Structure Sensitive Tier Projection: Applications and Formal Properties

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The Paper in a Nutshell

The research program

- a tight upper bound to the complexity of natural language dependencies?

Subregular Hypothesis for Phonology

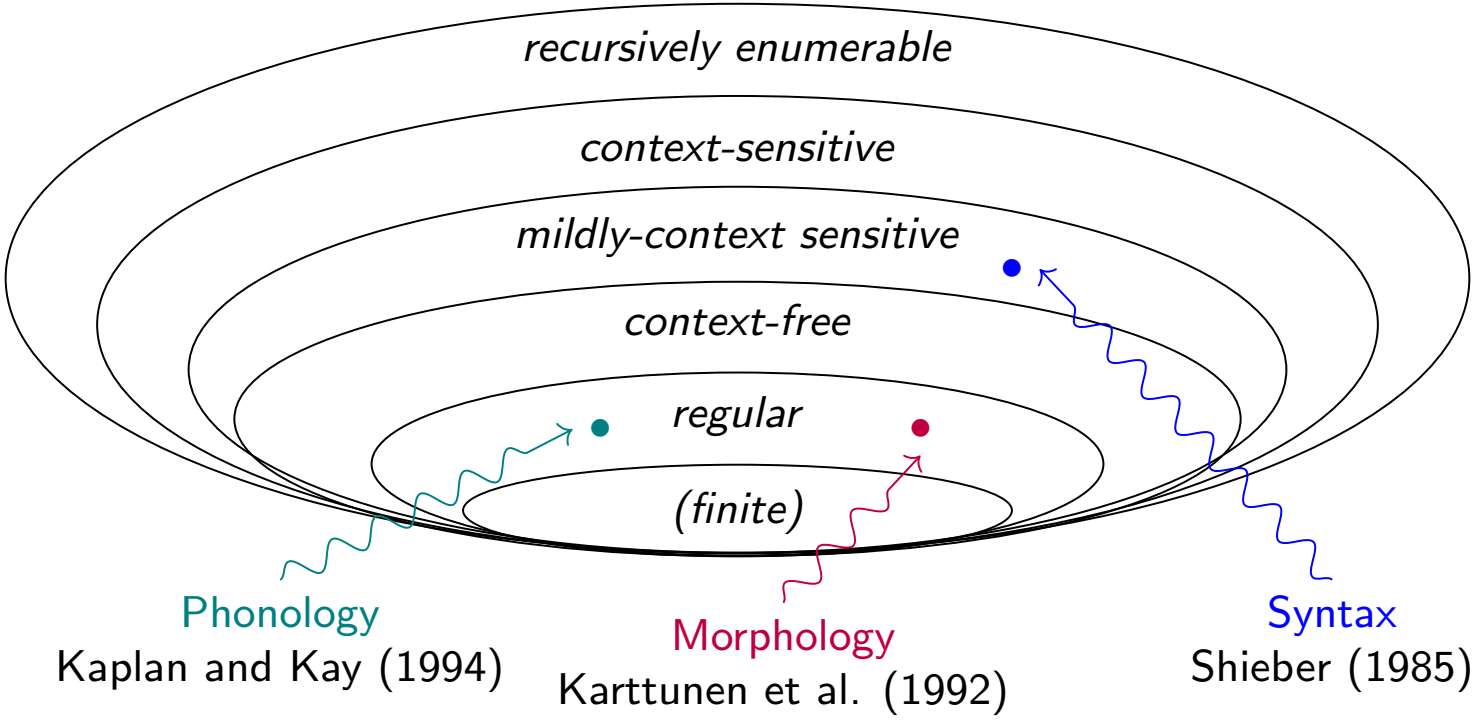
- Tier-based Strictly Local seems to be the right fit;
- But ... several outliers have been reported!

In This Talk

We explore (minimal) extensions to TSL

Outline

Computational Theories of Language

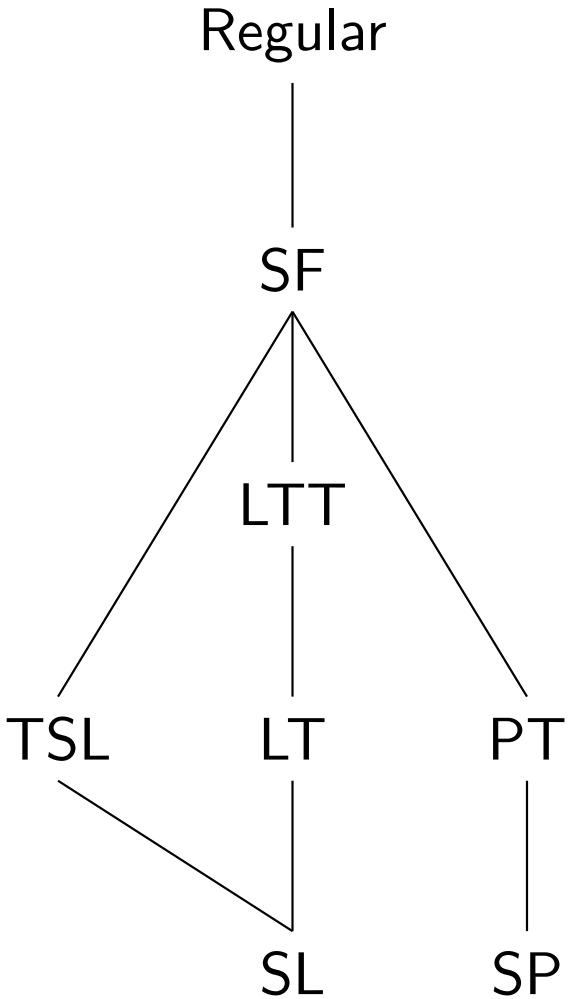


Precise predictions for:

- typology → e.g. no center embedding in phonology
- learnability → e.g. no Gold learning for regular languages
- cognition → e.g. finitely bounded working memory

Phonology as a Subregular System

Often forgotten: hierarchy of **subregular languages**
(McNaughton and Papert 1971; Rogers et al. 2010; Heinz et al. 2011; Graf 2017)



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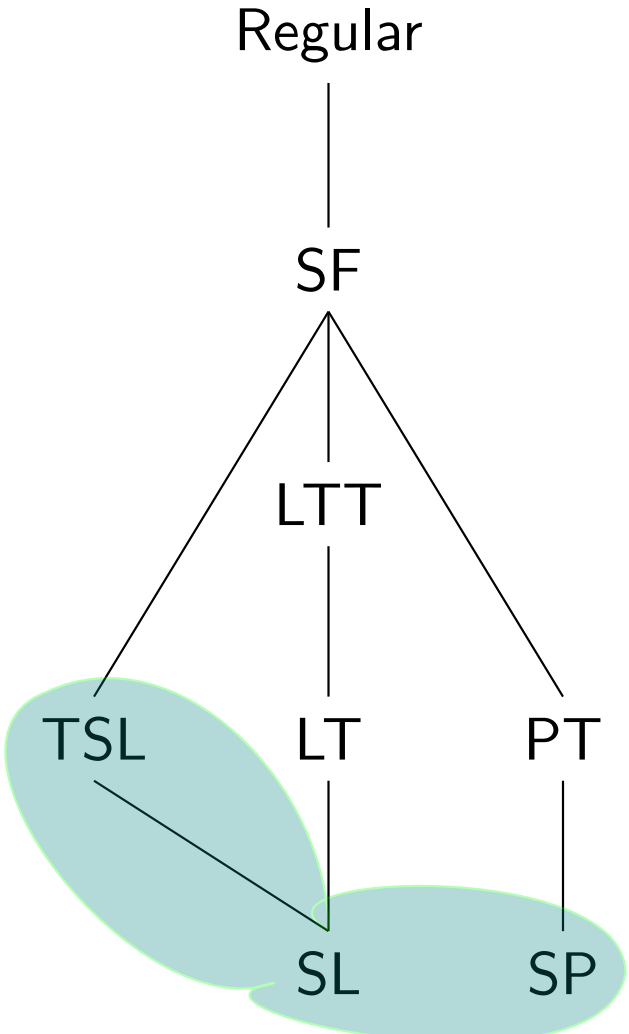

Local Dependencies in Phonology are SL

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

(1) a. * rad
b. rat

Example: Word-final devoicing

- Forbid word final voiced segments: *[+voice]$
- **German**: *z$, *v$,*d$ ($ = word edge).

$ r a d $ $ r a t $

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Unbounded Dependencies Are Not SL

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

(2) a. * ha**s**xintilawa**ʃ**
b. * ha**ʃ**xintilawa**s**
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Example: Samala

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- **Problem**: SL limited to locality domains of size n;
- **Solution**: locality over **tiers**. (Goldsmith 1976)

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

- E_T: Projection of selected segments on a tier T;
- Strictly local constraints over T determine wellformedness;

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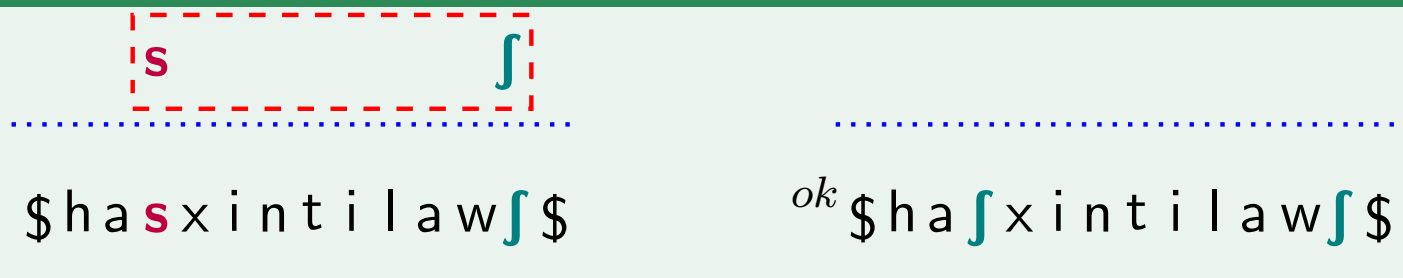

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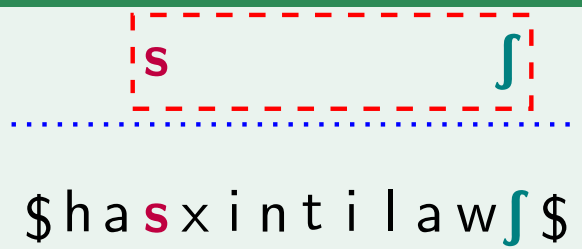

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- Captures wide range of phonotactic dependencies (McMullin 2016)
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- Low resource demands
- Rules out unattested patterns (cf. Aksënova et al. 2016)
- **But** not every long-distance pattern is TSL! (McMullin 2016; Mayer and Major 2018; Graf and Mayer 2018)

Full Samala: A TSL Outlier

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-tepu?/	ʃtepu?	"he gambles"

3) Long-distance agreement overrides local disagreement

a.	/s-iʃt-iʃti-jep-us/	sististijepus	"they show him"
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Is there a TSL grammar for the complete pattern?

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Sibilant Harmony in Samala (1/3)

Generalization

- Anticipatory Sibilant harmony

Grammar

T = {s, ʃ, z, ʒ} S = {*sʃ, *ʃs, ... }

^{ok} k ʃ u ʃ o j i n * k s u ʃ o j i n

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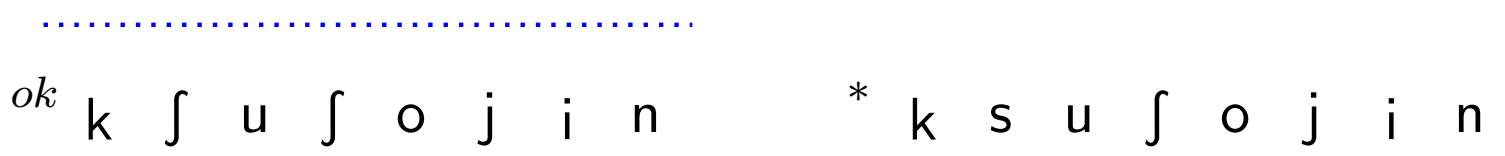

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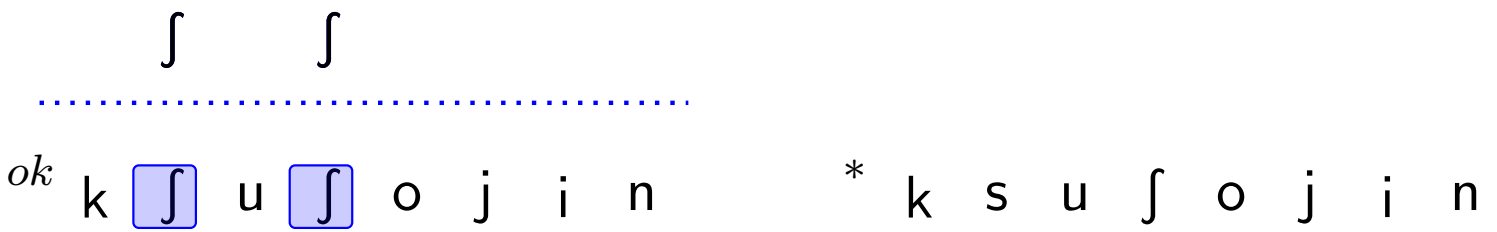

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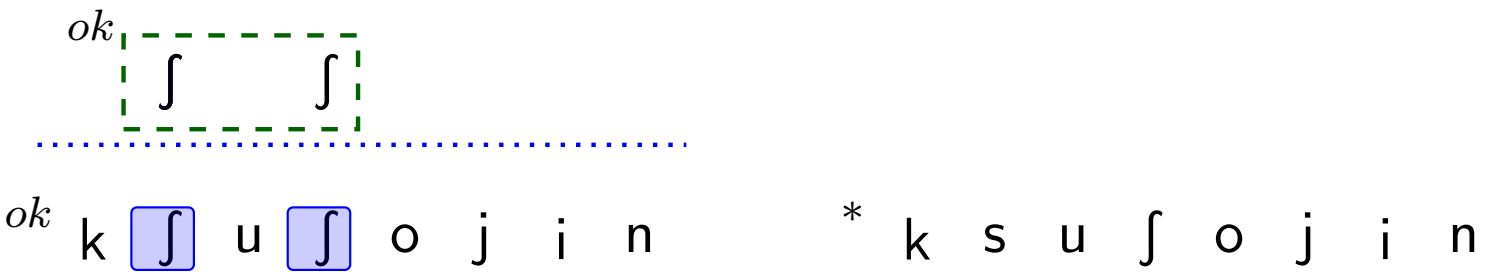

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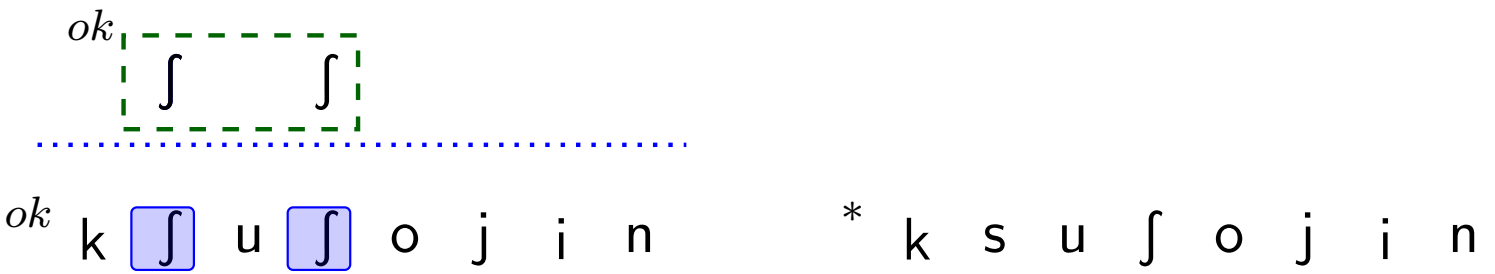

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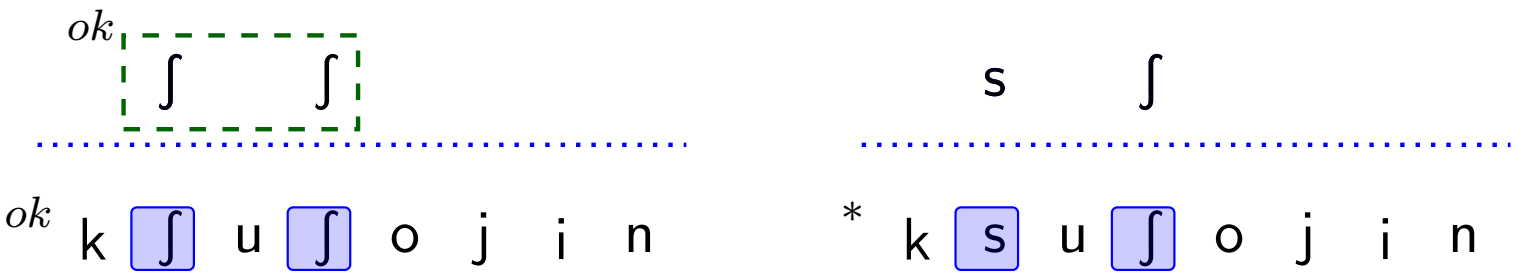


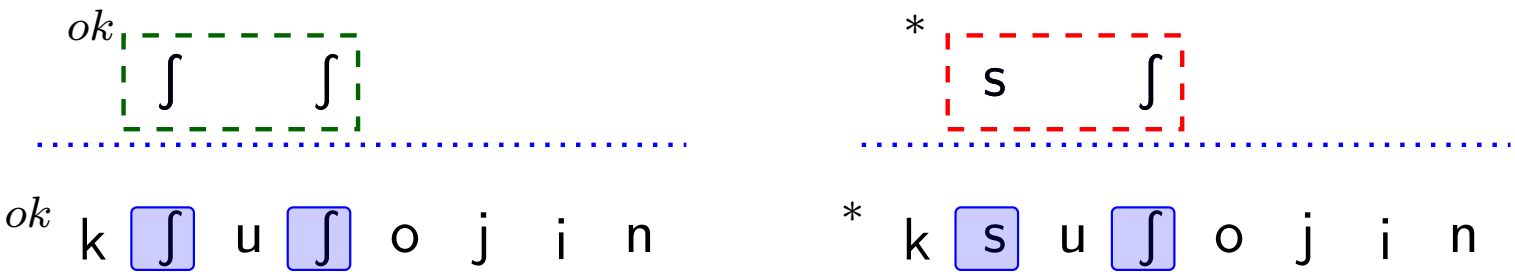
Sibilant Harmony in Samala (1/3)

Generalization

- Anticipatory Sibilant harmony

Grammar

T = {s, ʃ, z, ʒ} S = {*sʃ, *ʃs, ... }



Sibilant Harmony in Samala (2/3)

Generalization

- Anticipatory Sibilant harmony
- Local restriction against [*sn, *st, *sl]

Grammar

T = {s, ʃ, z, ʒ, **n**, **t**, **l**} S = {*sʃ, *ʃs, *sn, *st, *sl, ... }

^{ok} ʃ t e p u ʔ

* s t e p u ʔ

Sibilant Harmony in Samala (2/3)

Generalization

- Anticipatory Sibilant harmony
- Local restriction against [*sn, *st, *sl]

Grammar

T = {s, ʃ, z, ʒ, **n**, **t**, **l**} S = {*sʃ, *ʃs, *sn, *st, *sl, ... }

ʃ t

ok ʃ t e p u ʔ

* s t e p u ʔ

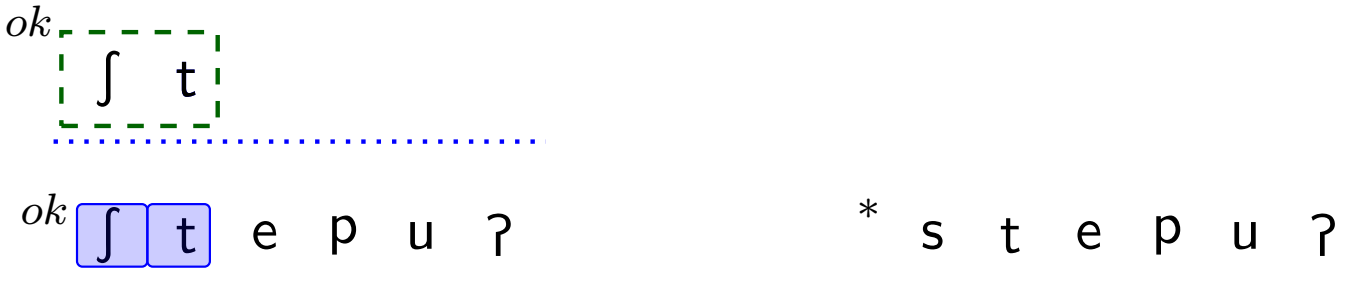
Sibilant Harmony in Samala (2/3)

Generalization

- Anticipatory Sibilant harmony
- Local restriction against [*sn, *st, *sl]

Grammar

T = {s, ʃ, z, ʒ, **n**, **t**, **l**} S = {*sʃ, *ʃs, *sn, *st, *sl, ... }



Sibilant Harmony in Samala (2/3)

Generalization

- Anticipatory Sibilant harmony
- Local restriction against [*sn, *st, *sl]

Grammar

T = {s, ʃ, z, ʒ, **n**, **t**, **l**} S = {*sʃ, *ʃs, *sn, *st, *sl, ... }

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Generalization

- Anticipatory Sibilant harmony
- Local restriction against [*sn, *st, *sl]

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T = {s, ʃ, z, ʒ, **n**, **t**, **l**} S = {*sʃ, *ʃs, *sn, *st, *sl, ... }

Sibilant Harmony in Samala (3/3)

Generalization

- anticipatory sibilant harmony [*sʃ, *sʃ]
- palatalization to avoid local restriction [*sn, *st, *sl]
- sibilant harmony overides palatalization

Grammar

T = {s, ʃ, n, t, l} S = {*sʃ, *sʃ, *sn, *st, *sl }

^{ok} s n e t u s

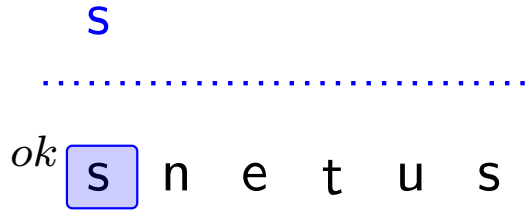
Sibilant Harmony in Samala (3/3)

Generalization

- anticipatory sibilant harmony [*sʃ, *sʃ]
- palatalization to avoid local restriction [*sn, *st, *sl]
- sibilant harmony overides palatalization

Grammar

T = {s, ʃ, n, t, l} S = {*sʃ, *sʃ, *sn, *st, *sl }



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Generalization

- anticipatory sibilant harmony [*sʃ, *sʃ]
- palatalization to avoid local restriction [*sn, *st, *sl]
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Grammar

