The Computational Basis of Locality in Syntactic Agreement

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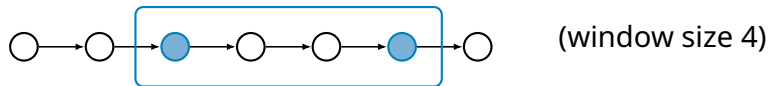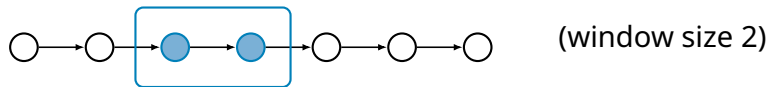
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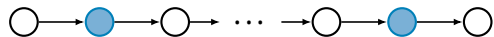
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What does it mean to be local?

Local → finitely bounded

(window size 2)

(window size 4)

Long-distance (non-local) → no finite bound

Not just local, *strictly local*

Strictly local (SL): constraints on substrings (or subtrees) of fixed size (Rogers et al. 2013; Rogers 1997).

Ex. Local assimilation

✓ a | m p | a p a | n d | a
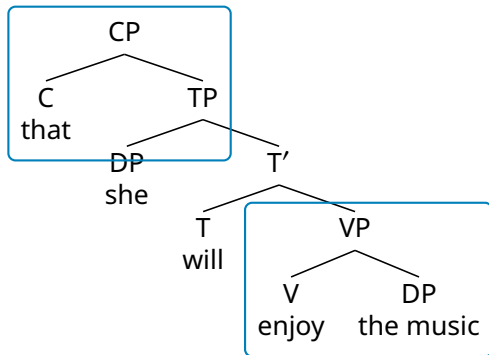
✗ a | n p | a p a | n d | a

✗ a | m p | a p a | m d | a

Constraints:

*np, *nb, *mt, *md, …

Not just local, *strictly local*

Strictly local (SL): constraints on substrings (or subtrees) of fixed size (Rogers et al. 2013; Rogers 1997).

Ex. Category selection

Constraints:
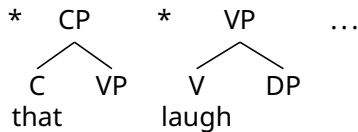
Adding in non-locality

Tier-based strictly local (TSL) patterns: like SL, but *irrelevant elements are ignored* (Heinz et al. 2011; Lambert and Rogers 2020).

Ex. Sibilant harmony (Heinz 2018)

Visible elements:	s, ʃ
Constraints:	*sʃ, *ʃs

Adding in non-locality

Tier-based strictly local (TSL) patterns: like SL, but *irrelevant elements are ignored* (Heinz et al. 2011; Lambert and Rogers 2020).

Ex. ϕ-agreement (this talk)

✓ There **seem$_{PL}$** [$_{TP}$ to be <u>some problems$_{PL}$</u> with this theory].

% There **seems$_{SG}$** [$_{TP}$ to be <u>some problems$_{PL}$</u> with this theory].

Visible elements:	finite T, all D
Constraints:	*SG·PL, *PL·SG

(To be revised.)

Overview

Main claim: Long-distance linguistic dependencies are predominantly TSL with a window size of two – they are **tier-based strictly 2-local (TSL-2)**.

- Phonotactics (McMullin 2016; McMullin and Hansson 2016)
- Morphotactics (Aksënova et al. 2016)
- Movement (Graf 2018; Graf 2022)
- Case assignment (Hanson 2023b)
- **Agreement (this work)**

Focus for today: TSL-2 provides a **unified model of locality** based on a **moving window of visibility**.

- Encompasses relativized minimality (Rizzi 1990; Rizzi 2013), selective opacity (Keine 2019), case discrimination (Bobaljik 2008), and more.
- Derives (one type of) myopia in grammar from computational considerations (Rogers et al. 2013; Lambert et al. 2021).

Roadmap

1. TSL patterns and their properties
2. A TSL model of agreement
3. Consequences for locality
4. Typological variation, parallels across domains
5. Strengths and limitations of the model

What is a TSL pattern?

