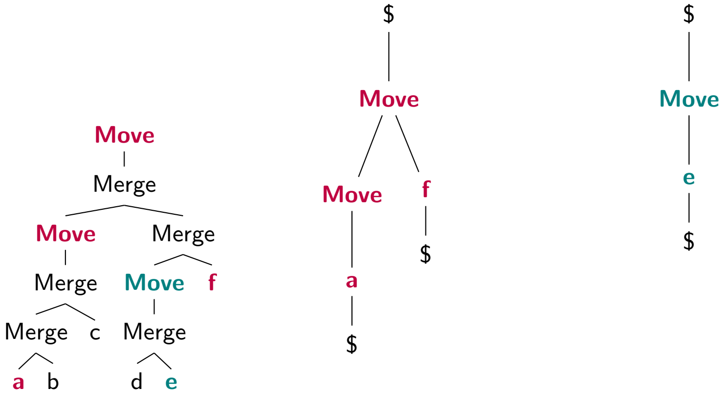

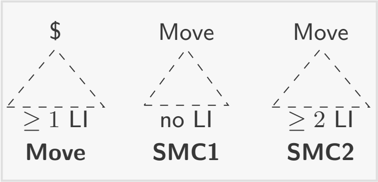

Remarks on Single Movement Normal Form

- Single Movement Normal Form seems unrealistic.
- **But:** does not rule out multiple movement steps, only says there is **single feature trigger in derivation**
- Intermediate landing sites can be part of structure built from the derivation tree.

A Conjecture on Movement Restrictions (Graf 2017a)

- Conversion of an MG into single movement normal form causes large blow-up in size of lexicon.
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- The more fixed the position of movers, the smaller the blow-up $\Rightarrow$ island constraints as a means to limit lexical blow-up?

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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

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 (**?**)
  - SRC $<$ ORC in English (**?**)
  - SRC $<$ ORC in East-Asian (**?**)
  - quantifier scope preferences (Pasternak 2016)

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)

Samala (Revisited)

Sibilant Harmony in SAMALA (McMullin 2016)

1) Unbounded sibilant harmony

a. /k-su-ʃojin/	kʃuʃojin	"I darken it"
b. /k-su-k'ili-mekeken-ʃ/	kʃuk'ilimekeketʃ	"I straighten up"

2) /s/→ [ʃ] when preceding (adjacent) [t, n, l]

a. /s-lok'in/	ʃlok'in	"he cuts it"
b. /s-tepuʔ/	ʃtepuʔ	"he gambles"

3) Long-distance agreement overrides local disagreement

a. /s-iʃt-iʃti-jep-us/	sististijepus	"they show him"
b. /s-net-us/	snetus	"he does it to him"

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Structure-Sensitive TSL (SS-TSL)

Samala Sibilant Harmony (Revisited)

- anticipatory sibilant harmony
- palatalization to avoid local restrictions
- sibilant harmony overrides palatalization

s n e t u s

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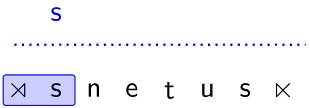

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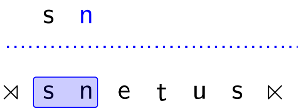

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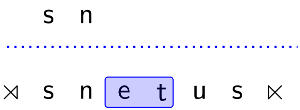

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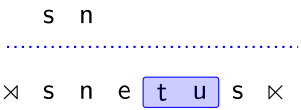

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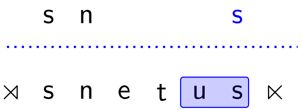

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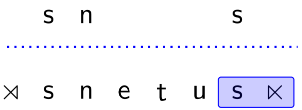

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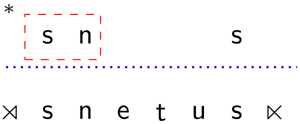

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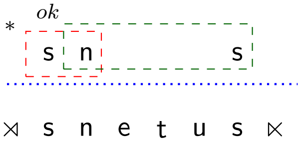

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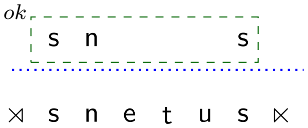

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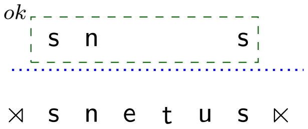
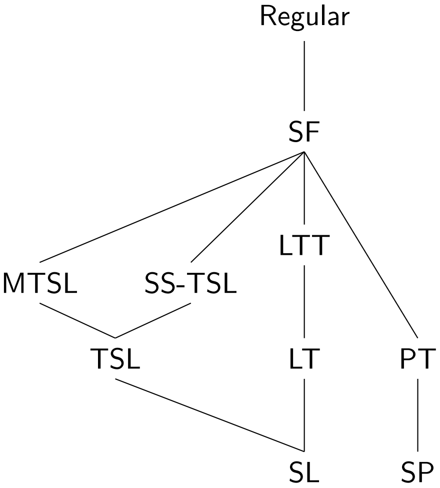


Grammar

T $= \{\ \sigma : \sigma \in \{$s, ʃ$\} \vee (\sigma \in \{$ n, t, l $\} \wedge$ s $\prec^+ \sigma)\}$
S $= \{$*sʃ, *sʃ, *sn(¬s), *st(¬s), *sl(¬s)$\}$

SS -TSL: Relations to other Classes



The TSL Neighborhood: a Plethora of Combinations