T = {s, ʃ, n, t, l} S = {*sʃ, *sʃ, *sn, *st, *sl }

s n

.....

ok s n e t u s

Sibilant Harmony in Samala (3/3)

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- anticipatory sibilant harmony [*sʃ, *sʃ]
- palatalization to avoid local restriction [*sn, *st, *sl]
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	s	n		t		
^{ok}	s	n	e	t	u	s

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	s	n		t		s
ok	s	n	e	t	u	s

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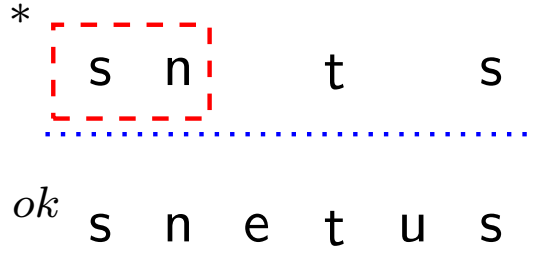

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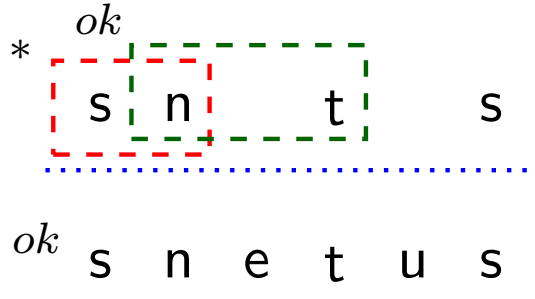

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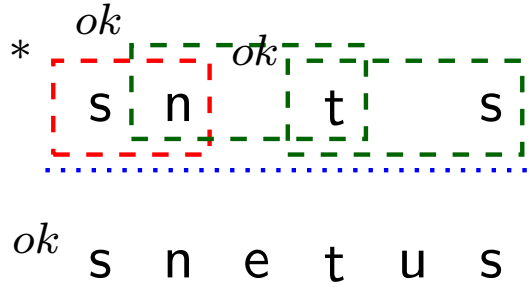

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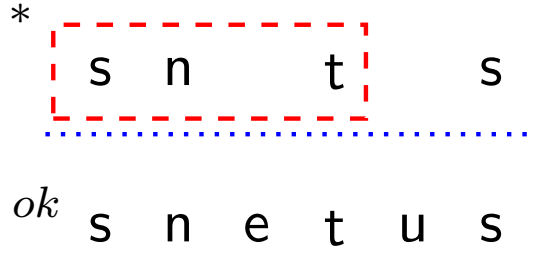

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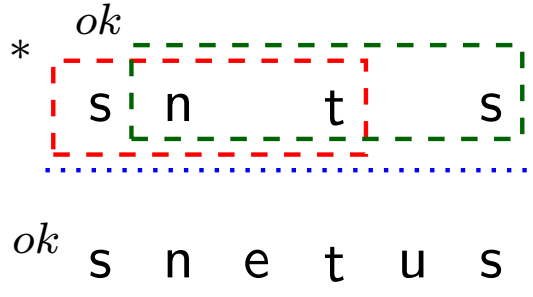

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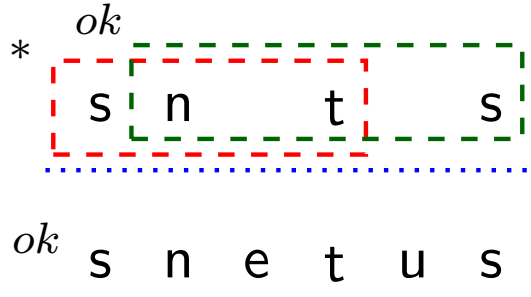

No TSL grammar can capture this patter...

Input-Sensitive TSL (ITSL) Languages

E_T

Tier projection controlled by:

1. label of segment

TSL

1

TSL languages are characterized by:

- a 1-local projection function E_T;
- strictly k-local constraints applied on T.

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Idea:

- E_T is an input-strictly local transduction (Chandlee 2014)
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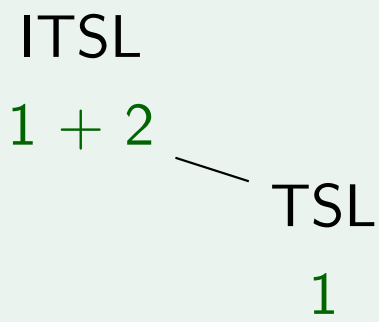
Input-Sensitive TSL (ITSL) Languages

E_T

Tier projection controlled by:

1. label of segment
2. local context



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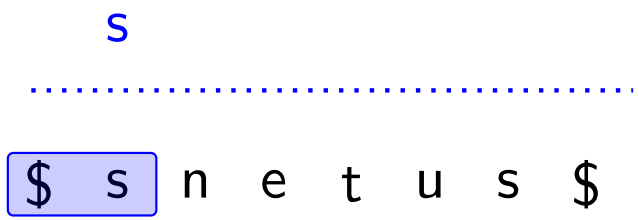

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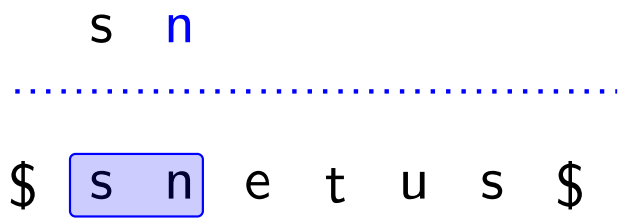

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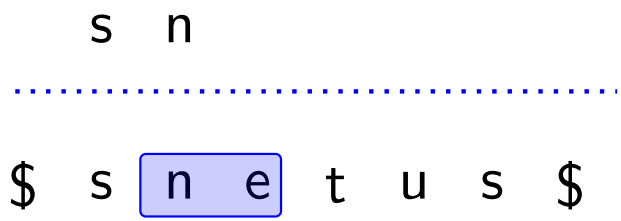

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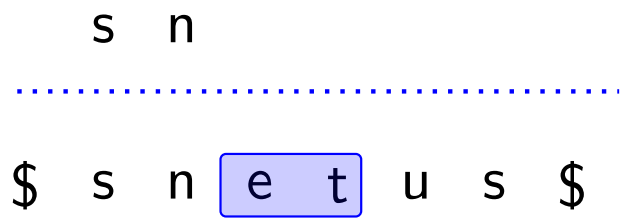

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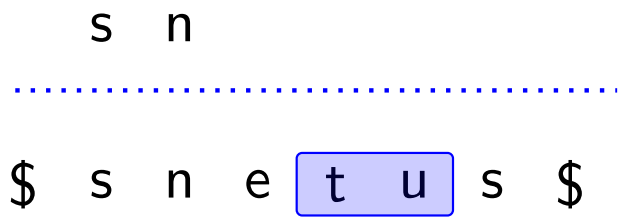

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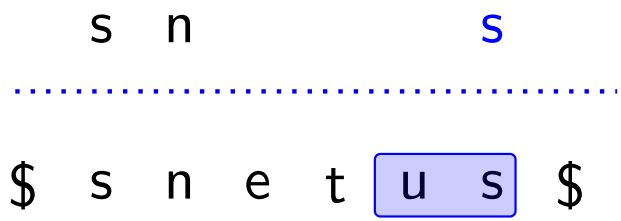

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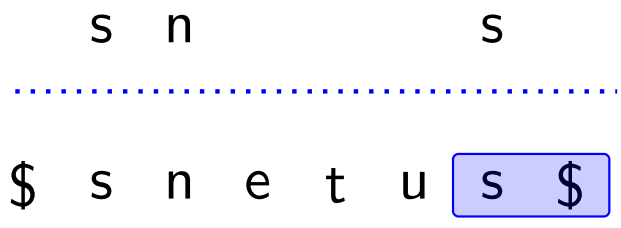

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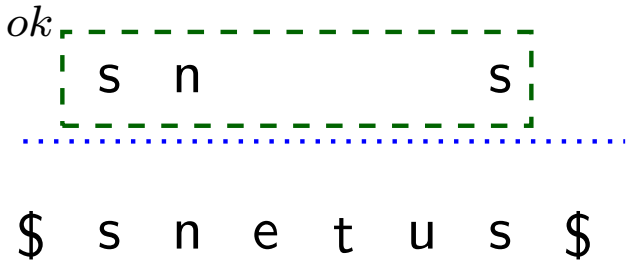

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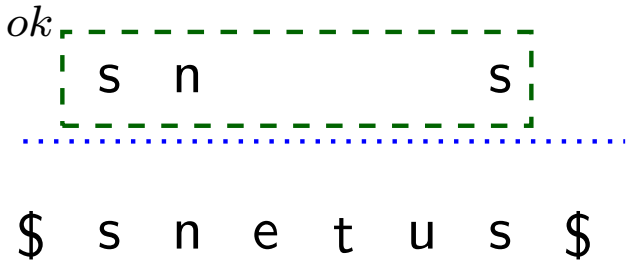
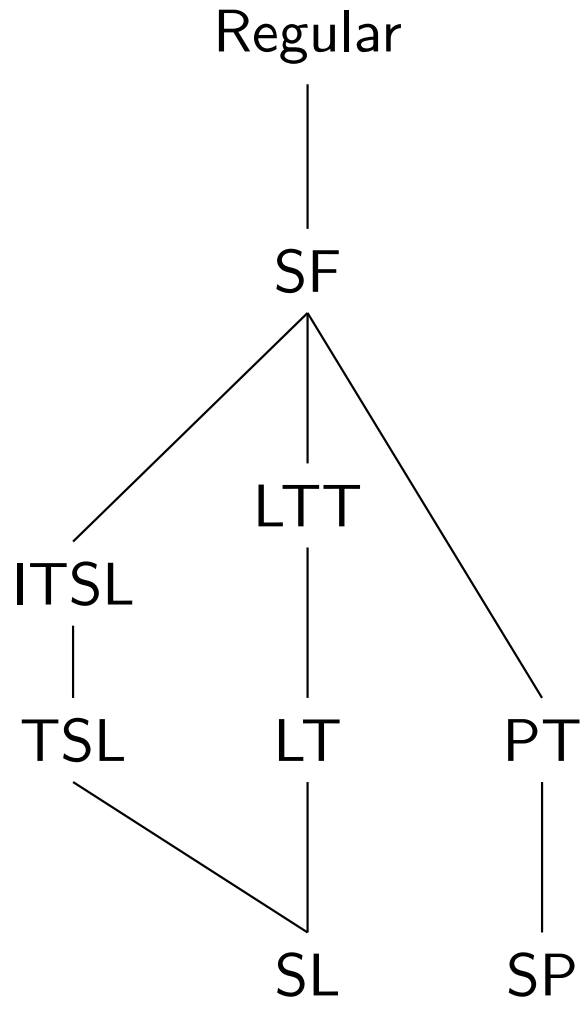


Grammar

$T = \{ \sigma : \sigma \in \{s, ʃ\} \vee (\sigma \in \{ n, t, l \} \wedge s \prec^{+} \sigma)\}$

$S = \{*sʃ, *sʃ, *sn(\neg s), *st(\neg s), *sl(\neg s)\}$

ITSL: Relations to other Classes?



Summing Up

Tracing Back our Steps

- TSL as a strong upper bound to phonotactic complexity.
- but there are patterns that are unaccounted for!

ITSL

- Natural generalization of TSL
- Covers a variety of patterns

  Korean vowel harmony, UTP, Yaka nasal harmony, ...
- Preserves TSL's computational properties
  - contained expressive power
  - Gold learnable

    Efficiently learnable? (cf. McMullin et al. 2019)
  - (lack of) closure properties

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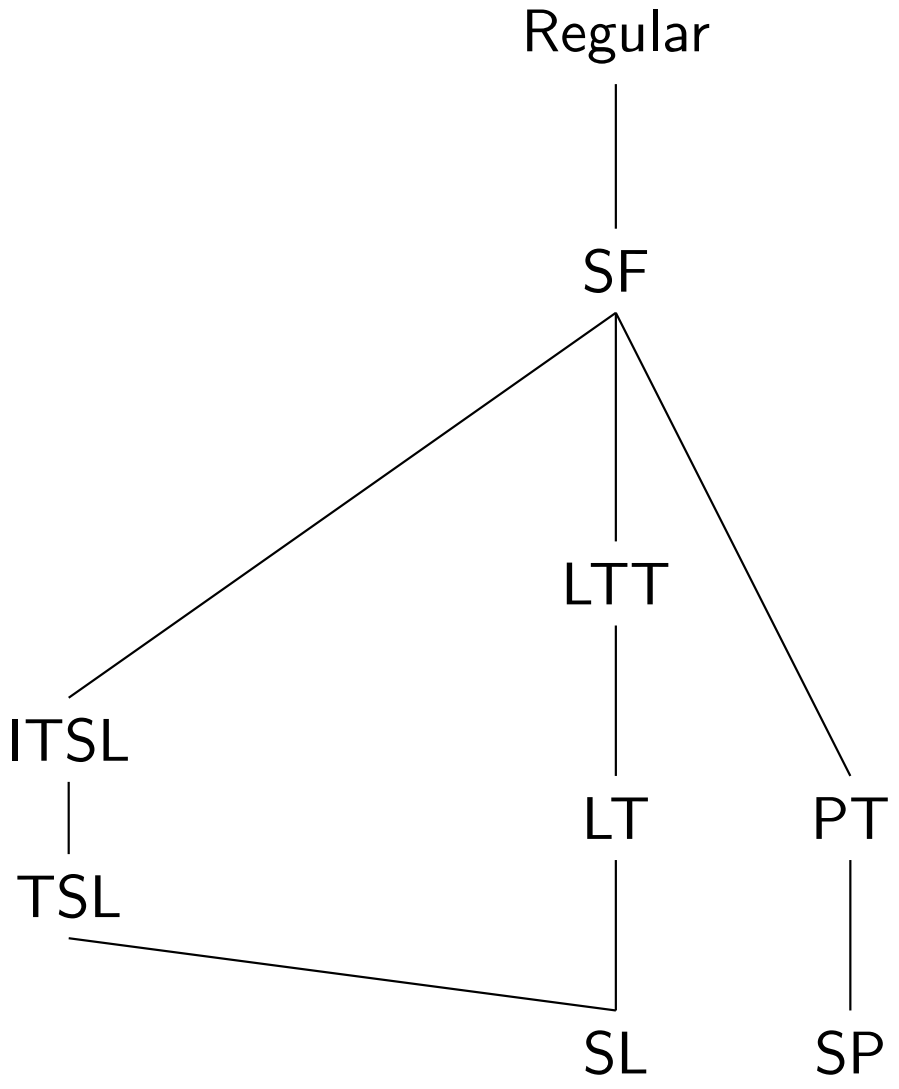
    Non-closure under intersection!

Exploring the TSL Neighborhood



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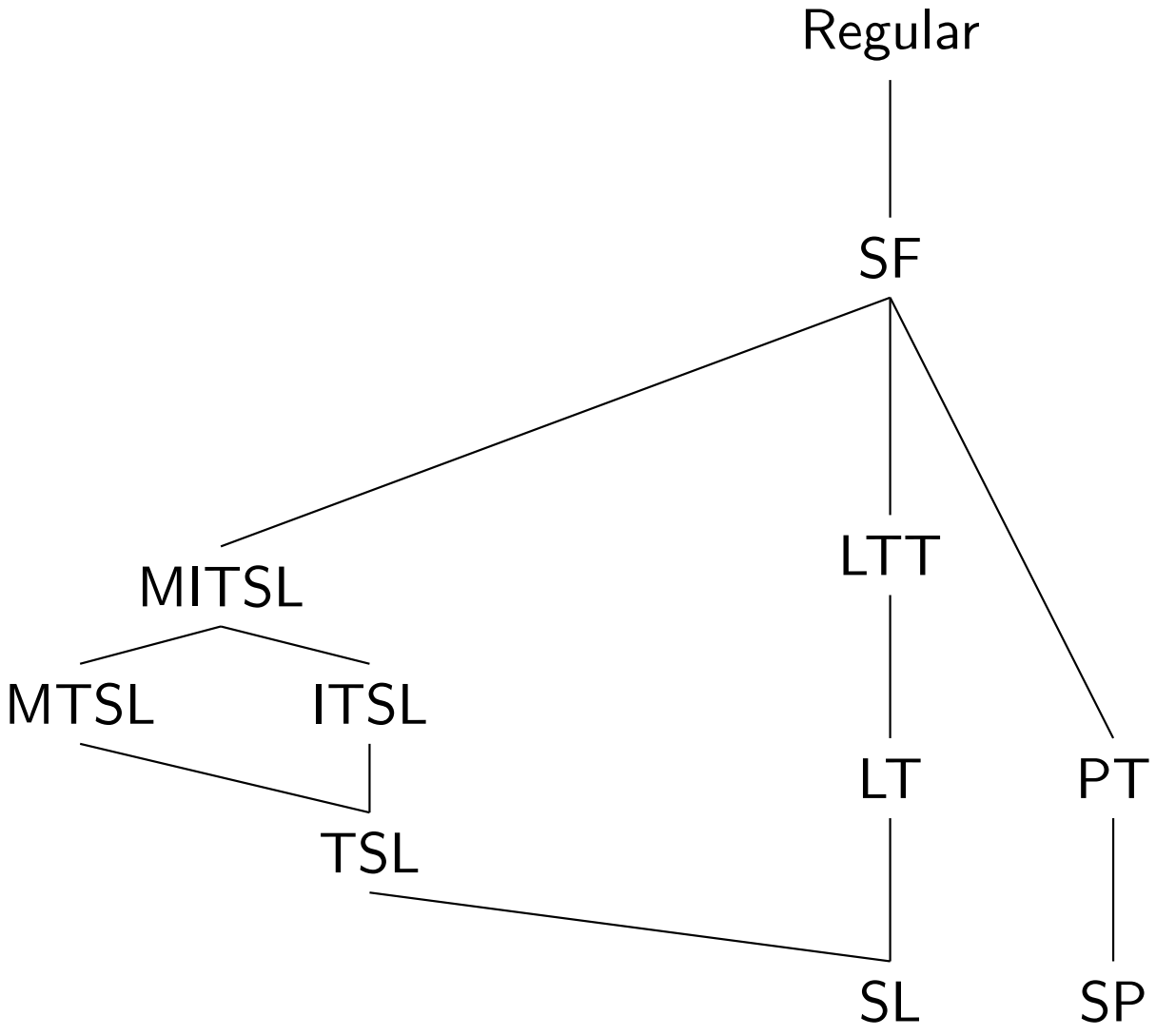

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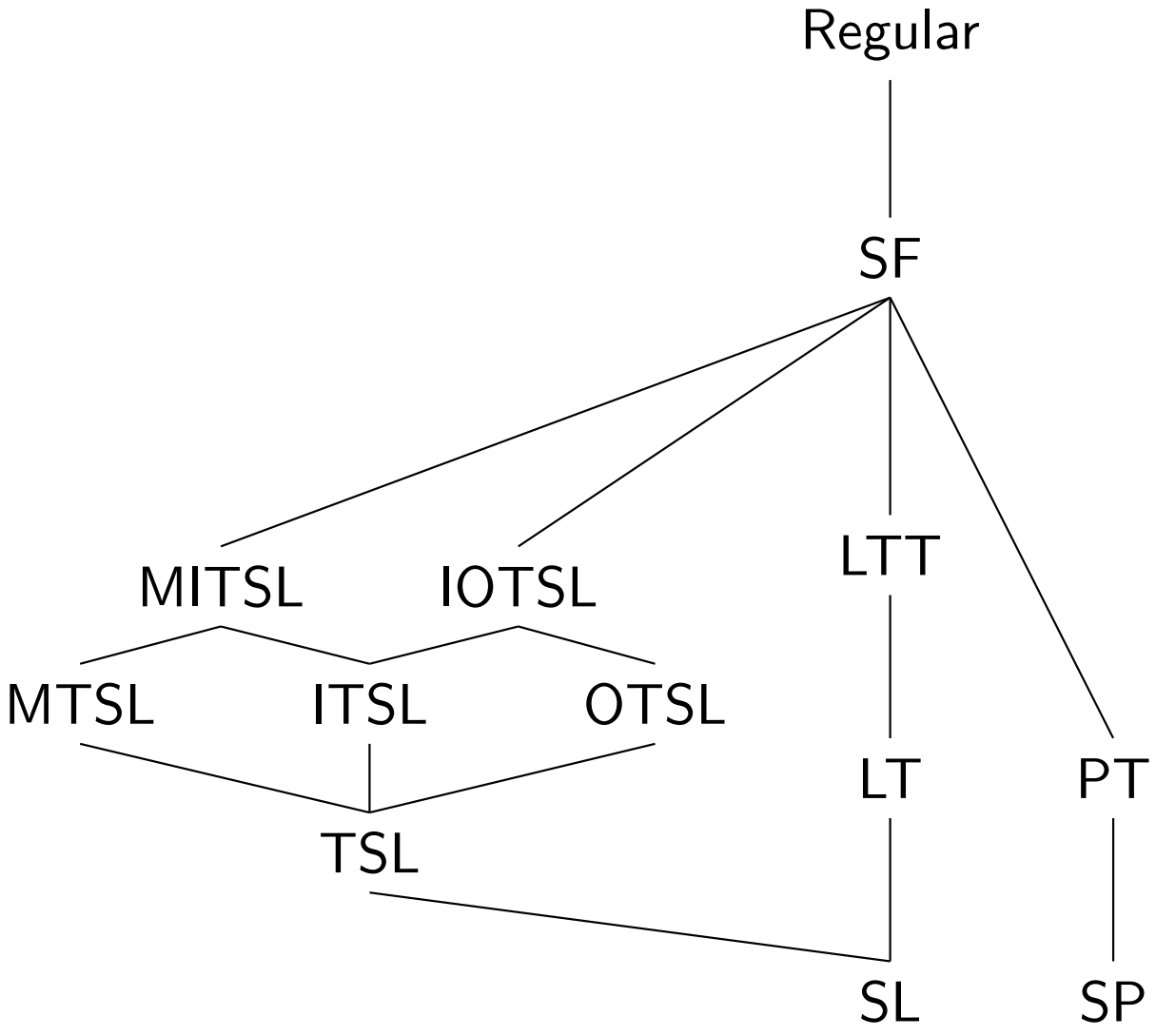

Future Work

- Test typological predictions
- Cross-domain (syntax, semantics) generalizations
  (cf. Vu et al. 2019; Graf and Shafiei 2019; Graf and De Santo 2019)
- Further study of the TSL neighborhood
  (cf. Mayer and Major 2018; Graf and Mayer 2018)
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Thank you!