1. Ignore the irrelevant items and treat the rest as if adjacent
2. All constraints must be stated within a fixed-size moving window

> **Example: Vowel harmony**
>
> i/u/o obey front-back harmony,   *e* is transparent/neutral,   *a* is opaque
> Tier elements: {i, u, o, a}   Constraints: {*iu, *ui, *io, *oi}
>
> | k | u | b | u | l | o | ✓ | k | i | b | i | l | o | ✗ |
> | k | u | b | e | l | o | ✓ | k | i | b | e | l | o | ✗ |
> | k | u | b | a | l | o | ✓ | k | i | b | a | l | o | ✓ |

See Appendix 1 for another example and a formal definition.

More about TSL

- Inspired by but distinct from autosegmental phonology (Goldsmith 1976)

- Special relational structure combined with very weak constraint logic (cf. Lambert and Rogers 2020; Lambert et al. 2021; Lambert 2023)

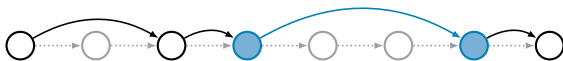- Related: ITSL and OTSL functions model a wide range of phonological maps (Burness et al. 2021)

Figure 1: Two adjacent elements on a tier

A TSL Model of Agreement

Setup

Assumptions:

- Bare phrase structure, feature-driven selection, movement, some method of case assignment
- Agreement between elements with initially unvalued features (probes) and elements which provide those values (goals)

**Question:** What are the possible arrangements of probes and goals for agreement?

Answer: They are TSL-2 constraints on the "search path" of the probe.

The search path

I assume that the search path follows the
derivational command (d-command) relation
(Graf and Shafiei 2019).

- Head < Spec < Comp
- d-command order ≈ height of XP
  ≈ order of last merge
  ≈ reverse order of selection
- Projections of a head are not
  distinguished.
- At each branching point, follow the
  complement spine (Graf and De Santo 2019).
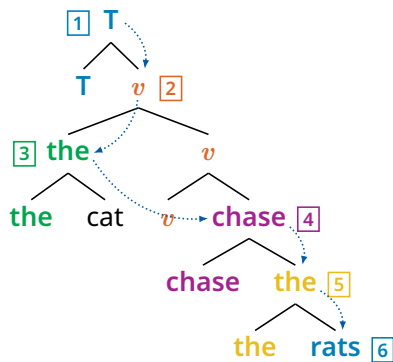
See Appendix 3 for how this works using derivation trees.

ex. 'The cat chases the rats.'

The TSL analysis

General principle: a probe must be immediately followed by its goal on a tier projected from the search path (and vice versa).

Notation: $p\phi$ = probe $g\phi$ = actual goal ϕ = other potential goal

Example: (canonical) subject-verb agreement
Tier elements: All agreeing elements (T/D) and blockers (C)
Constraints: $*T_{[p\phi]} \cdot D_{[\phi]}$, $*T_{[p\phi]} \cdot C$, $*D \cdot D_{[g\phi]}$, $*D_{[g\phi]} \cdot D_{[g\phi]}$, ...

The TSL analysis – example

General principle: a probe must be immediately followed by its goal on a tier projected from the search path (and vice versa).

The cat **chases** the rats.

Path: $\mathbf{T_{[p\phi]}} \cdot v \cdot \mathbf{D_{[g\phi]}} \cdot \mathrm{V} \cdot \mathrm{D_{[\phi]}} \cdot \mathrm{N}$

Tier: $\mathbf{T_{[p\phi]}} \cdot \mathbf{D_{[g\phi]}} \cdot \mathrm{D_{[\phi]}}$

Violations: n/a
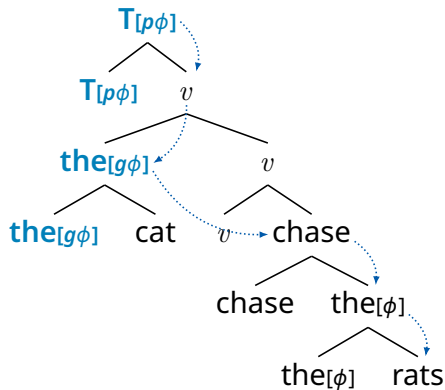
For simplicity, we substitute most items with their category labels in the path and tier projection.

Consequences for locality

Consequences for locality

- **Blocking:** if another element intervenes on the tier, agreement is blocked, regardless of whether the blocker itself can agree.
    - ▶ relativized minimality (Rizzi 1990; Rizzi 2013)
    - ▶ domain-based blocking
- **Invisibility:** if a DP is omitted from the tier, strict minimality may be violated.
    - ▶ agreement across *there*
    - ▶ case-sensitive agreement (Bobaljik 2008; Preminger 2014)
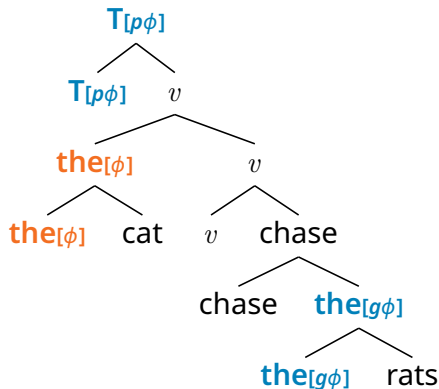
Minimality

If another potential goal intervenes on the tier, agreement is blocked.

* The cat **chase** <u>the rats</u>.

Path: $T_{[p\phi]} \cdot v \cdot D_{[\phi]} \cdot V \cdot D_{[g\phi]} \cdot N$

Tier: $T_{[p\phi]} \cdot D_{[\phi]} \cdot D_{[g\phi]}$

Violations: $*T_{[p\phi]} \cdot D_{[\phi]}, *D_{[\phi]} \cdot D_{[g\phi]}$

Domain-based blocking

If a non-agreeing element is projected on the tier, agreement is likewise blocked.

* It **are** possible for <u>cats</u> to swim.

cf. It **is** possible…

Path: $\mathsf{T}_{[p\phi]} \cdot v \cdot \mathsf{V} \cdot \mathbf{C} \cdot \top \cdot \mathsf{D}_{[g\phi]} \cdot v \cdot \mathsf{D}_{[g\phi]} \cdot \mathsf{V}$

Tier: $\mathsf{T}_{[p\phi]} \cdot \mathbf{C} \cdot \mathsf{D}_{[g\phi]}$

Violations: *$\mathsf{T}_{[p\phi]} \cdot \mathsf{C}$, *$\mathsf{C} \cdot \mathsf{D}_{[g\phi]}$
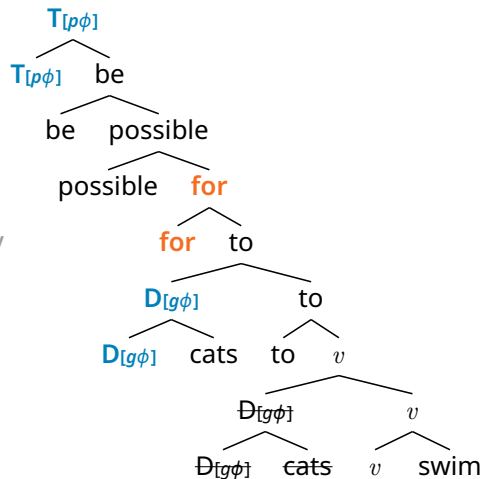
Assume for the sake of demonstration that expletive "it" is inserted late and does not agree.

Invisibility

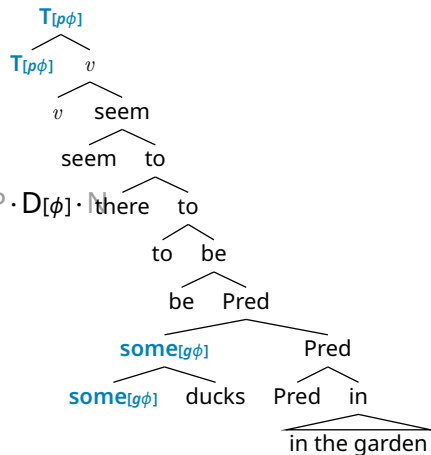If a DP is omitted from the tier, strict minimality may be violated.