Acknowledgments

This work was supported by the National Science Foundation under Grant No. BCS-1845344.

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Appendix

Closure Properties of Subregular Classes

	SL	TSL	MTSL	ITSL	IOTSL	SF	Reg
$\cup$	$\times$	$\times$	$\times$	$\times$	$\times$	✓	✓
$\cap$	✓	$\times$	✓	$\times$	$\times$	✓	✓
Relabeling	$\times$	$\times$	$\times$	$\times$	$\times$	$\times$	✓
Complement	$\times$	$\times$	$\times$	$\times$	$\times$	✓	✓

(I)TSL vs. SP

- **Strictly piecewise** (SP) grammars: forbidden **subsequences**.
  Precedence (not successor) as the core relation.

Sibilant harmony

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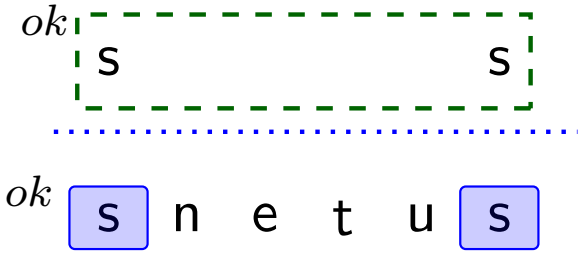

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(I)TSL vs. SP: Incomparability

(I)TSL $\not\subseteq$ SP

SAMALA's harmony is ITSL but not SP

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Another TSL Outlier

Sibilant Harmony in Imdlawn Tashlhiyt (McMullin 2016)

1) Underlying causative prefix /s(ː)-/

	Base	*Causative*	
a.	uga	sː-uga	"be evacuated"
b.	asːtwa	s-asːtwa	"settle, be levelled"

2) Sibilant harmony

	Base	*Causative*	
a.	fiaʃr	ʃ- fiaʃr	"be full of straw, of discord"
b.	nza	zː-nza	"be sold"

3) Sibilant voicing harmony blocked

	Base	*Causative*	
a.	ukz	sː-ukz	"recognize"
b.	qːuʒːi	ʃ- quʒːi	"be dislocated, broken"

Can we write a TSL grammar to capture this pattern?

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Generalization (1/2)

Sibilants must agree in anteriority and voicing.

Grammar

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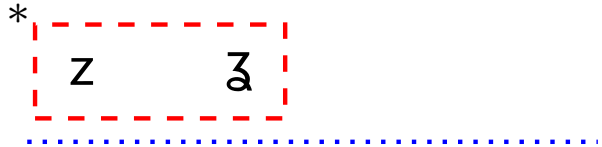

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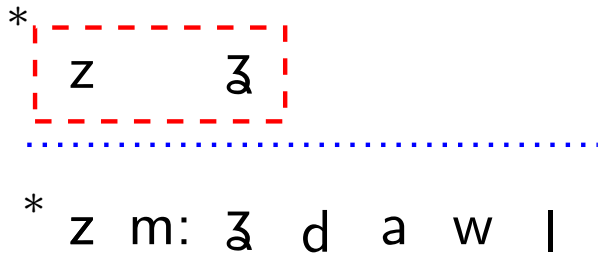

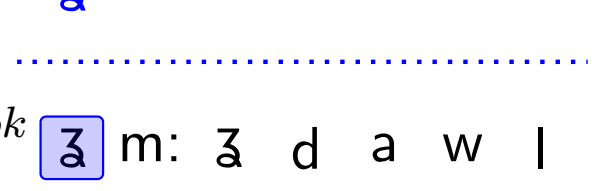

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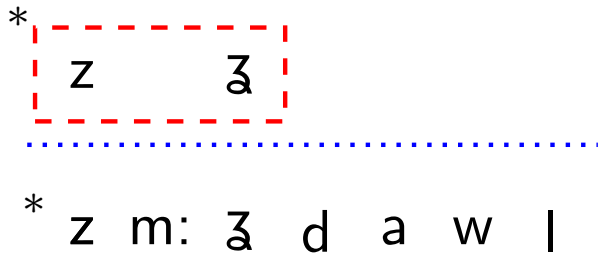

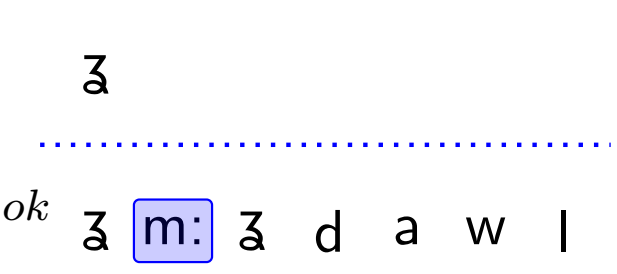

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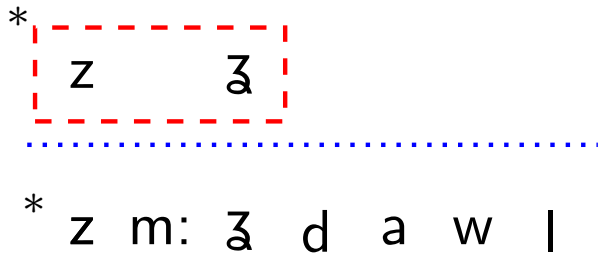

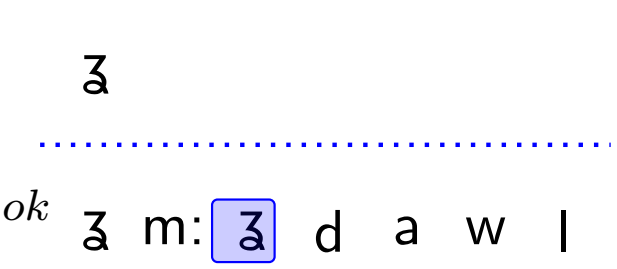

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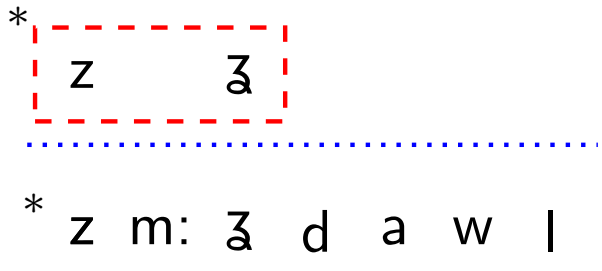

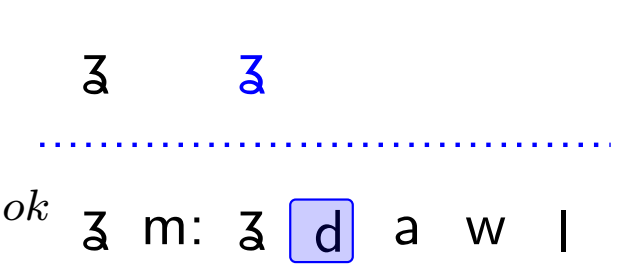

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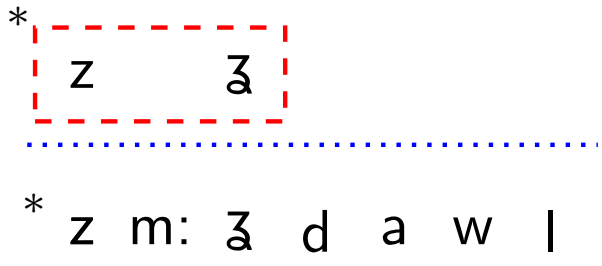

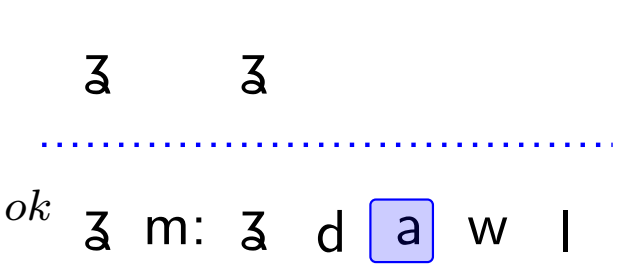

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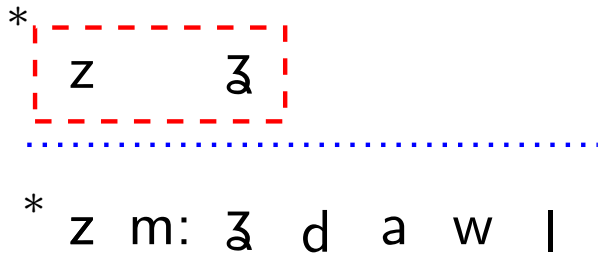

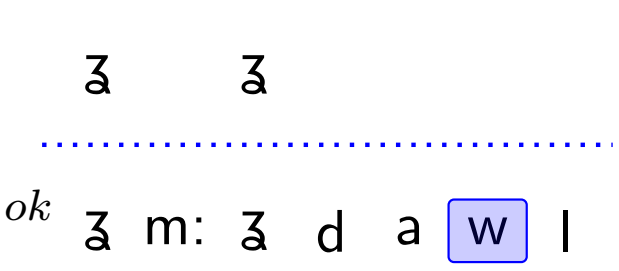

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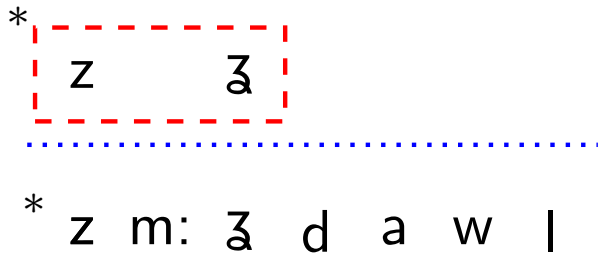

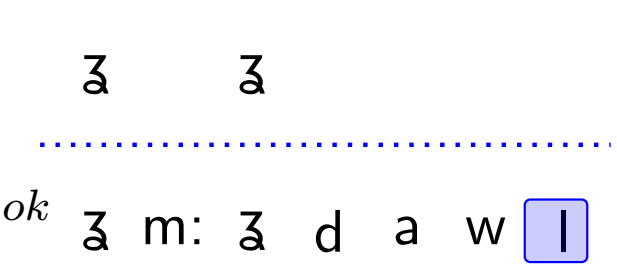

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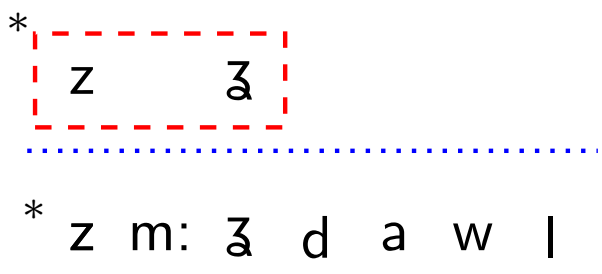

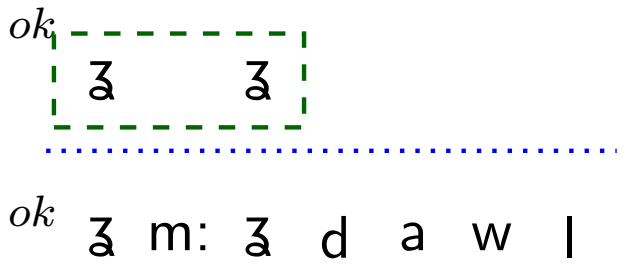

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Generalization (2/2)

Voiceless obstruents block agreement in voicing.

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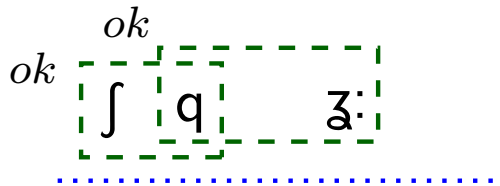

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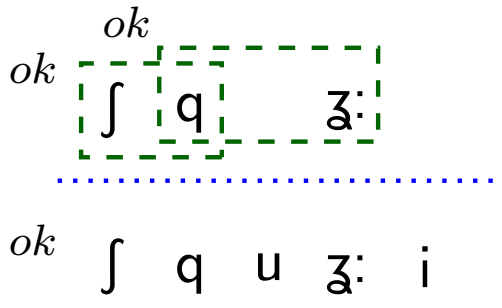
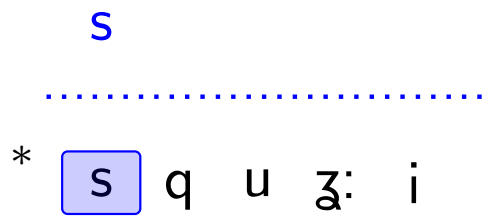
$S = \{$ *sʒ, *sz, *sʃ, *ʒs, *ʃs, *zs, *zʃ, *zʒ, *ʃz, *ʃʒ, * ʒʃ, *ʒz $\}$





Sibilant Harmony in Imdlawn Tashlhiyt

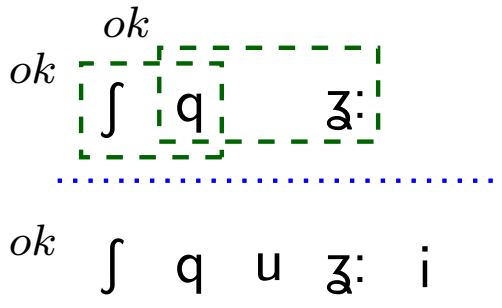
Generalization (2/2)

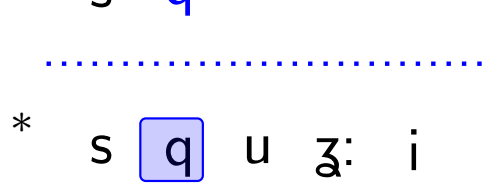
Voiceless obstruents block agreement in voicing.

Grammar

$T = \{$ ʒ, s, z, ʃ, q$\}$

$S = \{$ *sʒ, *sz, *sʃ, *ʒs, *ʃs, *zs, *zʃ, *zʒ, *ʃz, *ʃʒ, * ʒʃ, *ʒz $\}$





Sibilant Harmony in Imdlawn Tashlhiyt

Generalization (2/2)

Voiceless obstruents block agreement in voicing.

Grammar

$T = \{$ ʒ, s, z, ʃ, q$\}$

$S = \{$ *sʒ, *sz, *sʃ, *ʒs, *ʃs, *zs, *zʃ, *zʒ, *ʃz, *ʃʒ, * ʒʃ, *ʒz $\}$

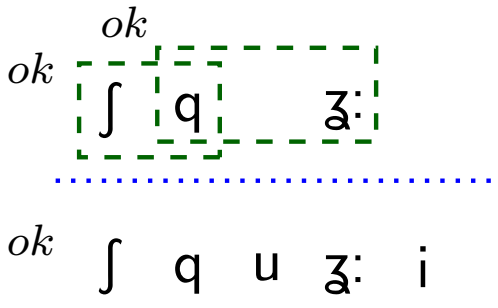
Sibilant Harmony in Imdlawn Tashlhiyt

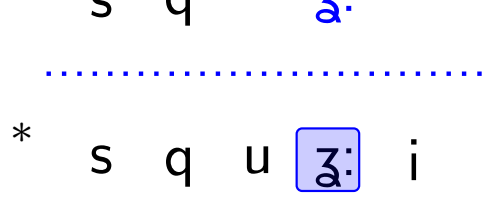
Generalization (2/2)

Voiceless obstruents block agreement in voicing.

Grammar

$T = \{$ ʒ͡ʕ, s, z, ʃ, q$\}$
$S = \{$ *sʒ͡ʕ, *sz, *sʃ, *ʒ͡ʕs, *ʃs, *zs, *zʃ, *zʒ͡ʕ, *ʃz, *ʃʒ͡ʕ, * ʒ͡ʕʃ, *ʒ͡ʕz $\}$





Sibilant Harmony in Imdlawn Tashlhiyt

Generalization (2/2)

Voiceless obstruents block agreement in voicing.

Grammar

$T = \{$ ʒ, s, z, ʃ, q$\}$

$S = \{$ *sʒ, *sz, *sʃ, *ʒs, *ʃs, *zs, *zʃ, *zʒ, *ʃz, *ʃʒ, * ʒʃ, *ʒz $\}$

Sibilant Harmony in Imdlawn Tashlhiyt

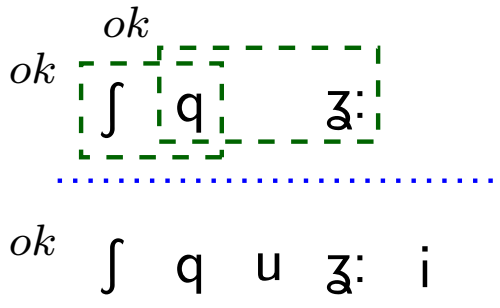
Generalization (2/2)

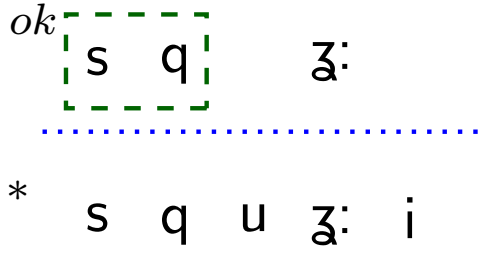
Voiceless obstruents block agreement in voicing.

Grammar

$T = \{$ ʒ, s, z, ʃ, q$\}$

$S = \{$ *sʒ, *sz, *sʃ, *ʒs, *ʃs, *zs, *zʃ, *zʒ, *ʃz, *ʃʒ, *ʒʃ, *ʒz $\}$





Sibilant Harmony in Imdlawn Tashlhiyt

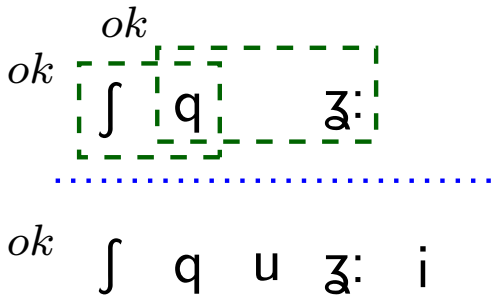
Generalization (2/2)

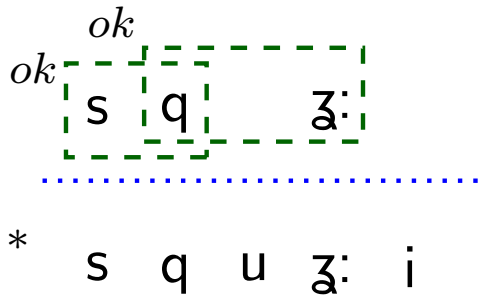
Voiceless obstruents block agreement in voicing.

Grammar

$T = \{$ ʒ, s, z, ʃ, q$\}$

$S = \{$ *sʒ, *sz, *sʃ, *ʒs, *ʃs, *zs, *zʃ, *zʒ, *ʃz, *ʃʒ, * ʒʃ, *ʒz $\}$





Sibilant Harmony in Imdlawn Tashlhiyt

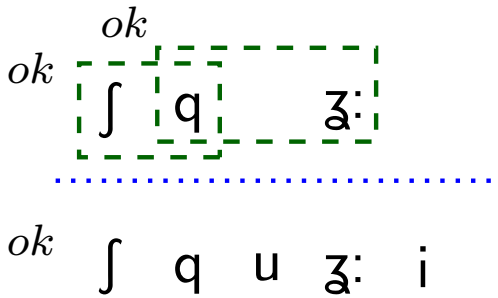
Generalization (2/2)

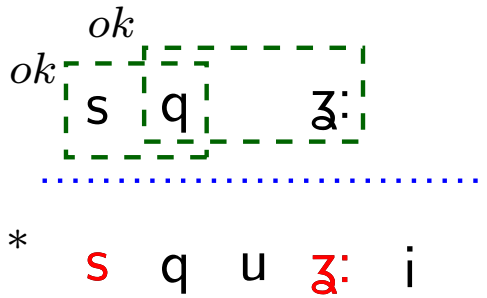
Voiceless obstruents block agreement in voicing.

Grammar

$T = \{$ ʒ, s, z, ʃ, q$\}$

$S = \{$ *sʒ, *sz, *sʃ, *ʒs, *ʃs, *zs, *zʃ, *zʒ, *ʃz, *ʃʒ, * ʒʃ, *ʒz $\}$





Sibilant Harmony in Imdlawn Tashlhiyt

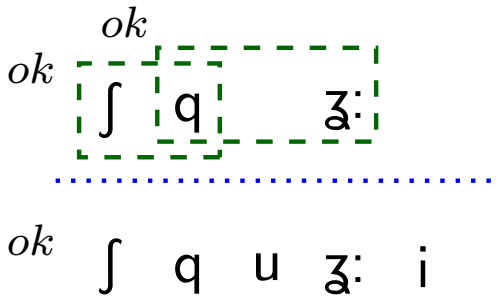
Generalization (2/2)

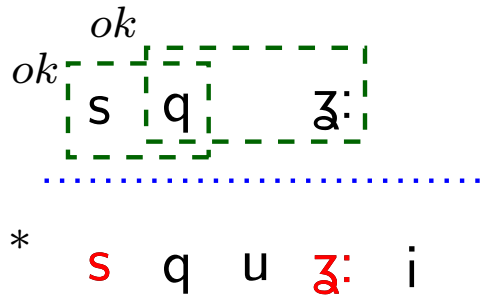
Voiceless obstruents block agreement in voicing.

Grammar

$T = \{$ ʒ, s, z, ʃ, q$\}$

$S = \{$ *sʒ, *sz, *sʃ, *ʒs, *ʃs, *zs, *zʃ, *zʒ, *ʃz, *ʃʒ, * ʒʃ, *ʒz $\}$





No TSL grammar can block voicing and enforce anteriority!