There **seem** to be <u>some ducks</u> in the garden.

Path: $T_{[p\phi]} \cdot v \cdot V \cdot T \cdot there \cdot v \cdot Pred \cdot D_{[g\phi]} \cdot P \cdot D_{[\phi]} \cdot N$
Tier: $T_{[p\phi]} \cdot D_{[g\phi]} \cdot D_{[\phi]}$
Violations: n/a

We can handle optional default agreement in several ways. Ask me if you are interested.

Case-sensitive agreement

In Hindi, the verb agrees with the closest *nominative* argument, which may not be the subject.

(1) Hindi verbal agreement ignores ergatives (Mahajan 1990)

  a. Raam   roTii   khaataa   thaa.
Raam.**M**.**NOM** bread.**F**.NOM eat.IPFV.**M** be.PST.**M**

    'Raam ate bread (habitually).'

  b. Raam-ne   roTii   khaayii.
Raam.**M**-**ERG** bread.**F**.NOM eat.PFV.**F**

    'Raam ate bread.'

Analysis: Project D only if nominative. Tier constraints are unchanged.

Case-sensitive agreement (2)

'Raam ate bread (habitually).'   (Nominative subject, subject agrees)

$\rightarrow \quad T_{[p\phi]} \cdot be \cdot v \cdot D_{[\text{NOM},g\phi]} \cdot eat \cdot D_{[\text{NOM},\phi]} \cdot bread$

$\downarrow$

$T_{[p\phi]} \cdot D_{[\text{NOM},g\phi]} \cdot D_{[\text{NOM},\phi]}$
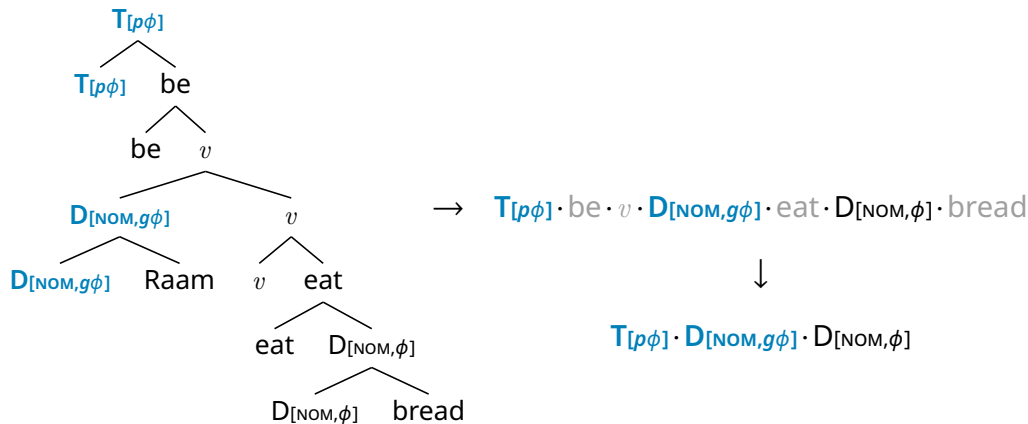
We ignore agreement on the non-finite verb for simplicity.

Case-sensitive agreement (3)

'Raam ate bread.'   (Ergative subject, object agrees)

$$\rightarrow \quad \mathsf{T}_{[p\phi]} \cdot v \cdot \mathsf{D}_{[\text{ERG}]} \cdot \text{eat} \cdot \mathsf{D}_{[\text{NOM},g\phi]} \cdot \text{bread}$$

$$\downarrow$$

$$\mathsf{T}_{[p\phi]} \cdot \mathsf{D}_{[\text{NOM},g\phi]}$$
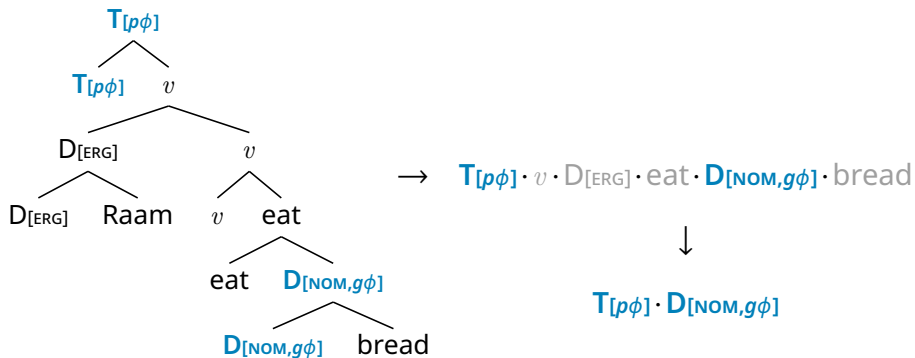
Locality – interim summary

Locality phenomena derive from TSL with a window of size two, a.k.a. **TSL-2**.

- Blocking: some (non-)agreeing element intervenes on the tier

$$T_{[p\phi]} \ldots \mathbf{C} \ldots D_{[g\phi]} \qquad T_{[p\phi]} \ldots \mathbf{D_{[\phi]}} \ldots D_{[g\phi]}$$

- Invisibility: hypothetical goal does not appear on tier

$$T_{[p\phi]} \ldots there \ldots D_{[g\phi]} \qquad T_{[p\phi]} \ldots D_{[\text{ERG},\phi]} \ldots D_{[\text{NOM},g\phi]}$$

The importance of the finite window

- Neither tiers nor the finite window alone are adequate.
  - ► Tiers provide relativized locality.
  - ► Keeping all constraints within the moving window limits the power of the system.
- Other combinations of locality profile and constraint logic are either too powerful, too weak, or both.

Limits on structural configurations

TSL computations can relate elements at a distance, but are otherwise severely restricted in what they can do.

- No arbitrary logic — "a DP can A-move out of a finite CP, but only if there is A′-movement within some (other) CP in the sentence"

- No counting — "up to three reflexive pronouns may occur in a sentence if each obeys the Binding Theory"

Three models of locality

Immediate precedence (SL)
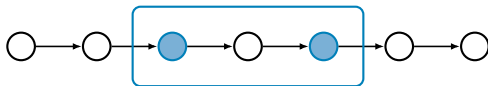
General precedence (SP)
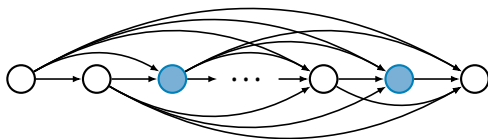
Tier precedence (TSL)
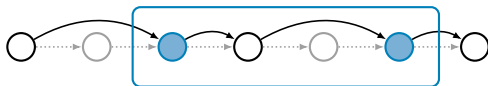
Name of formal class combining locality model with logic of banned substructures in parentheses.

Three models of locality (2)

- SL (immediate precedence) can handle local spreading.
- SP (general precedence) can handle unbounded processes, but can't handle blockers.
- Only TSL (tier precedence) can handle unbounded processes with blocking.

Typological variation

Variation in visibility

- Not all of invisibility and blocking can be analyzed purely in terms of relativized minimality

- Sometimes, even items which almost certainly possess the relevant features are invisible nonetheless

- Conversely, irrelevant items may block agreement

- Both types of exception are subject to variation across languages and dependencies

Case discrimination, revisited

Ergatives are not invisible in Nepali (though datives are).

(2) Agreement with ergative in Nepali (Coon and Parker 2019)

   a. Maile   yas pasal-mā patrikaā   kin-ē.
      1SG.**ERG** DEM store-LOC newspaper.ABS buy-**1SG**

      'I bought the newspaper in this store.'

   b. Ma   thag-ī-ē.
      1SG.**ABS** cheat-PASS-**1SG**

      'I was cheated.'