Multi-Tier Strictly Local (MTSL) Languages (1/2)

Sibilant Harmony in Imdlawn Tashlhiyt (Revisited)

Voiceless obstruents block agreement in voicing:

- $T_1 = \{$ʒ, s, z,ʃ, q$\}$ $S_1 = \{$*sʒ, *sz, *ʒs, *zs, *ʃz, *ʃʒ, *ʒʃ$\}$

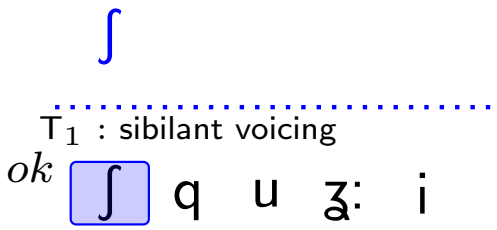
$$^{ok} \quad \text{ʃ} \quad \text{q} \quad \text{u} \quad \text{ʒ:} \quad \text{i}$$

Multi-Tier Strictly Local (MTSL) Languages (1/2)

Sibilant Harmony in Imdlawn Tashlhiyt (Revisited)

Voiceless obstruents block agreement in voicing:

- $T_1 = \{$ʒ, s, z, ʃ, q$\}$ $S_1 = \{^*$sʒ, *sz, *ʒs, *zs, *ʃz, *ʃʒ, *ʒʃ$\}$

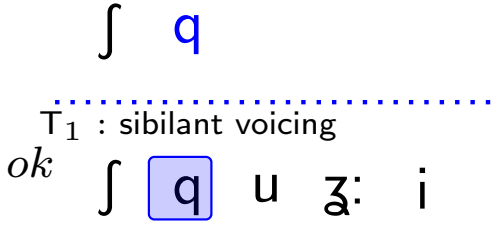


Multi-Tier Strictly Local (MTSL) Languages (1/2)

Sibilant Harmony in Imdlawn Tashlhiyt (Revisited)

Voiceless obstruents block agreement in voicing:

- $T_1 = \{$ʒ, s, z, ʃ, q$\}$ $S_1 = \{$*sʒ, *sz, *ʒs, *zs, *ʃz, *ʃʒ, *ʒʃ$\}$



Multi-Tier Strictly Local (MTSL) Languages (1/2)

Sibilant Harmony in Imdlawn Tashlhiyt (Revisited)

Voiceless obstruents block agreement in voicing:

- $T_1 = \{$ʒ, s, z, ʃ, q$\}$ $S_1 = \{$*sʒ, *sz, *ʒs, *zs, *ʃz, *ʃʒ, *ʒʃ$\}$

ʃ q

T_1 : sibilant voicing

ok ʃ q u ʒː i

Multi-Tier Strictly Local (MTSL) Languages (1/2)

Sibilant Harmony in Imdlawn Tashlhiyt (Revisited)

Voiceless obstruents block agreement in voicing:

- $T_1 = \{$ʒ͡ʃ, s, z, ʃ, q$\}$ $S_1 = \{$*sʒ͡ʃ, *sz, *ʒ͡ʃs, *zs, *ʃz, *ʃʒ͡ʃ, *ʒ͡ʃʃ$\}$

ʃ q ʒ͡ʃː

T_1 : sibilant voicing

ok ʃ q u ʒ͡ʃː i

Multi-Tier Strictly Local (MTSL) Languages (1/2)

Sibilant Harmony in Imdlawn Tashlhiyt (Revisited)

Voiceless obstruents block agreement in voicing:

- $T_1 = \{$ʒ, s, z, ʃ, q$\}$ $S_1 = \{$*sʒ, *sz, *ʒs, *zs, *ʃz, *ʃʒ, *ʒʃ$\}$

ʃ q ʒː

T_1 : sibilant voicing

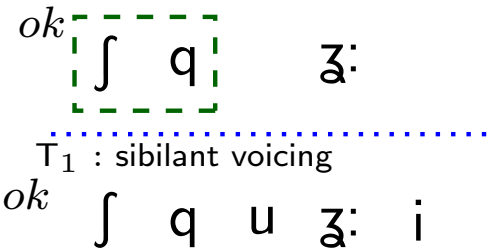
ok ʃ q u ʒː i

Multi-Tier Strictly Local (MTSL) Languages (1/2)

Sibilant Harmony in Imdlawn Tashlhiyt (Revisited)

Voiceless obstruents block agreement in voicing:

- $T_1 = \{$ʒ, s, z, ʃ, q$\}$ $S_1 = \{$*sʒ, *sz, *ʒs, *zs, *ʃz, *ʃʒ, *ʒʃ$\}$

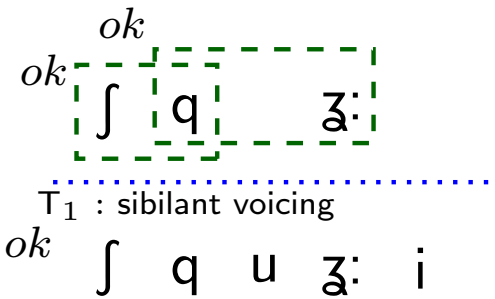


Multi-Tier Strictly Local (MTSL) Languages (1/2)

Sibilant Harmony in Imdlawn Tashlhiyt (Revisited)

Voiceless obstruents block agreement in voicing:

- $T_1 = \{$ʒ, s, z, ʃ, q$\}$ $S_1 = \{$*sʒ, *sz, *ʒs, *zs, *ʃz, *ʃʒ, *ʒʃ$\}$



Multi-Tier Strictly Local (MTSL) Languages (1/2)

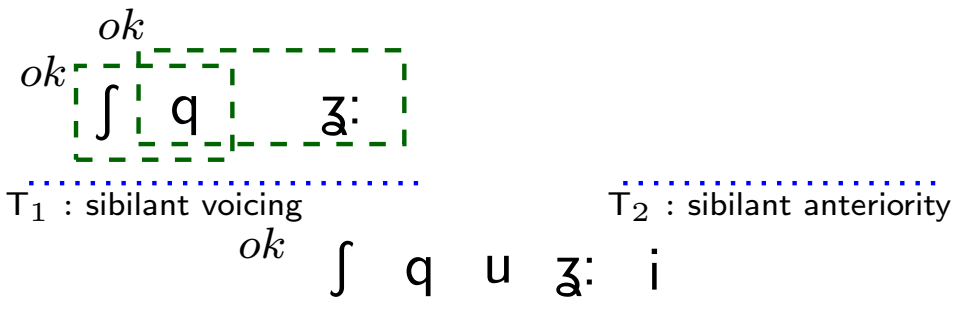
Sibilant Harmony in Imdlawn Tashlhiyt (Revisited)

Voiceless obstruents block agreement in voicing:

- $T_1 = \{$ʒ, s, z, ʃ, q$\}$ $S_1 = \{$*sʒ, *sz, *ʒs, *zs, *ʃz, *ʃʒ, *ʒʃ$\}$

Unbounded agreement in anteriority:

- $T_2 = \{$ʒ, s, z, ʃ$\}$ $S_2 = \{$*sʒ, *sʃ, *ʒs, *ʃs, *zs, *zʃ, *zʒ, *ʃz, *ʒz $\}$



Multi-Tier Strictly Local (MTSL) Languages (1/2)

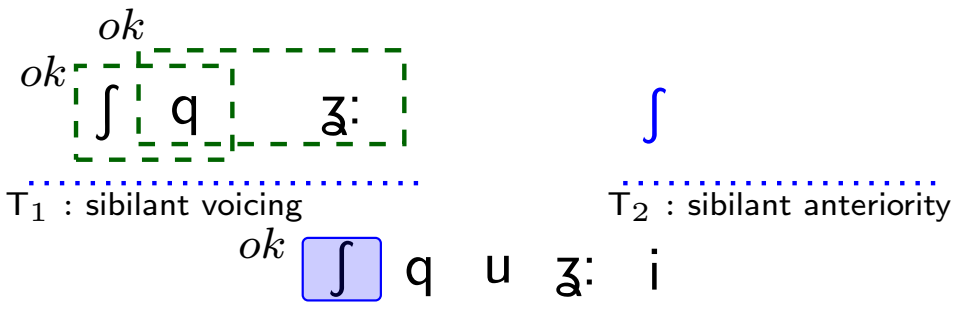
Sibilant Harmony in Imdlawn Tashlhiyt (Revisited)

Voiceless obstruents block agreement in voicing:

- $T_1 = \{$ʒ, s, z,ʃ, q$\}$ $S_1 = \{$*sʒ, *sz, *ʒs, *zs, *ʃz, *ʃʒ, *ʒʃ$\}$

Unbounded agreement in anteriority:

- $T_2 = \{$ʒ, s, z,ʃ$\}$ $S_2 = \{$*sʒ, *sʃ, *ʒs,*ʃs, *zs, *zʃ, *zʒ, *ʃz, *ʒz $\}$



Multi-Tier Strictly Local (MTSL) Languages (1/2)

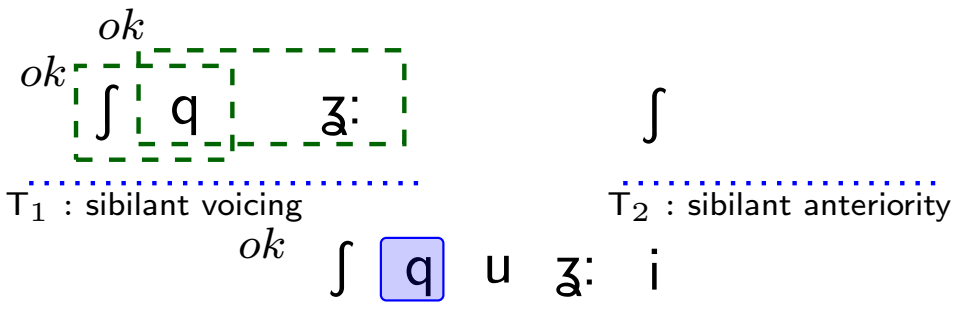
Sibilant Harmony in Imdlawn Tashlhiyt (Revisited)

Voiceless obstruents block agreement in voicing:

- $T_1 = \{$ʒ, s, z, ʃ, q$\}$ $S_1 = \{$*sʒ, *sz, *ʒs, *zs, *ʃz, *ʃʒ, *ʒʃ$\}$

Unbounded agreement in anteriority:

- $T_2 = \{$ʒ, s, z, ʃ$\}$ $S_2 = \{$*sʒ, *sʃ, *ʒs, *ʃs, *zs, *zʃ, *zʒ, *ʃz, *ʒz $\}$



Multi-Tier Strictly Local (MTSL) Languages (1/2)

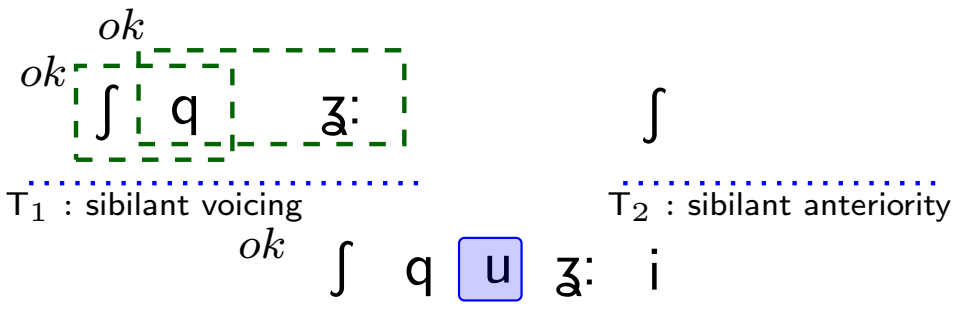
Sibilant Harmony in Imdlawn Tashlhiyt (Revisited)

Voiceless obstruents block agreement in voicing:

- $T_1 = \{$ʒ, s, z, ʃ, q$\}$ $S_1 = \{$*sʒ, *sz, *ʒs, *zs, *ʃz, *ʃʒ, *ʒʃ$\}$

Unbounded agreement in anteriority:

- $T_2 = \{$ʒ, s, z, ʃ$\}$ $S_2 = \{$*sʒ, *sʃ, *ʒs, *ʃs, *zs, *zʃ, *zʒ, *ʃz, *ʒz $\}$



Multi-Tier Strictly Local (MTSL) Languages (1/2)

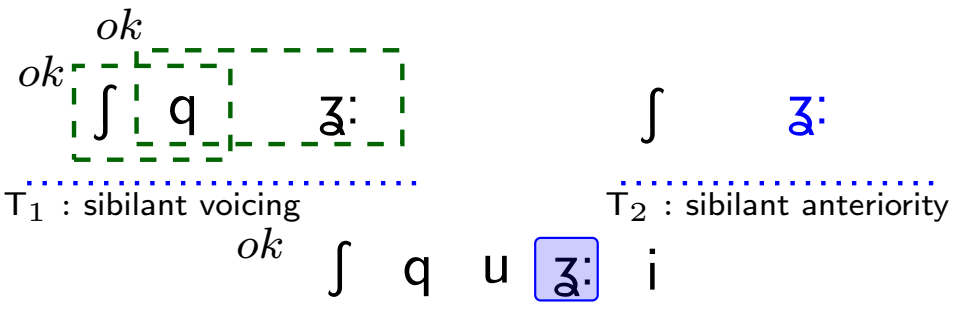
Sibilant Harmony in Imdlawn Tashlhiyt (Revisited)

Voiceless obstruents block agreement in voicing:

- $T_1 = \{$ʒ, s, z,ʃ, q$\}$ $S_1 = \{$*sʒ, *sz, *ʒs, *zs, *ʃz, *ʃʒ, *ʒʃ$\}$

Unbounded agreement in anteriority:

- $T_2 = \{$ʒ, s, z,ʃ$\}$ $S_2 = \{$*sʒ, *sʃ, *ʒs,*ʃs, *zs, *zʃ, *zʒ, *ʃz, *ʒz $\}$



Multi-Tier Strictly Local (MTSL) Languages (1/2)

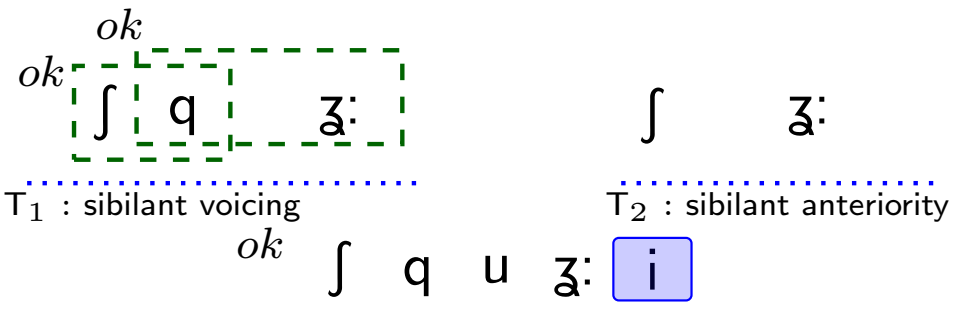
Sibilant Harmony in Imdlawn Tashlhiyt (Revisited)

Voiceless obstruents block agreement in voicing:

- $T_1 = \{$ʒ, s, z, ʃ, q$\}$ $S_1 = \{$*sʒ, *sz, *ʒs, *zs, *ʃz, *ʃʒ, *ʒʃ$\}$

Unbounded agreement in anteriority:

- $T_2 = \{$ʒ, s, z, ʃ$\}$ $S_2 = \{$*sʒ, *sʃ, *ʒs, *ʃs, *zs, *zʃ, *zʒ, *ʃz, *ʒz $\}$



Multi-Tier Strictly Local (MTSL) Languages (1/2)

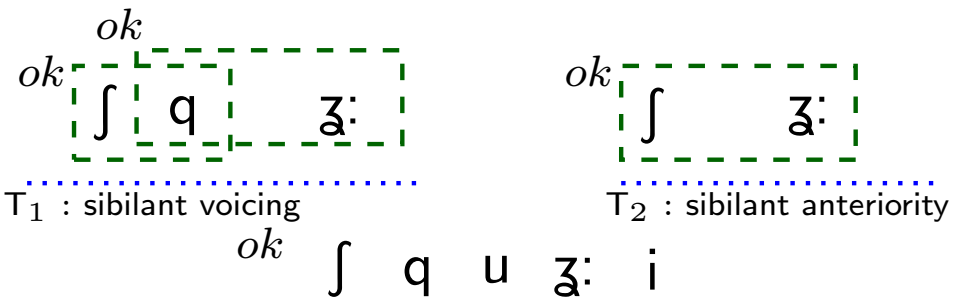
Sibilant Harmony in Imdlawn Tashlhiyt (Revisited)

Voiceless obstruents block agreement in voicing:

- $T_1 = \{$ʒ, s, z, ʃ, q$\}$ $S_1 = \{$*sʒ, *sz, *ʒs, *zs, *ʃz, *ʃʒ, *ʒʃ$\}$

Unbounded agreement in anteriority:

- $T_2 = \{$ʒ, s, z, ʃ$\}$ $S_2 = \{$*sʒ, *sʃ, *ʒs, *ʃs, *zs, *zʃ, *zʒ, *ʃz, *ʒz $\}$



Multi-Tier Strictly Local (MTSL) Languages (2/2)

Sibilant Harmony in Imdlawn Tashlhiyt (Revisited)

Voiceless obstruents block agreement in voicing:

- $T_1 = \{$ʒ, s, z, ʃ, q$\}$ $S_1 = \{$*sʒ, *sz, *ʒs, *zs, *ʃz, *ʃʒ, *ʒʃ$\}$

Unbounded agreement in anteriority:

- $T_2 = \{$ʒ, s, z, ʃ$\}$ $S_2 = \{$*sʒ, *sʃ, *ʒs, *ʃs, *zs, *zʃ, *zʒ, *ʃz, *ʒz $\}$

* s q u ʒː i

Multi-Tier Strictly Local (MTSL) Languages (2/2)

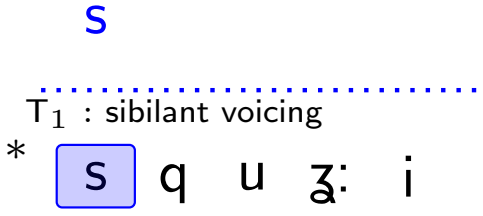
Sibilant Harmony in Imdlawn Tashlhiyt (Revisited)

Voiceless obstruents block agreement in voicing:

- $T_1 = \{$ʒ, s, z, ʃ, q$\}$ $S_1 = \{$*sʒ, *sz, *ʒs, *zs, *ʃz, *ʃʒ, *ʒʃ$\}$

Unbounded agreement in anteriority:

- $T_2 = \{$ʒ, s, z, ʃ$\}$ $S_2 = \{$*sʒ, *sʃ, *ʒs, *ʃs, *zs, *zʃ, *zʒ, *ʃz, *ʒz $\}$



Multi-Tier Strictly Local (MTSL) Languages (2/2)

Sibilant Harmony in Imdlawn Tashlhiyt (Revisited)

Voiceless obstruents block agreement in voicing:

- $T_1 = \{$ʒ, s, z, ʃ, q$\}$ $S_1 = \{$*sʒ, *sz, *ʒs, *zs, *ʃz, *ʃʒ, *ʒʃ$\}$

Unbounded agreement in anteriority:

- $T_2 = \{$ʒ, s, z, ʃ$\}$ $S_2 = \{$*sʒ, *sʃ, *ʒs, *ʃs, *zs, *zʃ, *zʒ, *ʃz, *ʒz $\}$

s q

T_1 : sibilant voicing

* s q u ʒː i

Multi-Tier Strictly Local (MTSL) Languages (2/2)

Sibilant Harmony in Imdlawn Tashlhiyt (Revisited)

Voiceless obstruents block agreement in voicing:

- $T_1 = \{$ʒ, s, z, ʃ, q$\}$ $S_1 = \{$*sʒ, *sz, *ʒs, *zs, *ʃz, *ʃʒ, *ʒʃ$\}$

Unbounded agreement in anteriority:

- $T_2 = \{$ʒ, s, z, ʃ$\}$ $S_2 = \{$*sʒ, *sʃ, *ʒs, *ʃs, *zs, *zʃ, *zʒ, *ʃz, *ʒz $\}$

s q

T_1 : sibilant voicing

* s q u ʒː i

Multi-Tier Strictly Local (MTSL) Languages (2/2)

Sibilant Harmony in Imdlawn Tashlhiyt (Revisited)

Voiceless obstruents block agreement in voicing:

- $T_1 = \{$ʒ, s, z, ʃ, q$\}$ $S_1 = \{$*sʒ, *sz, *ʒs, *zs, *ʃz, *ʃʒ, *ʒʃ$\}$

Unbounded agreement in anteriority:

- $T_2 = \{$ʒ, s, z, ʃ$\}$ $S_2 = \{$*sʒ, *sʃ, *ʒs, *ʃs, *zs, *zʃ, *zʒ, *ʃz, *ʒz $\}$

s q ʒː

T_1 : sibilant voicing

* s q u ʒː i

Multi-Tier Strictly Local (MTSL) Languages (2/2)

Sibilant Harmony in Imdlawn Tashlhiyt (Revisited)

Voiceless obstruents block agreement in voicing:

- $T_1 = \{$ʒ, s, z,ʃ, q$\}$ $S_1 = \{$*sʒ, *sz, *ʒs, *zs, *ʃz, *ʃʒ, *ʒʃ$\}$

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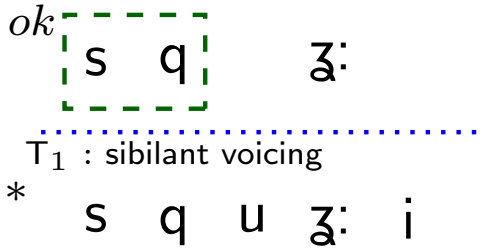

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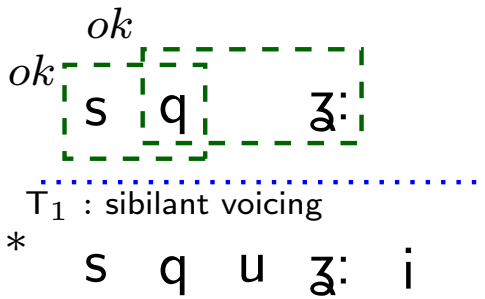

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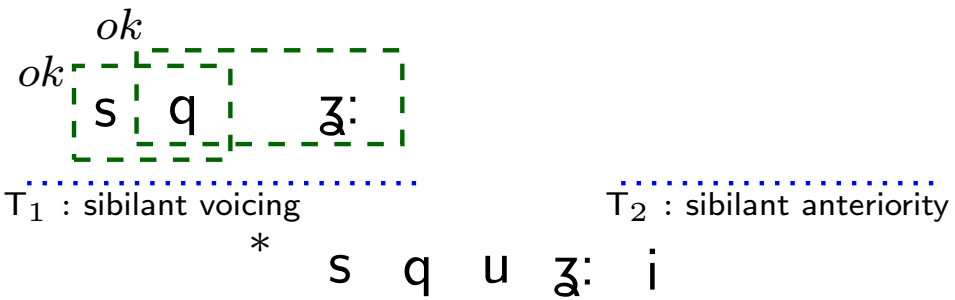

Multi-Tier Strictly Local (MTSL) Languages (2/2)

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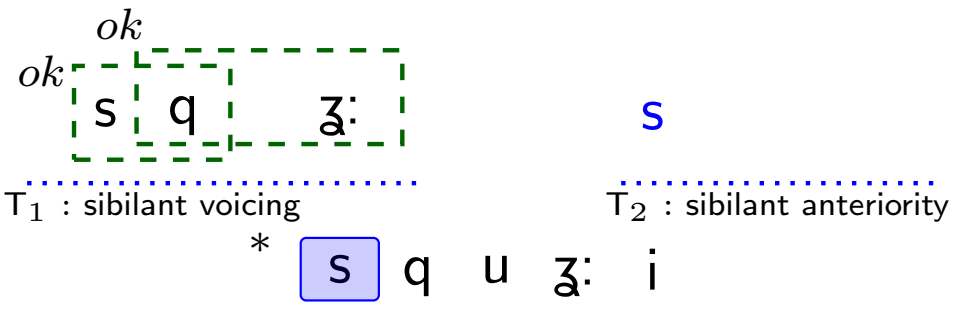

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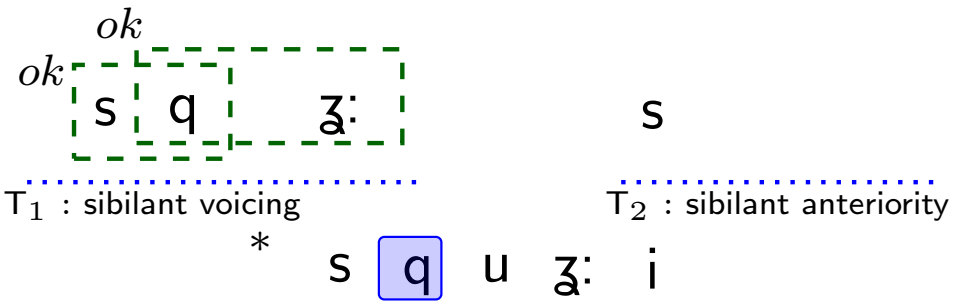

Multi-Tier Strictly Local (MTSL) Languages (2/2)

Sibilant Harmony in Imdlawn Tashlhiyt (Revisited)

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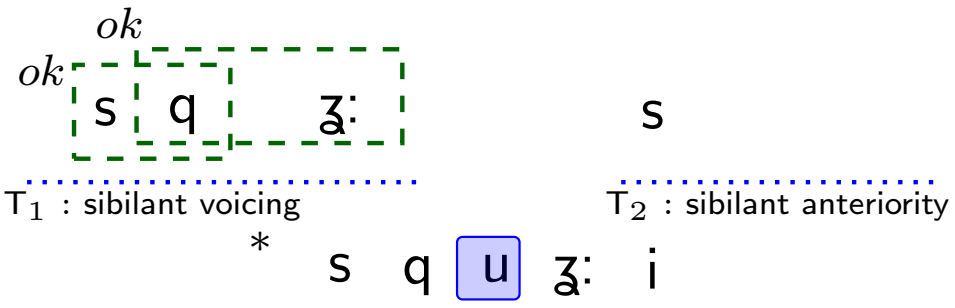

Multi-Tier Strictly Local (MTSL) Languages (2/2)

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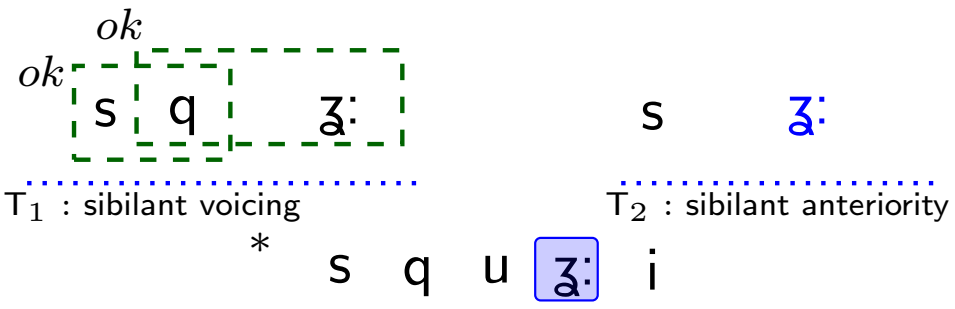

Multi-Tier Strictly Local (MTSL) Languages (2/2)

Sibilant Harmony in Imdlawn Tashlhiyt (Revisited)

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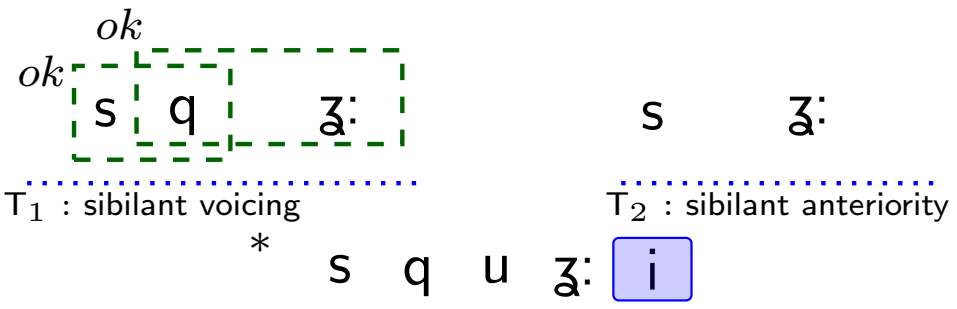

Multi-Tier Strictly Local (MTSL) Languages (2/2)

Sibilant Harmony in Imdlawn Tashlhiyt (Revisited)

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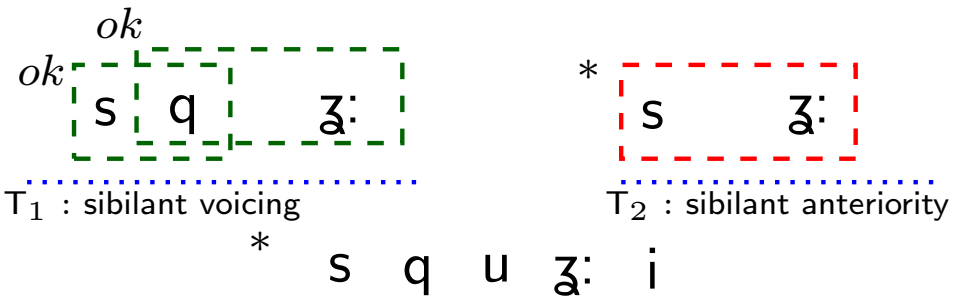
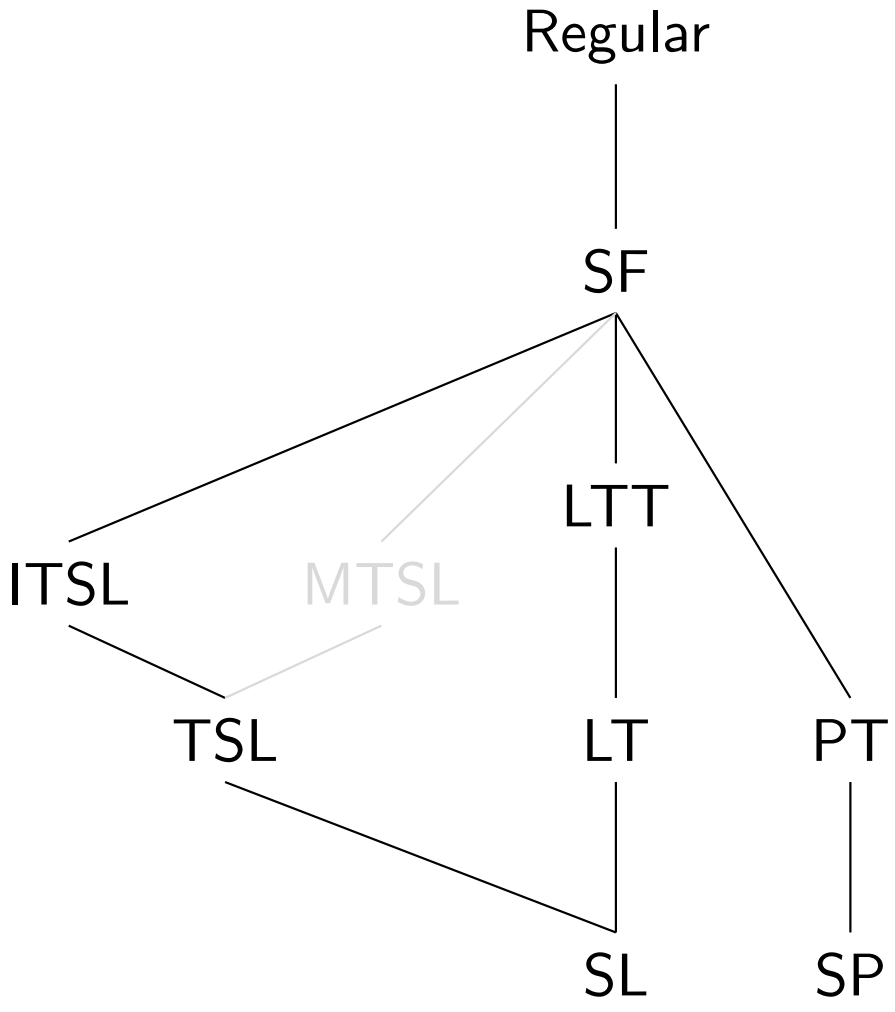


MTSL: Relations to other Classes



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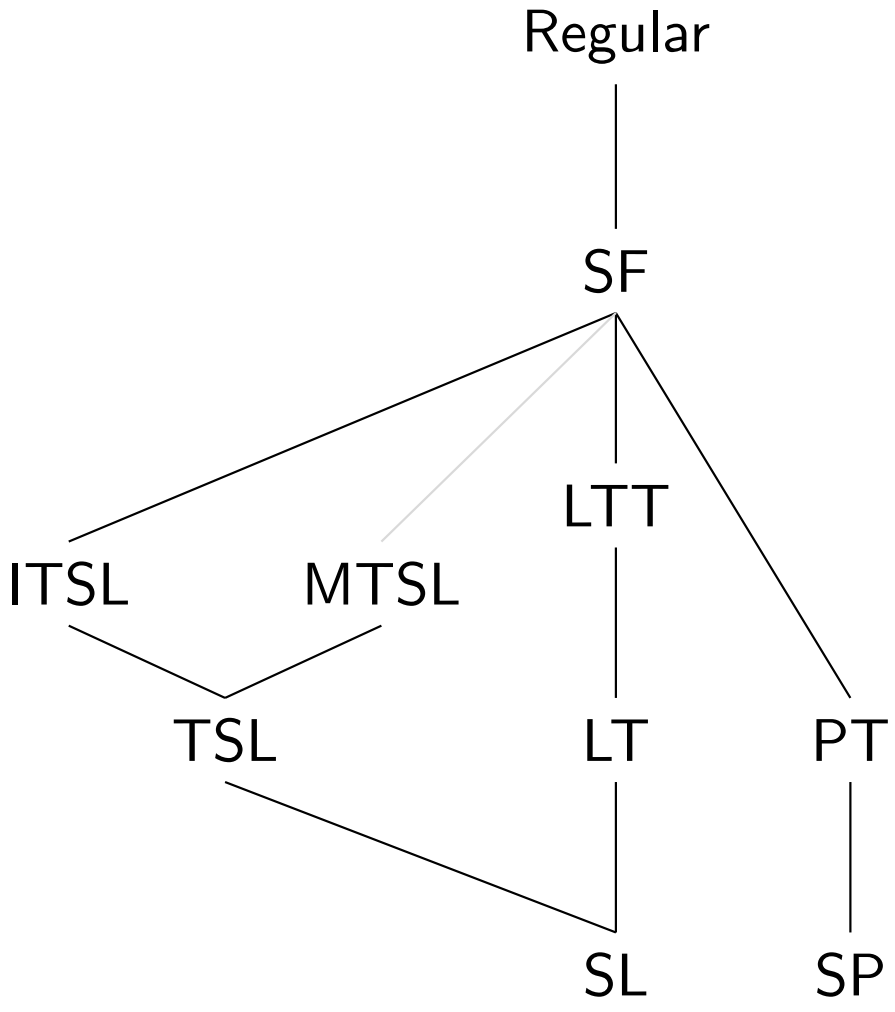

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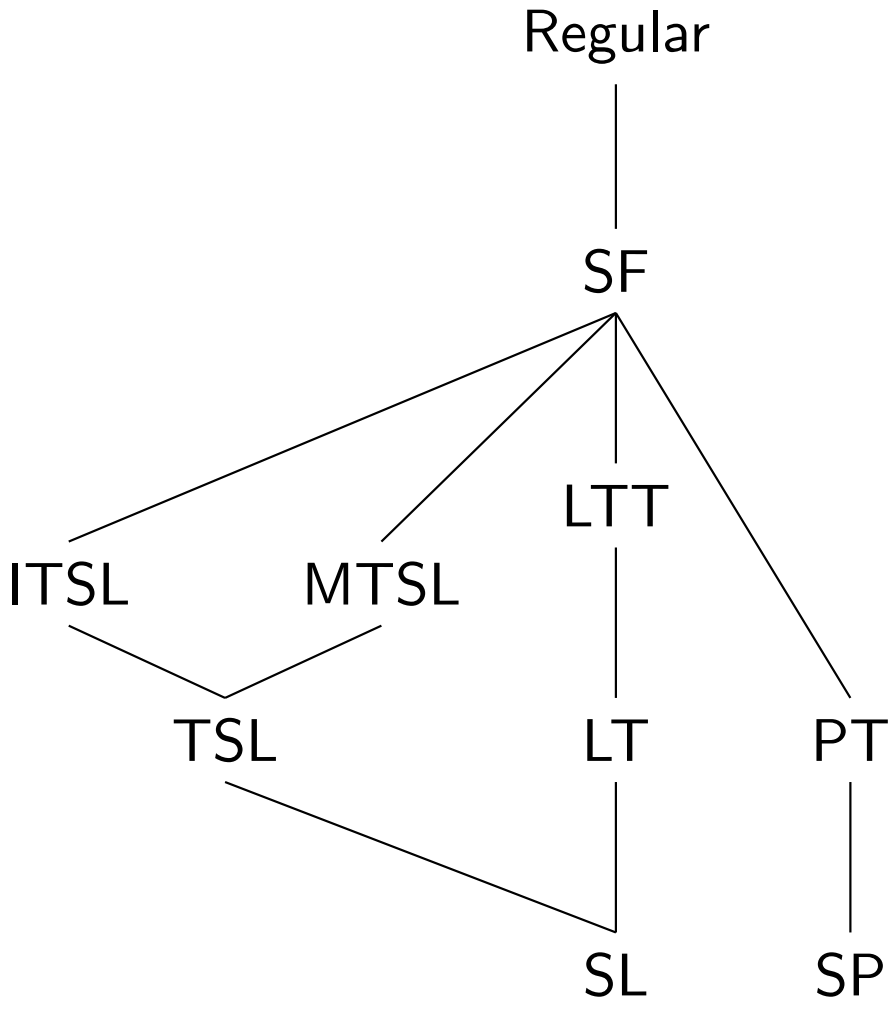

Incomparability of ITSL and MTSL (1/2)

MTSL $\not\subseteq$ ITSL

We already have an example

- Imdlawn Tashlhiyt's harmony is MTSL but not ITSL

ITSL $\subseteq$ MTSL?

- Is every ITSL language also MTSL?

Imdlawn Tashlhiyt's Sibilant Harmony $\notin$ ITSL

Reminder: Sibilant Harmony in Imdlawn Tashlhiyt

Voiceless obstruents block agreement in voicing:

- $T = \{$ʒ, s, z, ʃ, q$\}$ $S = \{$*sʒ, *sz, *ʒs, *zs, *ʃz, *ʃʒ, *ʒʃ$\}$

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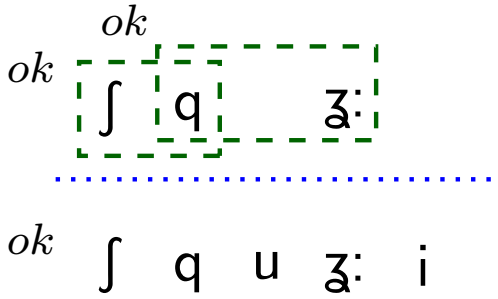

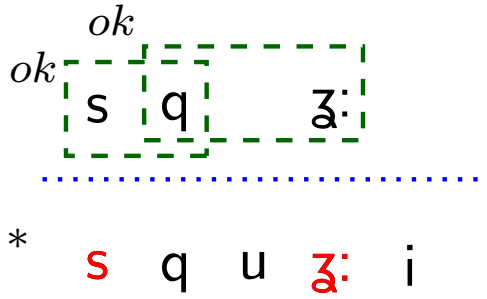

This pattern is not ITSL!

Imdlawn Tashlhiyt's Sibilant Harmony $\notin$ ITSL

Reminder: Sibilant Harmony in Imdlawn Tashlhiyt

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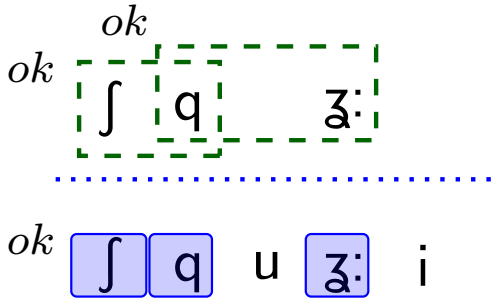

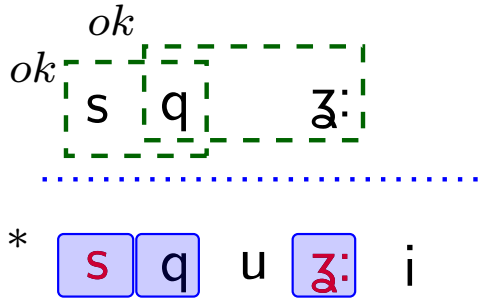

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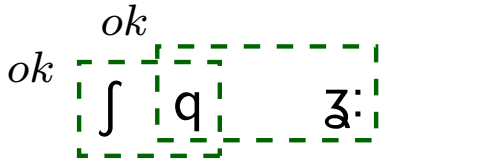

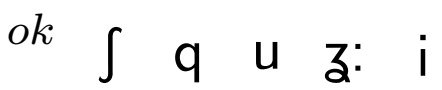

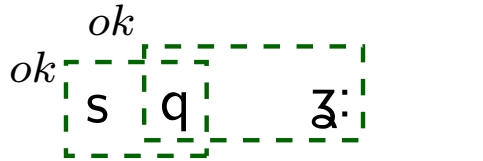

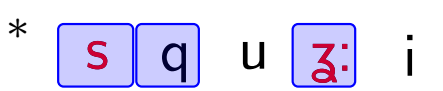

This pattern is not ITSL!

Incomparability of ITSL and MTSL (2/2)

MTSL $\not\subseteq$ ITSL

Imdlawn Tashlhiyt's harmony is MTSL but not ITSL.

ITSL $\not\subseteq$ MTSL

We have already seen an example:

- Samala's harmony is ITSL but not MTSL.

An MTSL Account for Samala?

Samala Sibilant Harmony (Revisited)

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

^{ok} s n e t u s

This pattern is not MTSL!

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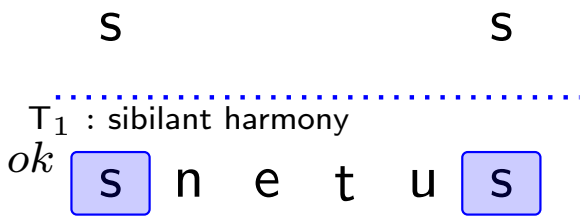

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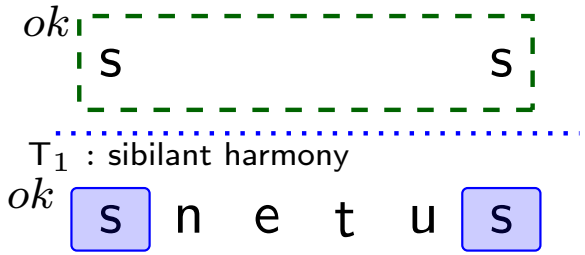

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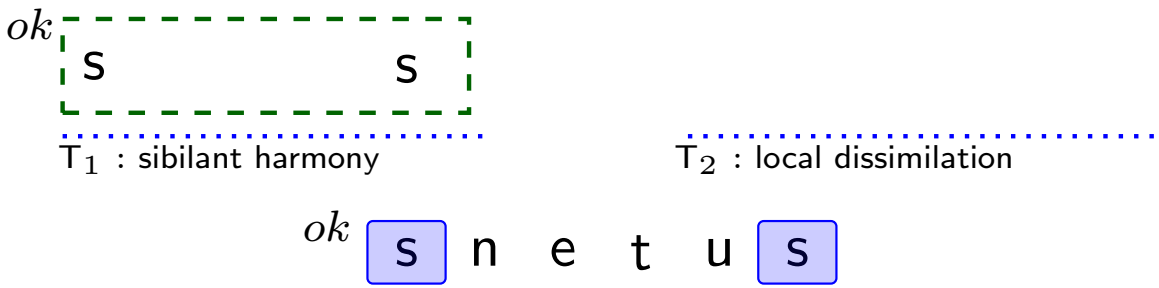

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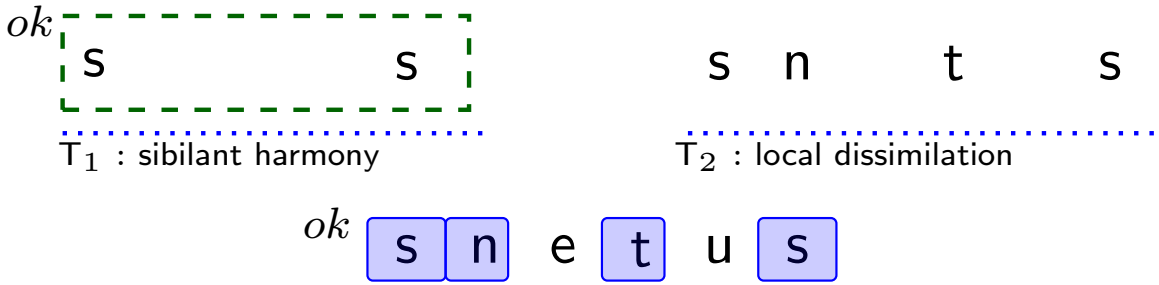

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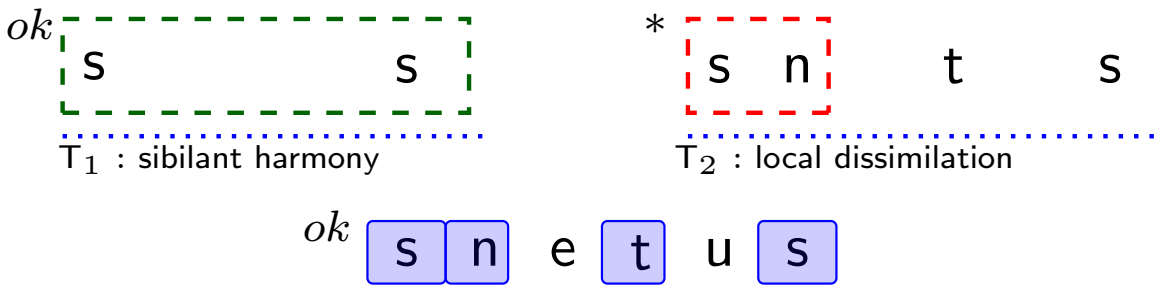