No problem! We project $D_{[NOM]}$ and $D_{[ERG]}$ but not $D_{[DAT]}$.

Selective opacity

"A particular structure may allow one movement [or agreement] type to proceed out of it but at the same time block other types of extraction [agreement]." — Keine (2019)

	Probe location	Size of clause		
		CP (finite)	TP (nonfinite)	vP (nonfinite)
ϕ-agreement	T	*	*	✓
A-movement	T	*	*	✓
Wh-licensing	C	*	✓	✓
A′-movement	C	✓	✓	✓

Table 1: Selective opacity in Hindi (adapted from Keine 2019)

Formal vs substantive constraints

- Case visibility hierarchy (Bobaljik 2008):
  Nom > Acc/Erg > Obliques

- Height-locality connection (Keine 2019): The possible horizons for a (nonvacuous) probe on a head X which is a projection of Y **exclude** all extended projections of Y below X
  e.g. T cannot be a horizon for a probe on C

- We can encode the attested patterns in a TSL-2 grammar, but the implicational hierarchy itself requires a separate explanation.

Parameters for variation

The parameters for TSL-2 (tier elements and constraints) correspond neatly to variation in long-distance dependencies.

1. Visibility — which elements are relevant and which are ignored?
   - ▶ Case-sensitive agreement (cf. Bobaljik 2008; Preminger 2014)
   - ▶ Probe horizons (Keine 2019)
2. Iteration — if you allow AB and BB, then you get ABB, ABBB, etc.
   - ▶ Case/gender/number concord
3. Directionality — do we ban AB or BA?
   - ▶ Upward/downward agreement (cf. Chomsky 2000; Zeijlstra 2012; Carstens 2016)

For #2 & #3, see Appendix 2

What else is TSL-2?

Phenomenon	One line summary
Defective intervention*	Some DPs project even if they are never $g\phi$
A′-agreement (Van Urk 2015)*	Only project DPs with a certain A′ feature
Omnivorous number	Only project DPs with [PL], not [SG]
Upward C agr. (Diercks 2013)*	C probes up, only project DPs that EPP-move
Default agreement*	Allow lone $p\phi$ under limited circumstances
Interaction/Satisfaction (Deal 2015)*	Allow multiple $g\phi$ under limited circumstances
Parasitic agreement (Bhatt 2005)	Allow parasitic elements btw. $p\phi$ and $g\phi$
Independent subfeatures of ϕ	Each probe gets its own tier/constraints

Also: many movement (Graf 2022) and case patterns (Vu et al. 2019; Hanson 2023b), though these analyses use a different tier-based model.

*See Hanson (2023a) and Hanson (2024a) for details.

What *isn't* TSL?

Some linguistic patterns are not TSL, but SS-TSL (structure-sensitive TSL):

- Some long-distance harmony (De Santo and Graf 2019; Graf and Mayer 2018)

- Some tone patterns (e.g. unbounded tone plateauing)

- Some binding rules (Graf and Shafiei 2019)

Parallels across domains

Parallels across domains

Parameter	ϕ-agreement	Wh-movement	Vowel harmony
Participants	Probe and most DPs	Probe and Wh-DPs	Most vowels
Invisible	Non-DPs, some DPs	Non-Wh elements	Consonants, some V
Blockers	Finite C, some DPs	Certain islands	Some vowels
Directionality	Downward/upward	???	Progressive/regressive
Chaining	Concord/no concord	Wh-agreement[*]	Spreading/"icy targets"

[*]See Graf (2022).

Locality and typology

Type	Class	Example	Visible Cs
Unbounded	TSL-2	Aari	Only sibilants
LD w/ blocking	TSL-2	Slovenian	All coronals
Transvocalic	TSL-2	Koyra	All consonants
At most 1 C intervenes	TSL-3	Unattested	—
Exactly 1 C intervenes	TSL-3	Unattested	—
At least 1 C intervenes	TLT[**]	Unattested	—

Table 2: Typology of consonant (dis)-harmony (adapted from McMullin and Hansson 2016)

[**]Maybe also SS-TSL, specifically OTSL [K.H.].

Locality and typology (2)

Non-TSL-2 and unattested island types (Graf 2022):

- Gang-up islands: A mover can escape n islands, but not $n + 1$.

- Configurational islands: XP is an island iff it is inside an embedded clause.

- Cowardly islands: XP is an island iff there are at least n XPs in the same clause.

- Narcissist islands: XP is an island iff there are no other XPs in the same clause.

- Rationed island effects: At most n phrases per clause can be an island.

- Discerning islands: XP is an island only for movers that contain a PP.

Locality and typology (3)

Non-TSL-2 and unattested subject-verb agreement types:

- Matrix T agrees with the embedded subject, and embedded T with the matrix subject.

- T agrees with the subject only in a ditransitive clause, otherwise default agreement is required.

- T agrees with the subject unless there is a temporal adjunct, in which case it agrees with the object.

- When finite clauses are coordinated, agreement occurs in exactly one of them.

- Only DPs which contain a relative clause which contains two PPs can agree.

Strengths and limitations of the model

Advantages of the model

- Clear separation of concerns:
  - ▶ Structural representation
  - ▶ Computations over said structure
  - ▶ Substance of elements of structure
- Restrictive, independently rooted in well-understood mathematics
  - ▶ Subregular language hierarchy, relativized adjacency, etc.
- Agnostic to many analytical choices
  - ▶ e.g. Basic functional hierarchy vs cartographic hierarchy

Limitations of the model

Puzzles for the path-based approach:

- What to do about violations of c-command (e.g. sub-command)?
- How to handle exceptions to the complement spine generalization?

What the formal model does not tell us:

- Why does case matter for ϕ-agreement? Why should nominatives always be visible, ergatives sometimes visible, and datives usually invisible?
- Why do probes seem to look downward more often than upward?
- How do children identify the visible elements and constraints for each dependency? (see Hanson 2024b; Belth 2023)

Summary

- A wide range of facts about the locality profiles of linguistic dependencies are explained if they are TSL with a window size of 2.

- From this perspective, agreement turns out to be especially similar to phonological harmony — perhaps because both are feature-matching phenomena.

- Most of the logical possibilities of the model are realized within a single phenomenon — this is not necessarily expected!

Some open questions

- Do we ever need a window size larger than 2?
- Are there agreement patterns that are not TSL under any reasonable analysis?
- How far can we take the parallel with harmony in phonology?

Takeaways

- Computational approaches to linguistic analysis reveal insights that might otherwise not be obvious.

- In other cases, they provide independent support to conclusions reached in other ways (e.g. visibility is parameterized).

- A clear understanding of the formal patterns can help us understand other aspects of linguistic structure.

Acknowledgments

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Extras

Even more on TSL

More agreement patterns

A more formal syntactic model

Computational background

Extra example: Sibilant harmony

Sibilants match in anteriority, *t* blocks harmony, other C's transparent

(based on Slovenian)

All elements:	{s, ∫, t, k, a}
Tier elements:	{s, ∫, t}
Constraints:	{*s∫, *∫s}

Word	Tier	
s a s a s a	s s s	✓
s a **s** a ∫ a	s **s** ∫	✗
s a k a s a	s s	✓
s a k a ∫ a	**s** ∫	✗
s a t a s a	s t s	✓
s a t a ∫ a	s t ∫	✓

TSL string languages – formal definition

In a **tier-based strictly k-local (TSL-k)** language, a string is well-formed iff its **tier projection** does not contain any forbidden substrings of some length k.

- Σ = "alphabet" = set of all symbols
- T = "tier alphabet" = set of visible symbols
- G = "grammar" = forbidden substrings
- The tier projection is obtained by deleting all non-tier elements and concatenating the remaining elements.

Concord in the DP

To allow for iterated agreement, just permit $p\phi \cdot p\phi$.