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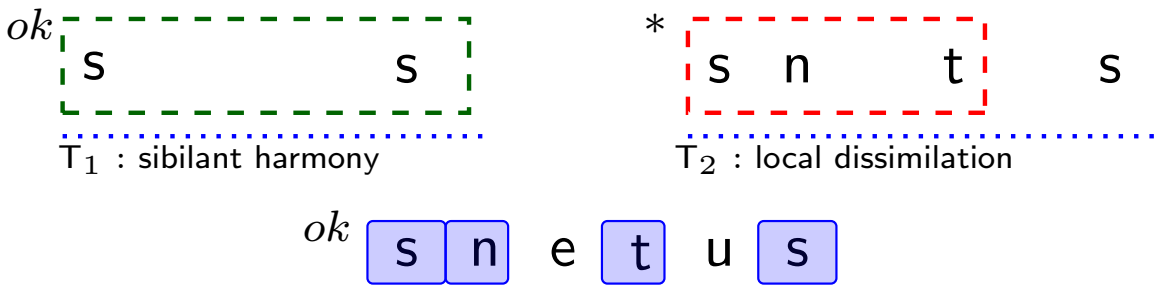

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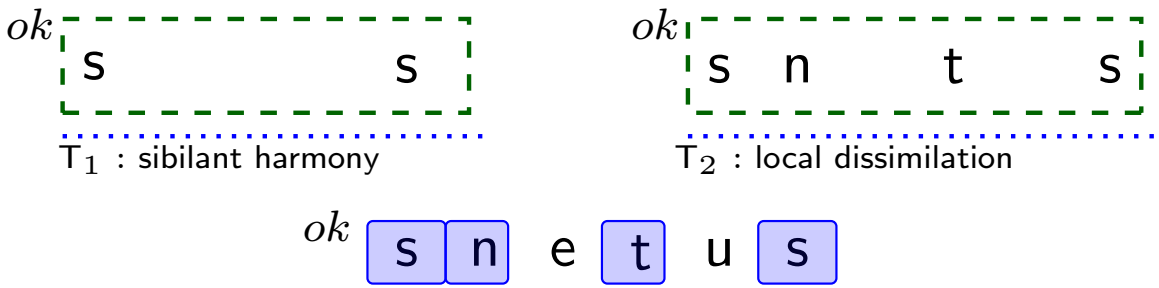

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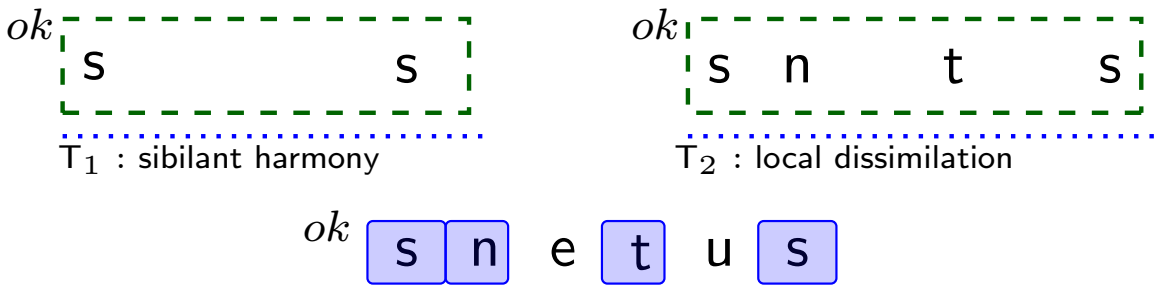

This pattern is not MTSL!

Structure-Sensitive TSL: Overgeneration

Anticipatory Harmony in Samala

T = { s, ʃ, tʃʰ }, S= {* sʃ, *ʃs, *stʃʰ, *tʃʰ}

ʃ a p i tʃʰ o l u ʃ w a ʃ

Structure-Sensitive TSL: Overgeneration

Anticipatory Harmony in Samala

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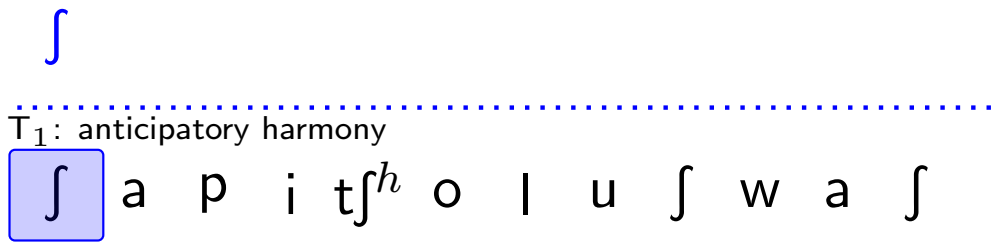

Structure-Sensitive TSL: Overgeneration

Anticipatory Harmony in Samala

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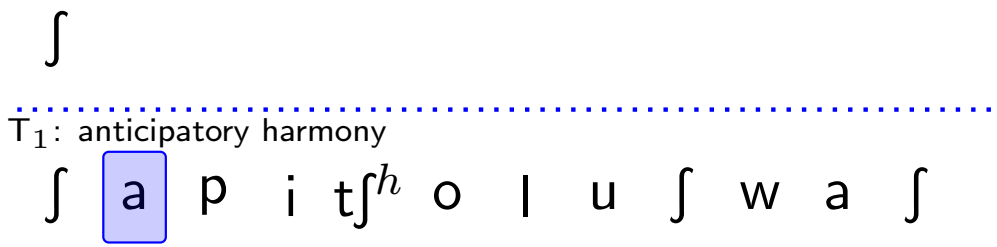

Structure-Sensitive TSL: Overgeneration

Anticipatory Harmony in Samala

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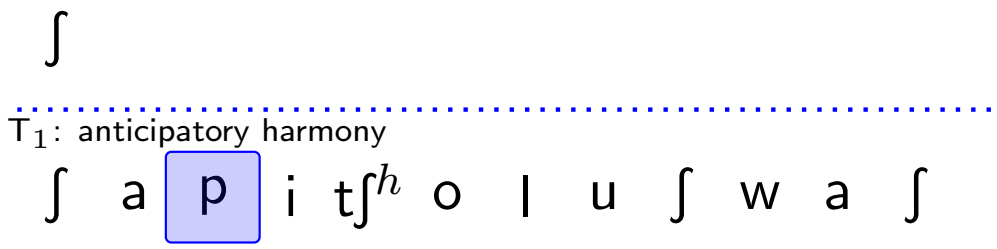

Structure-Sensitive TSL: Overgeneration

Anticipatory Harmony in Samala

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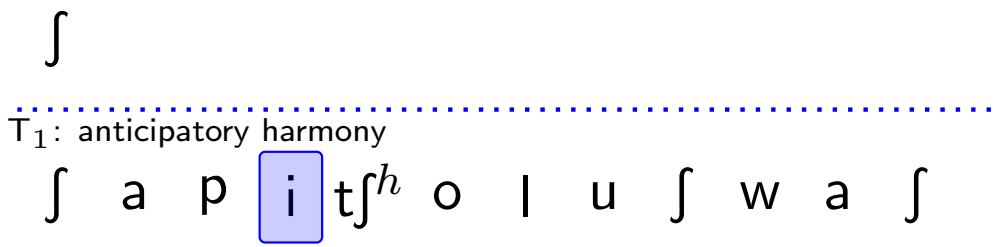

Structure-Sensitive TSL: Overgeneration

Anticipatory Harmony in Samala

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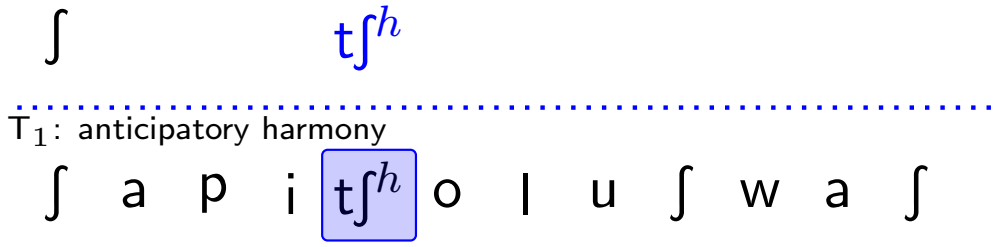

Structure-Sensitive TSL: Overgeneration

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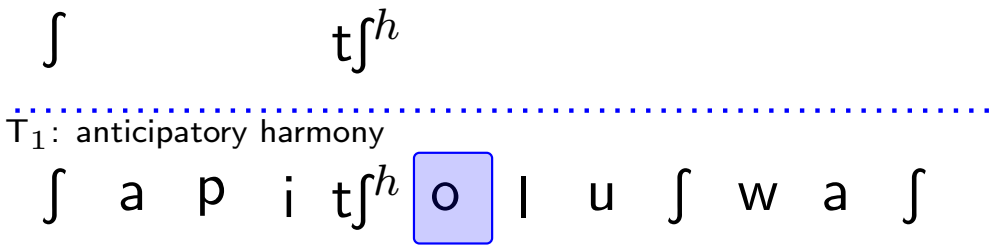

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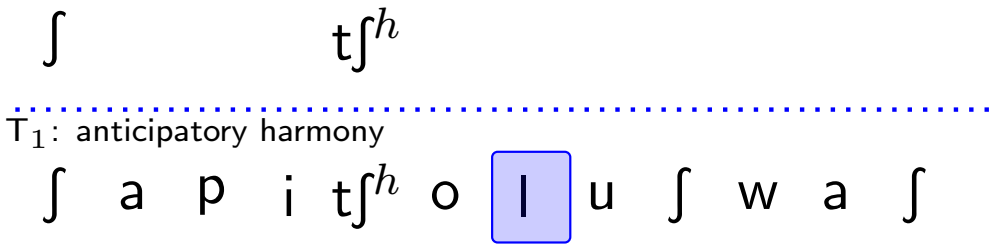

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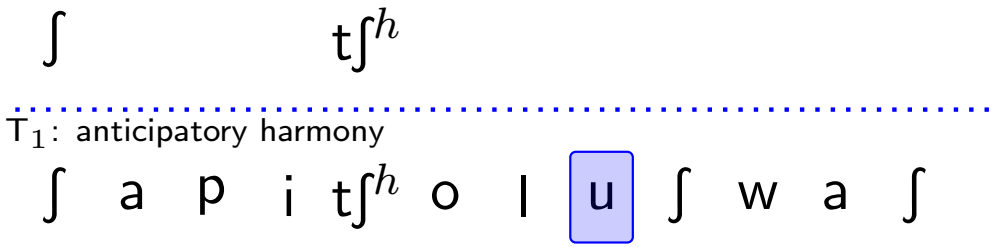

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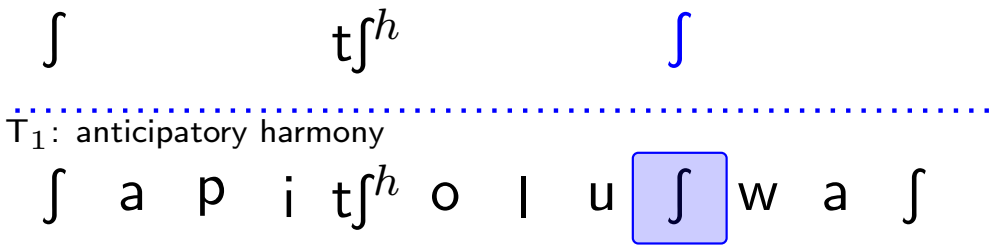

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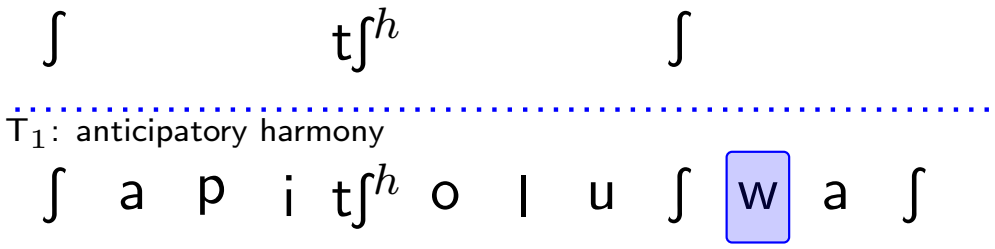

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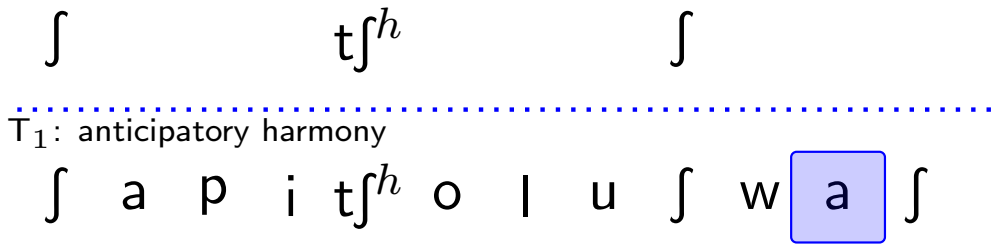

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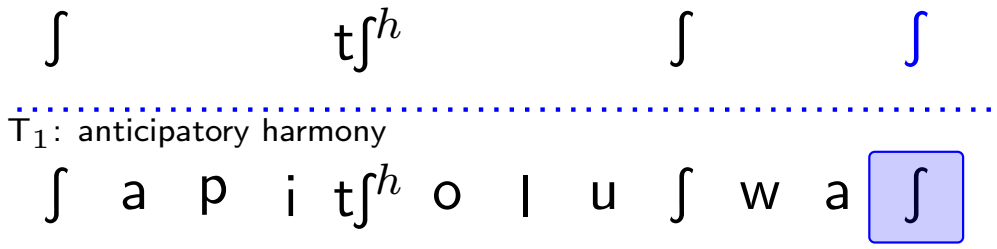

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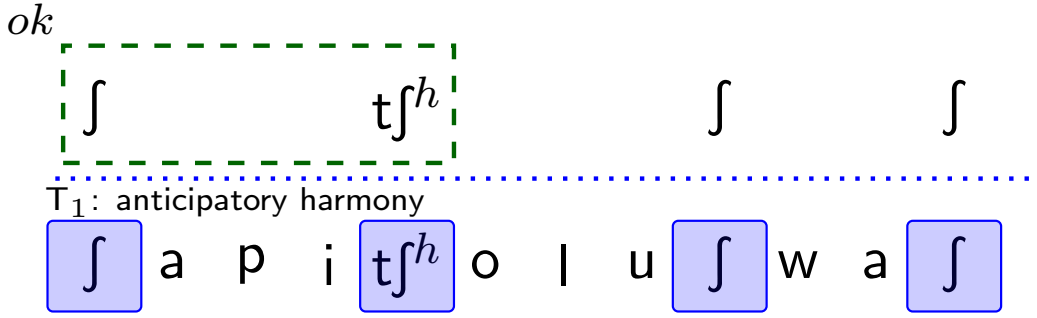

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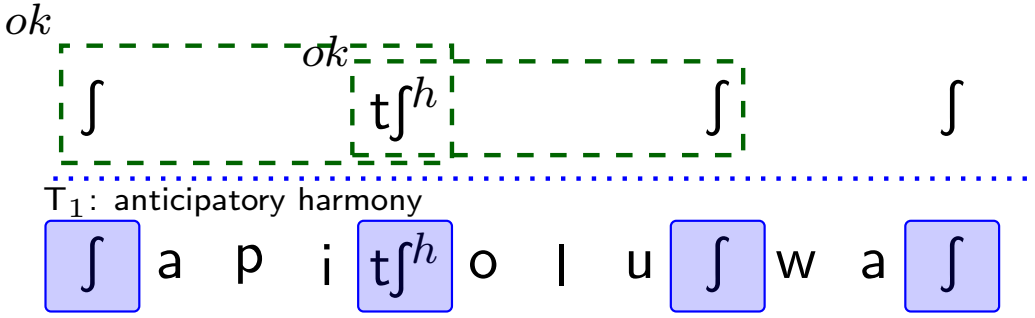

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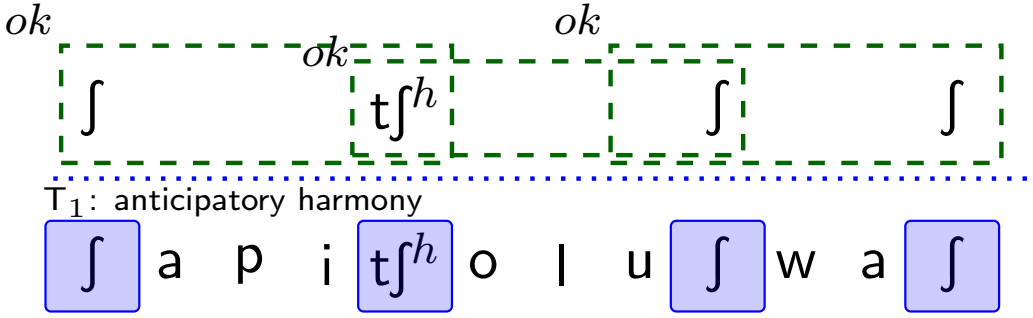

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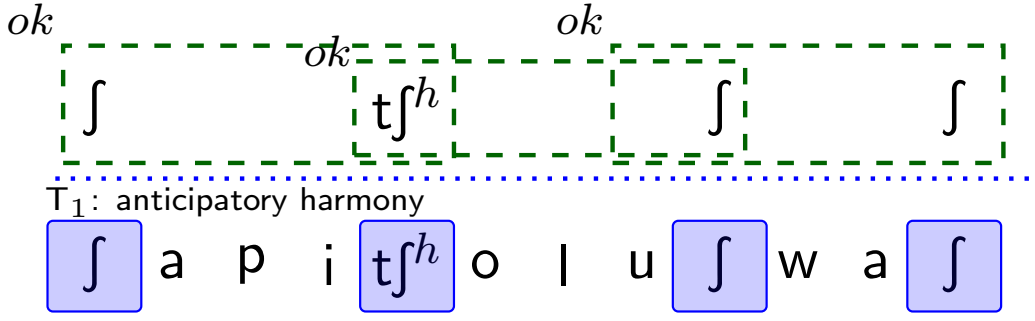

First/Last Harmony in Pseudo-Samala

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ʃ a p i tʃʰ o l u s w a ʃ

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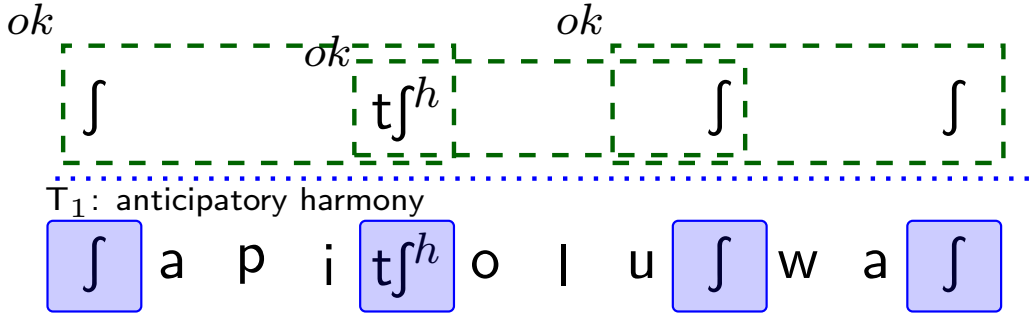

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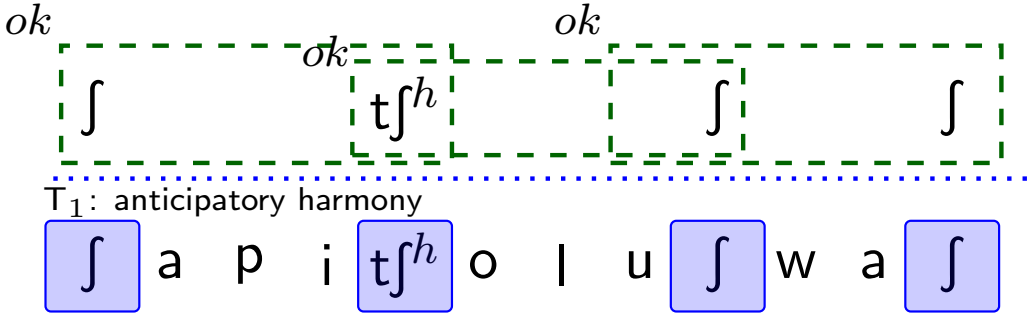

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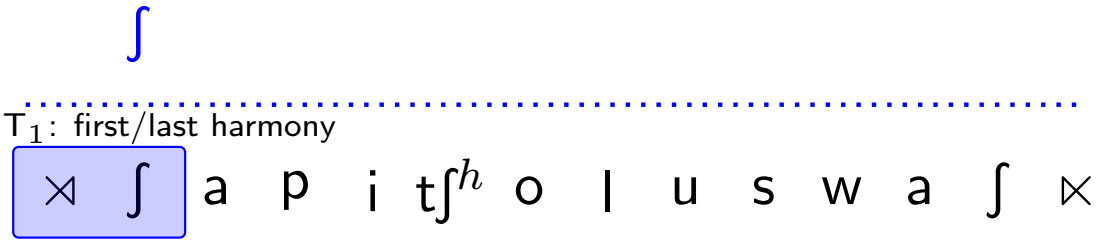

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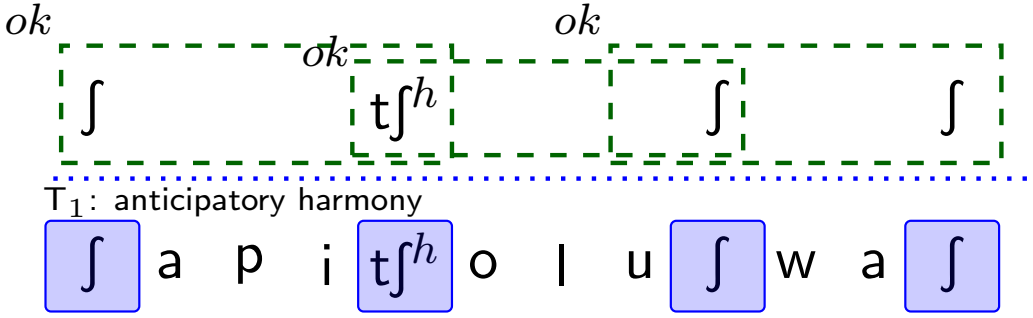

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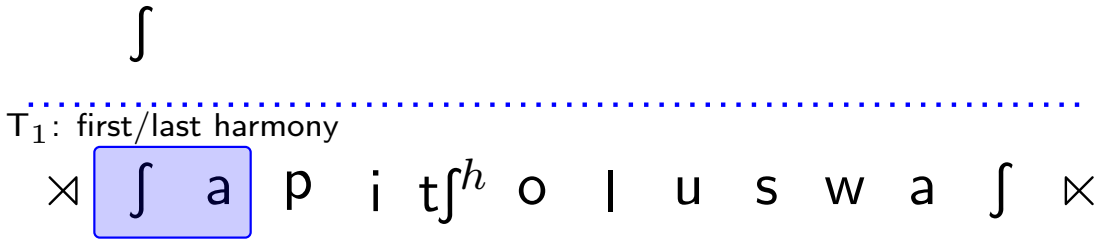

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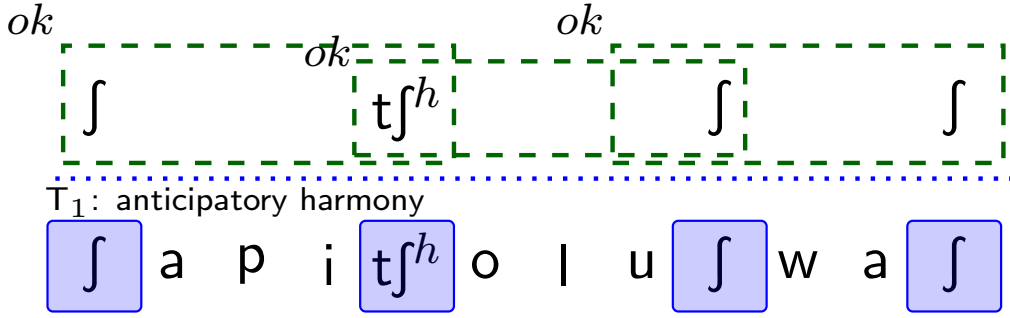

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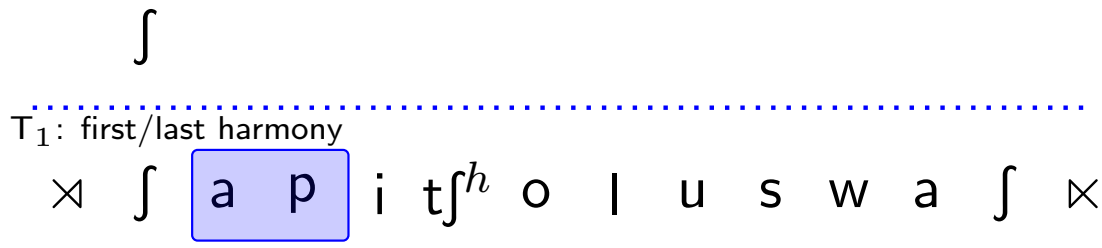

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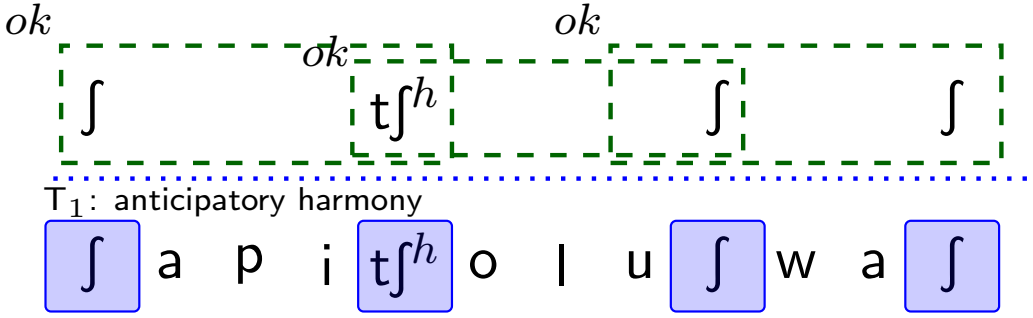

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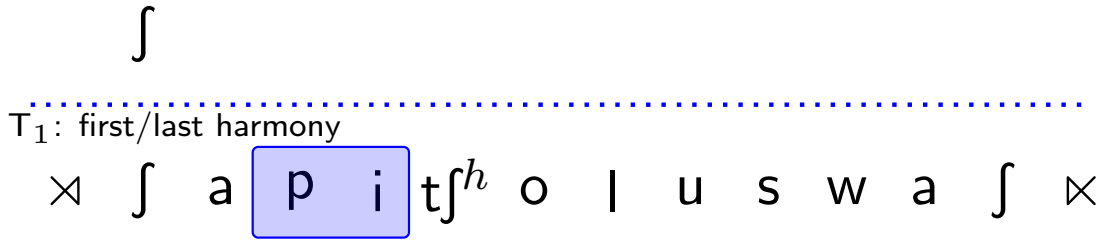

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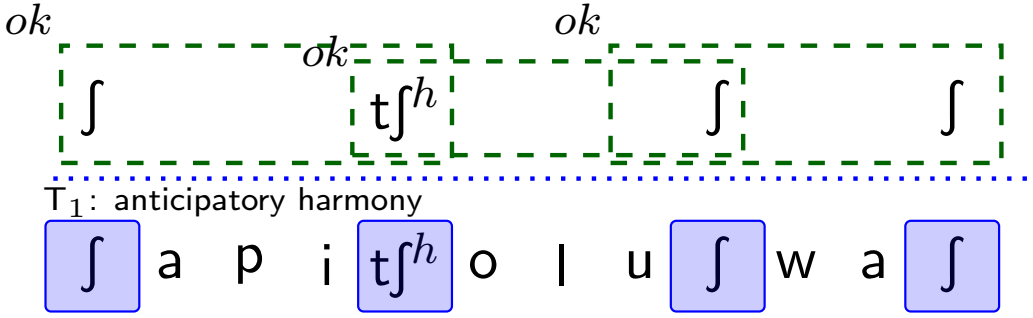

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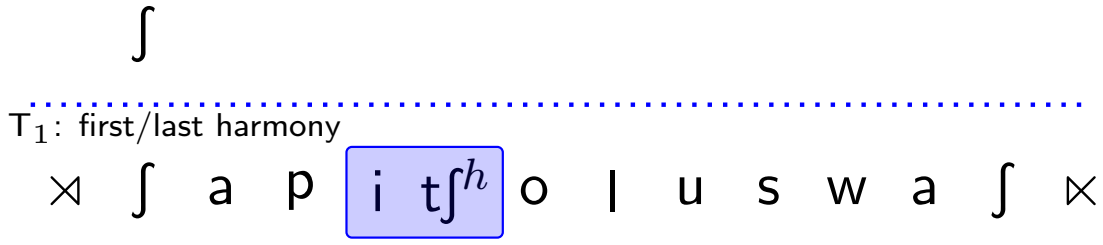

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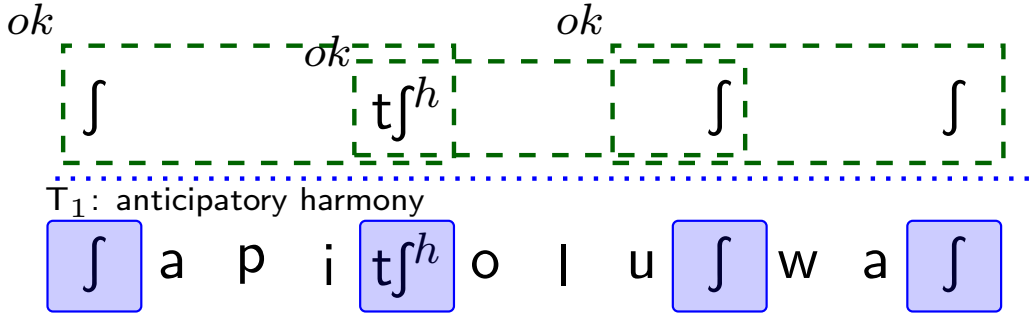

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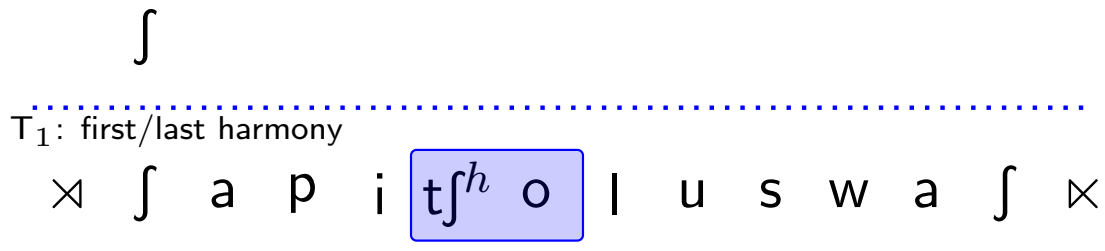

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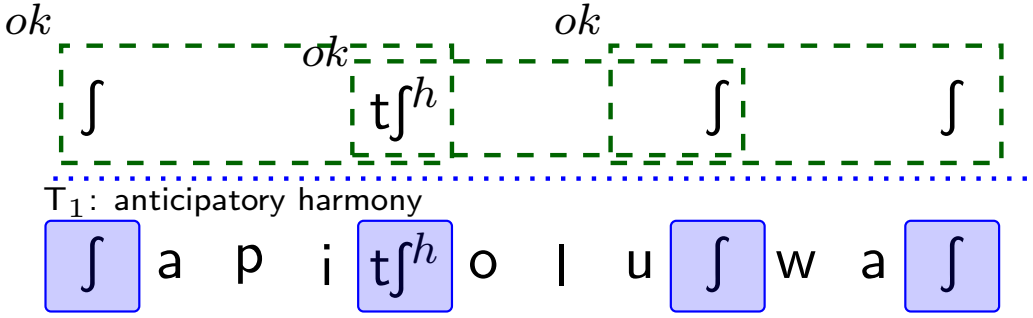

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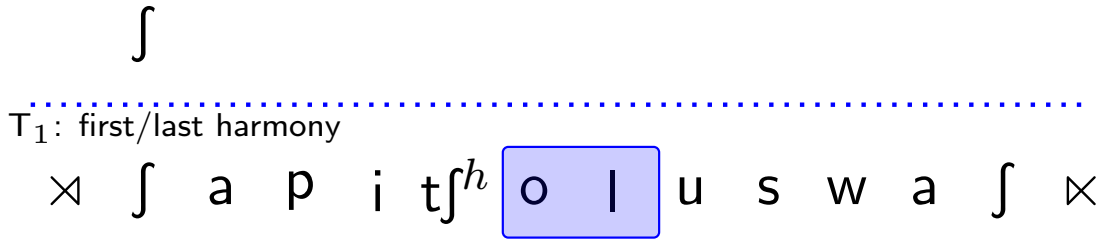

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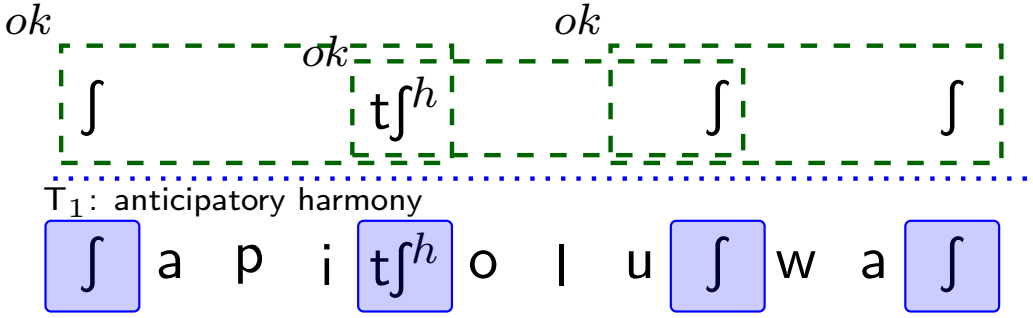

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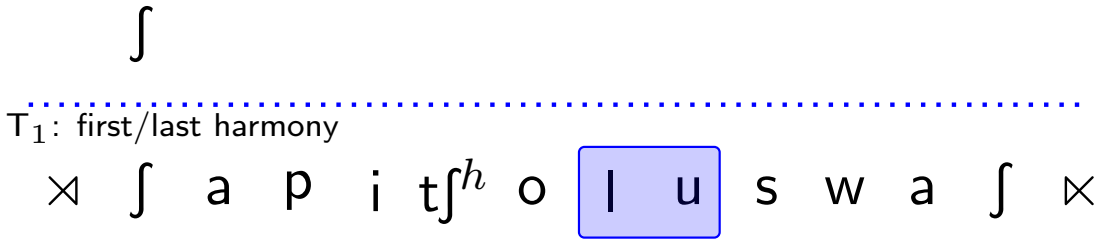

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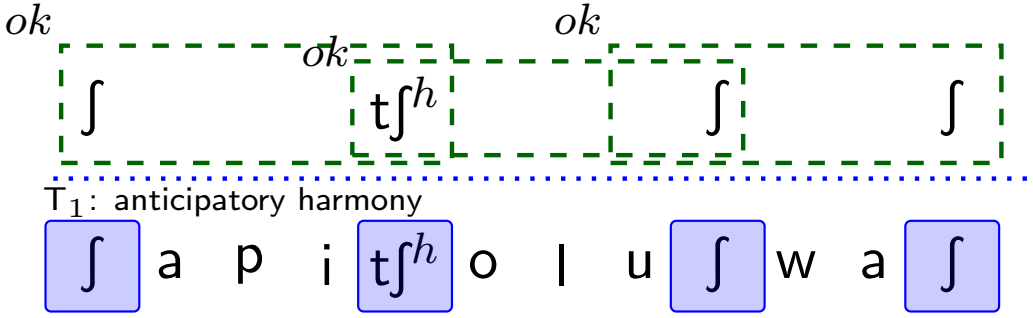

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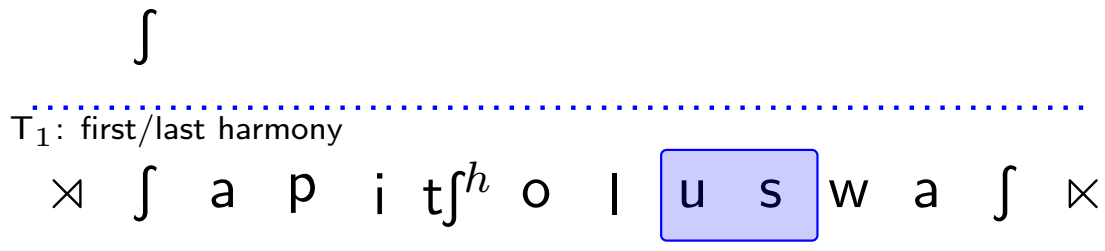

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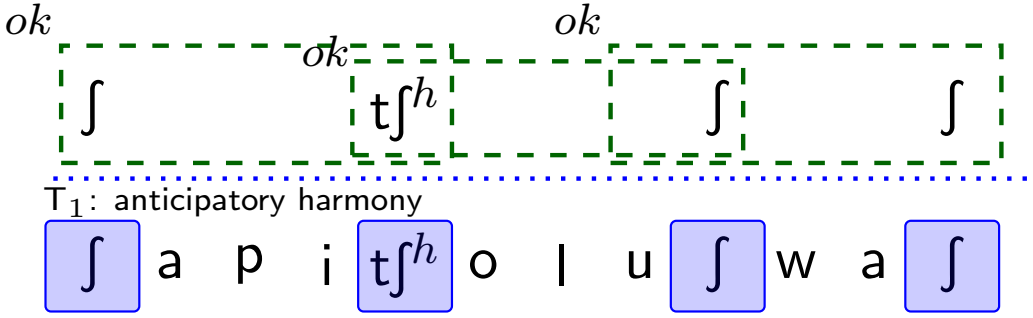

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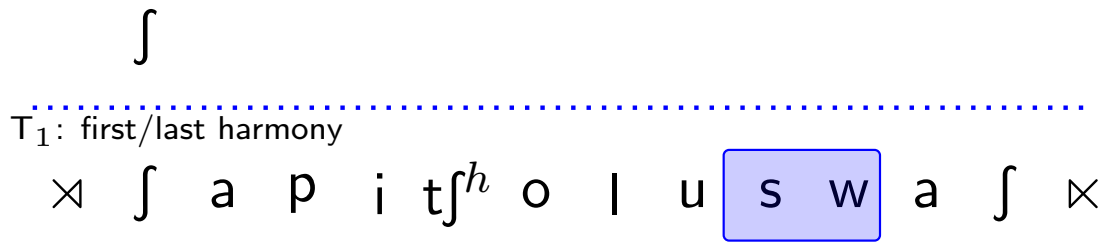

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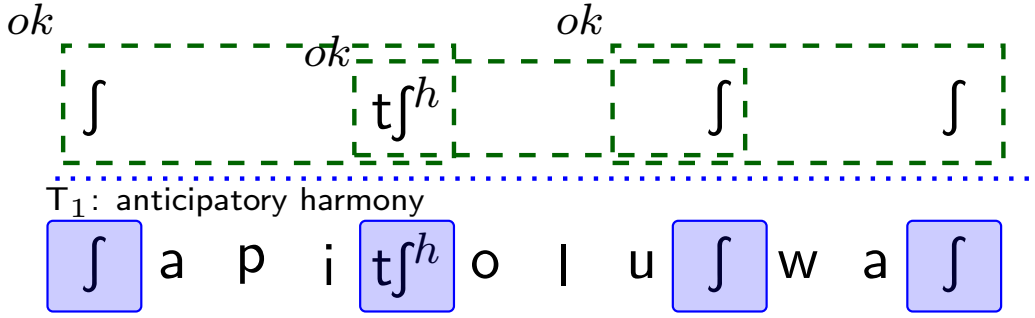

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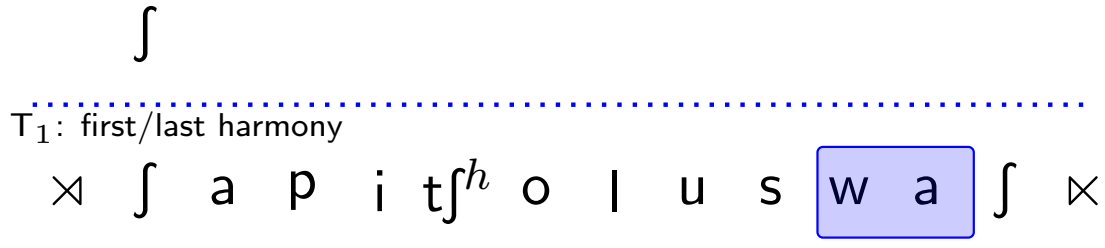

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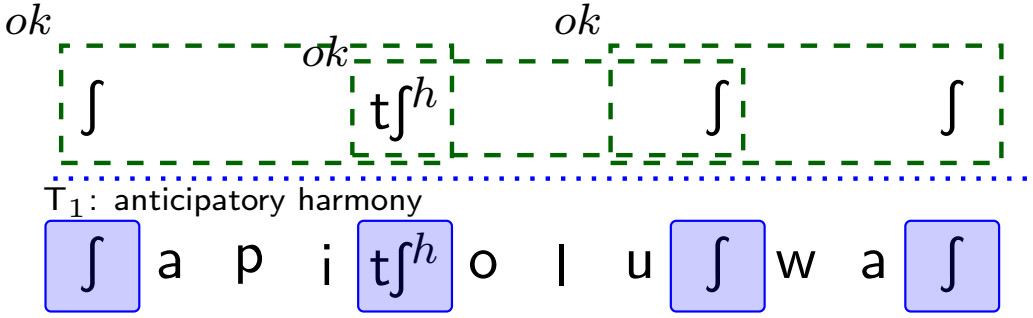

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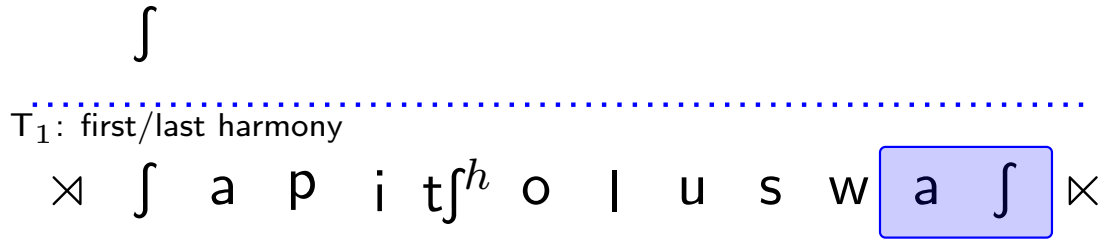

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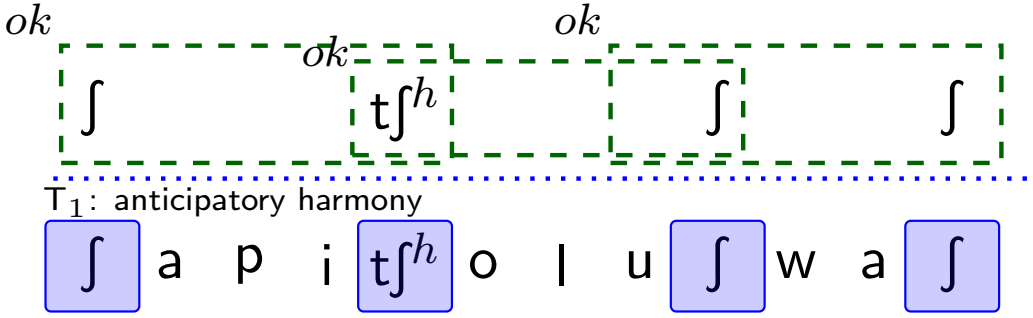

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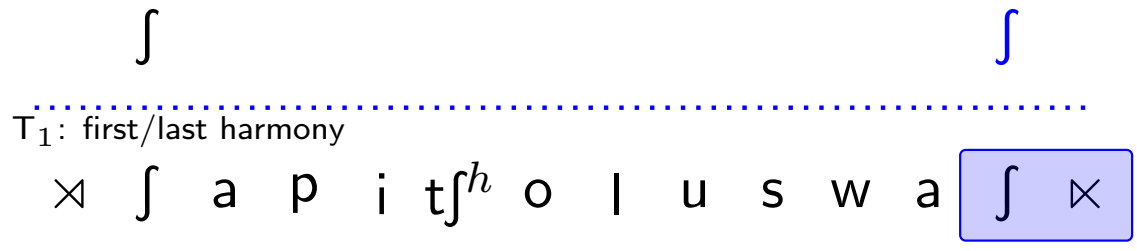

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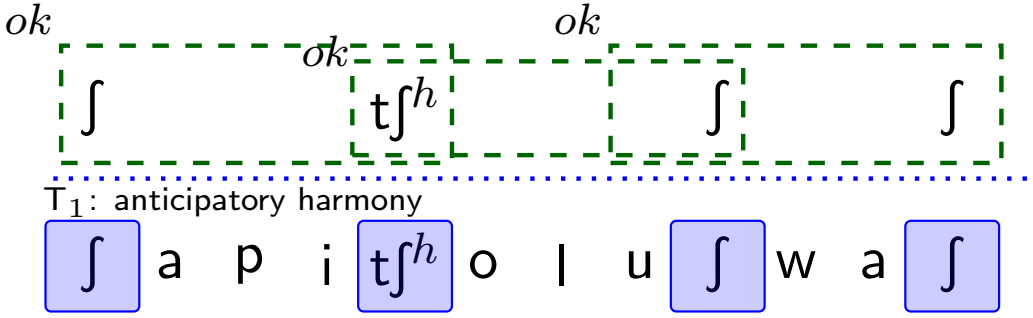
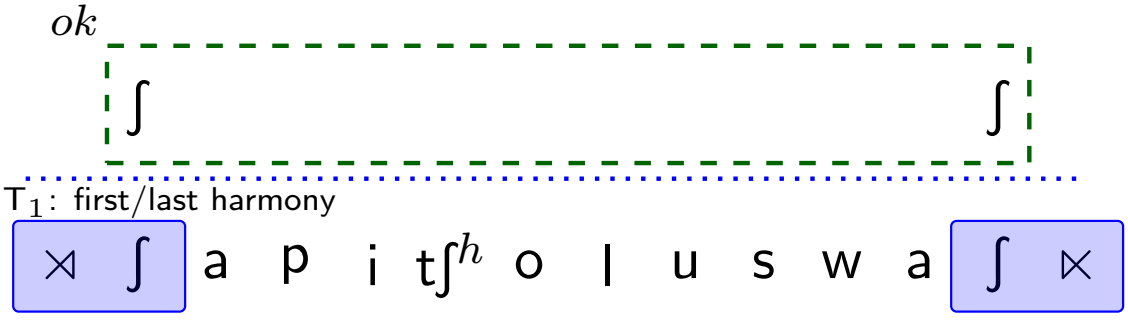


First/Last Harmony in Pseudo-Samala

T = {σ: σ ∈ {s, ʃ, tʃʰ} ∧(⋊σ ∨ σ⋉)} S= {*sʃ, *ʃs, *stʃʰ, *tʃʰ s}



TESL: Example

Tier Grammar(s) for L

$$T_1 = \{\sigma : \sigma \in \{a, b, c\}\}, S_1 = \{\}$$

$$T_2 = \{\sigma : \sigma \in \{a, b\} \wedge (c \prec^+ \sigma)\}, S_2 = \{{}^*\rtimes b, {}^* bb, {}^* aa, {}^* a\ltimes\}$$

a)

$\rtimes$ c a c d b $\ltimes$

b)

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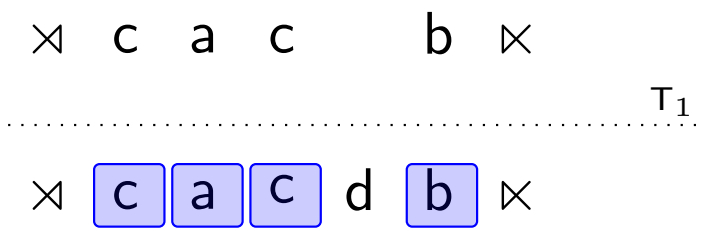

b)

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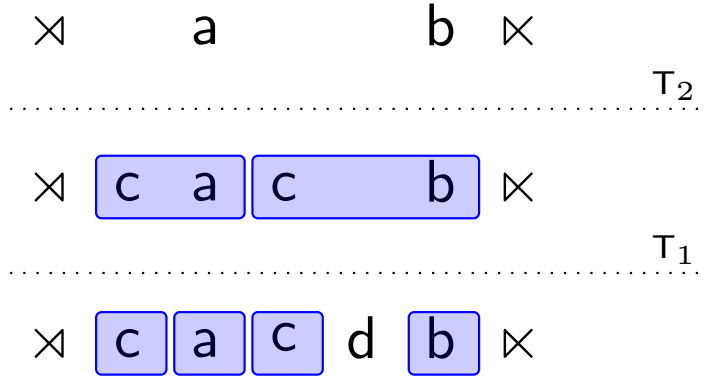

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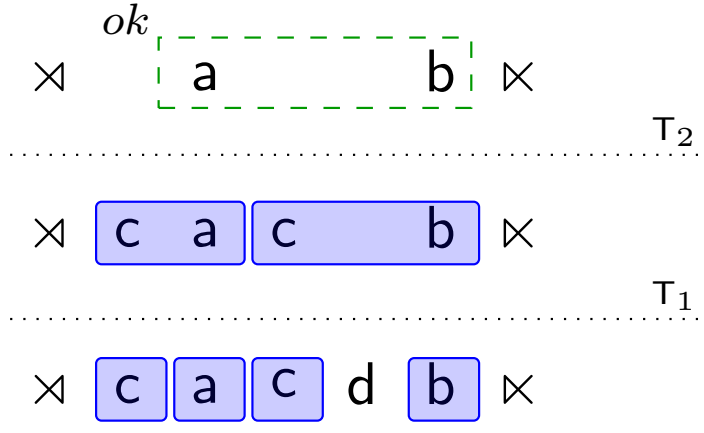

b)

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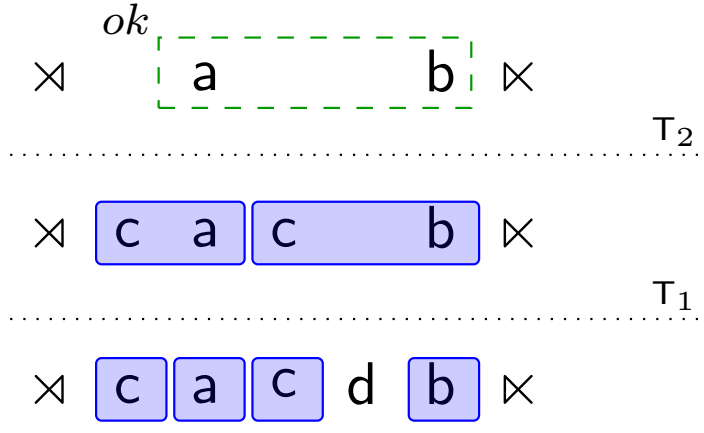
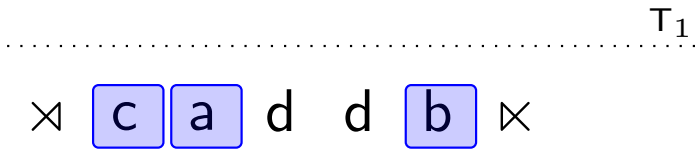


b)



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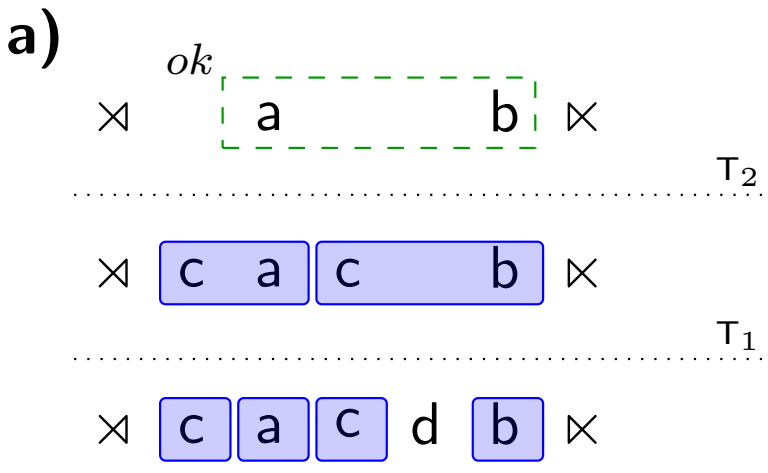

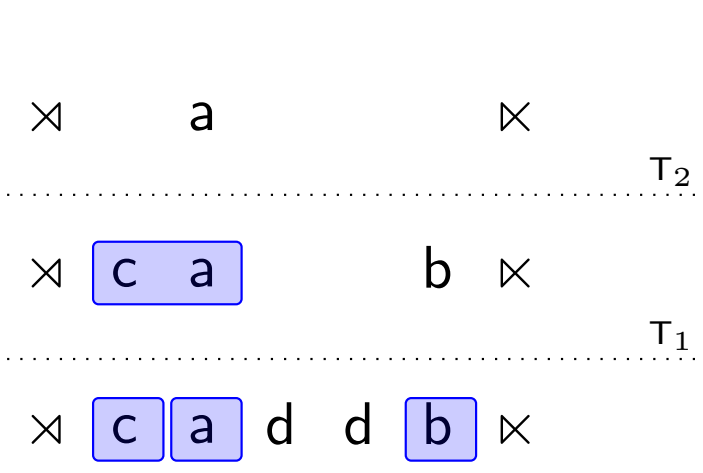

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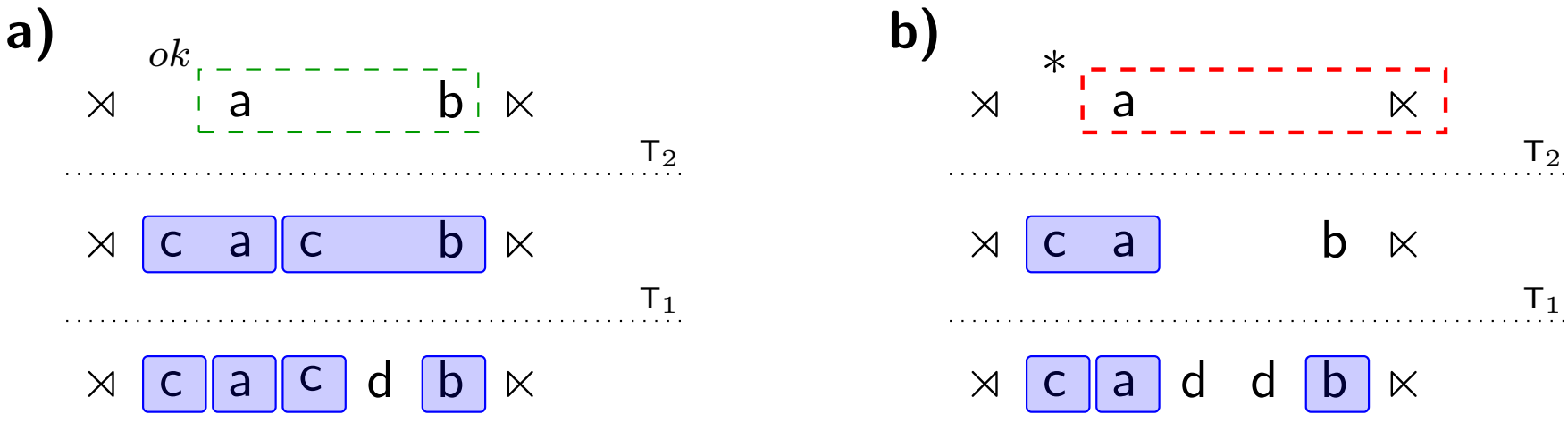

TSL Syntax (of the Intuition)

TSL syntax

Merge and Move dependencies are TSL! (Graf and Heinz 2016)

- We move from strings to trees.
- We project tiers for trees.
- We enforce n-local tree constraints.

Tree n-gram grammars:

- Patterns are described by forbidden tree n-gram(s).
- A derivational tree is well formed iff no tier T contains any forbidden n-gram(s).

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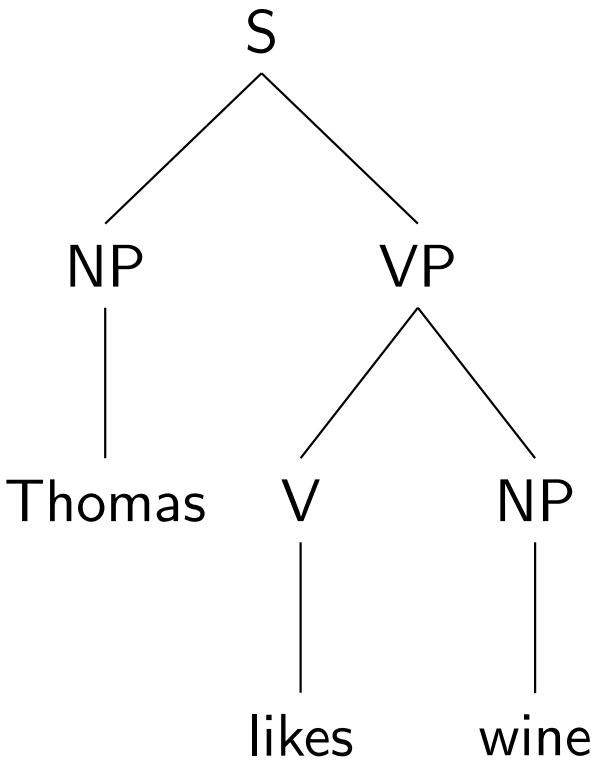
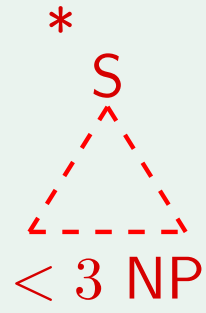
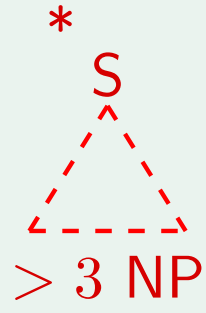


Tier-grammar





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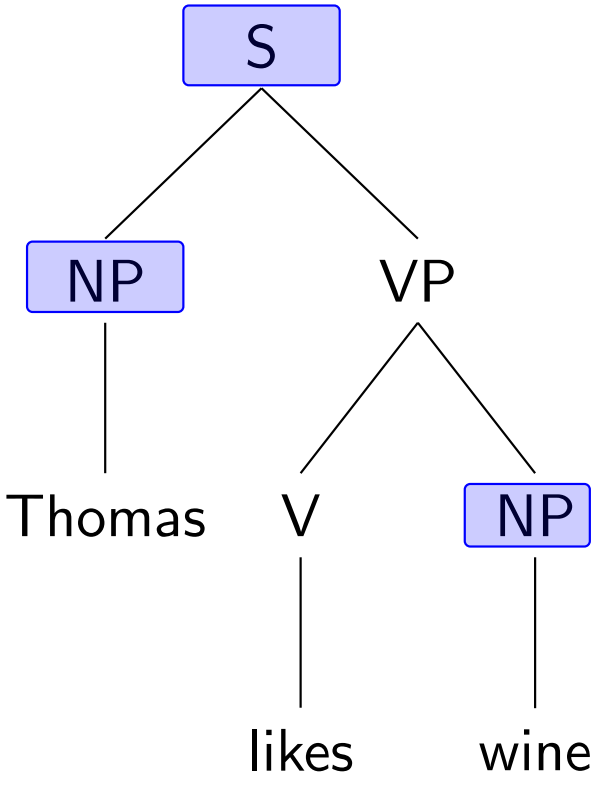
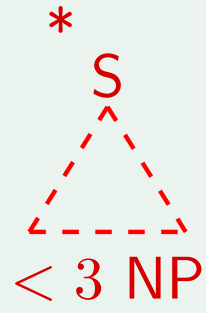
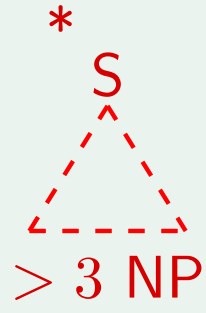


Tier-grammar





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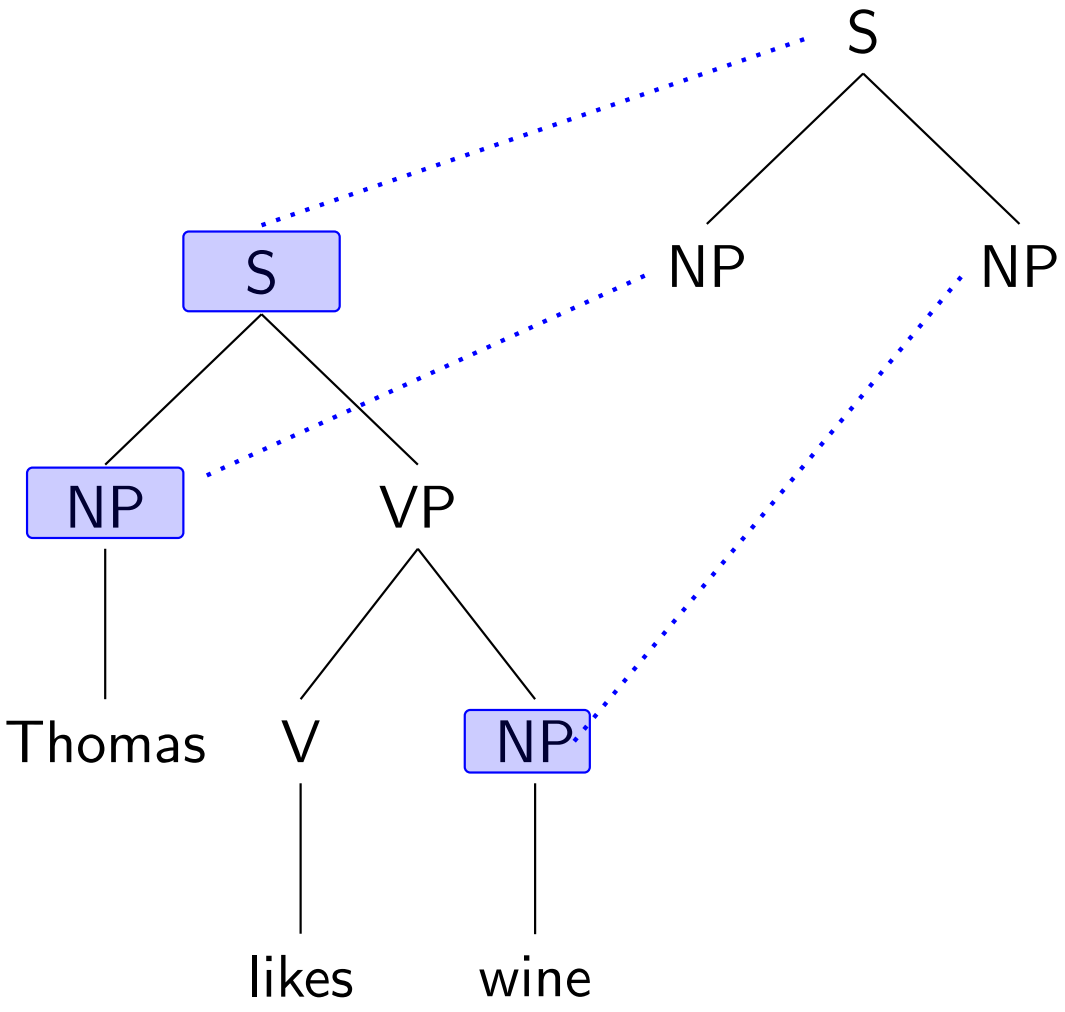
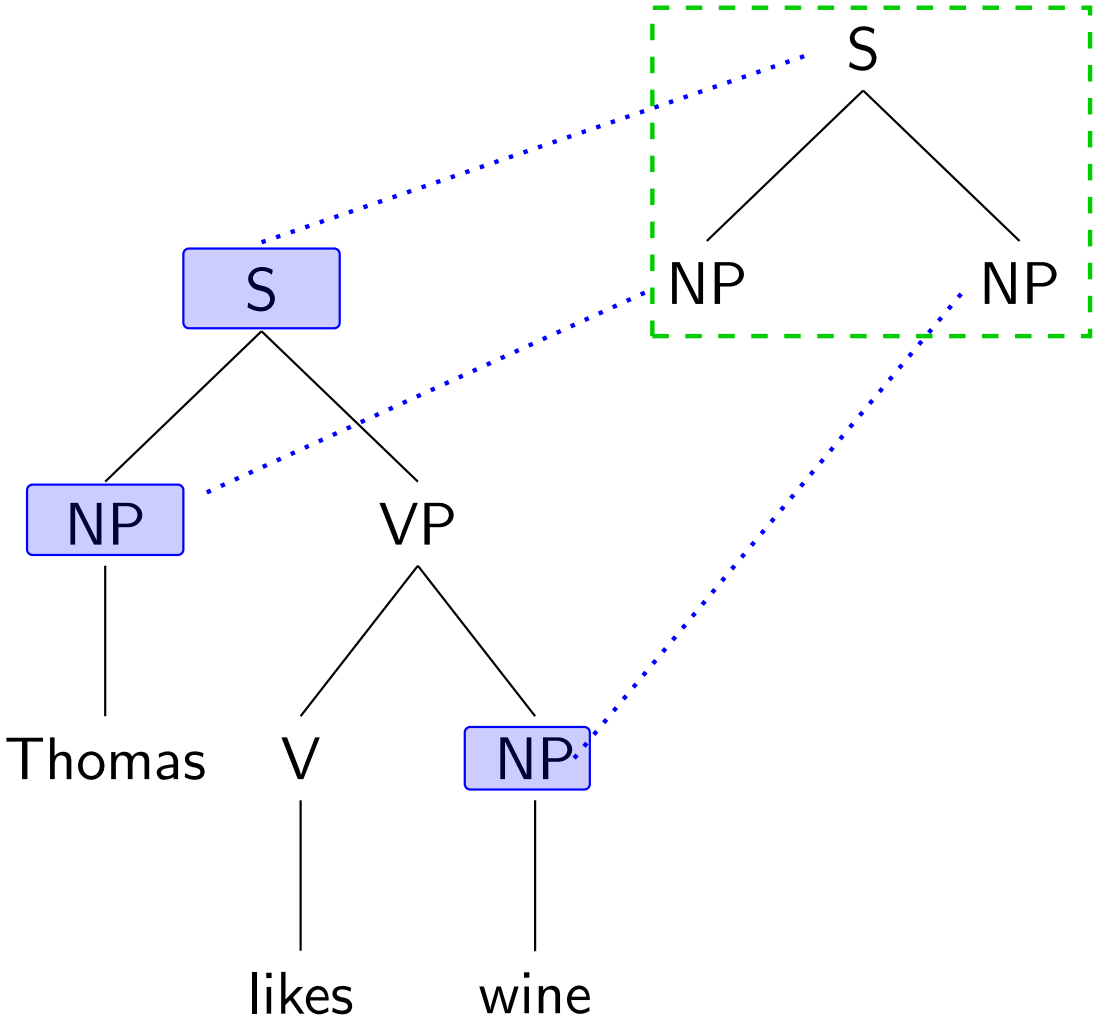


Tier-grammar

$*$
S
< 3 NP

$*$
S
> 3 NP

TSL Syntax: Example (of the Intuition)



Tier-grammar

$*$ S < 3 NP

$*$ S > 3 NP