(3) Gender concord in German

Ich habe [eine hübsche Muschel]   gefunden.
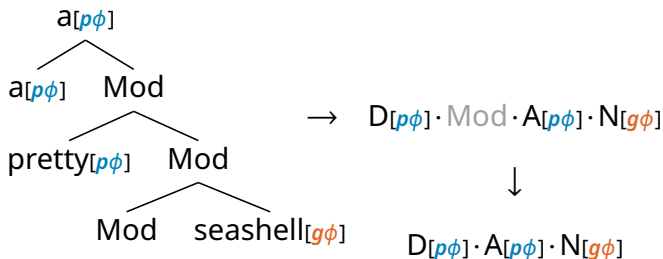I   have [a.**F**   pretty.**F**   seashell.**F**] found

'I found a pretty seashell.'

Analysis: Ignore Mod on the tier, permit $D_{[p\phi]} \cdot A_{[p\phi]}$ and $A_{[p\phi]} \cdot A_{[p\phi]}$.

Concord in the DP (2)

Analysis: Ignore Mod on the tier, permit $D_{[p\phi]} \cdot A_{[p\phi]}$ and $A_{[p\phi]} \cdot A_{[p\phi]}$.

```
            a[pφ]
           /    \
    a[pφ]      Mod
              /    \
     pretty[pφ]   Mod         →   D[pφ] · Mod · A[pφ] · N[gφ]
                 /    \
             Mod    seashell[gφ]         ↓

                                 D[pφ] · A[pφ] · N[gφ]
```

The Mod head is not crucial. If direct adjunction is used, then the pattern is local: the tier contains everything.

Upward agreement

If the constraints are mirrored, then the direction of agreement is reversed.
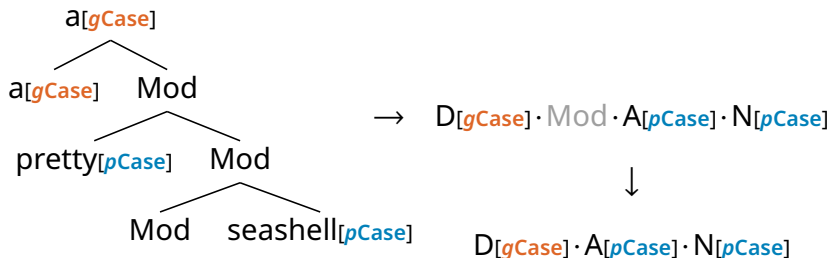
(4) Case concord in German

   Ich habe [eine   hübsche   Muschel]   gefunden.
   I   have [a.**ACC** pretty.**ACC** seashell.**ACC**] found

Analysis: allow D[*g*Case]·A[*p*Case] instead of D[*p*Case]·A[*g*Case], etc.

Upward agreement (2)

Analysis: allow $D_{[g\text{Case}]} \cdot A_{[p\text{Case}]}$ instead of $D_{[p\text{Case}]} \cdot A_{[g\text{Case}]}$, etc.

$$\rightarrow \quad D_{[g\text{Case}]} \cdot \text{Mod} \cdot A_{[p\text{Case}]} \cdot N_{[p\text{Case}]}$$

$$\downarrow$$

$$D_{[g\text{Case}]} \cdot A_{[p\text{Case}]} \cdot N_{[p\text{Case}]}$$

We can handle definiteness agreement on the adjective (ignored here) in the same way.

What does it mean to probe upward?

- In the MG derivation tree formalism (Graf and Shafiei 2019), we have a static representation of the entire derivation, so there is no problem.

- In a bottom-up Minimalist derivation, it is not obvious what it means for a probe to search upward. Some possibilities:
  - ▶ Let valued features search downward for unvalued features (Adger 2003)
  - ▶ Let Agree be upward, triggered once the relevant items are merged (Zeijlstra 2012)
  - ▶ Replace the search metaphor with the sliding window metaphor (my suggestion)

Interaction and satisfaction (Deal 2015)

Basic idea: Every probe has features that it interacts with (interaction set) and features that cause probing to stop (satisfaction set).

TSL analysis: Probe may be followed by zero or more interacting heads, followed by one that satisfies it.

Formally:

- Let $p\phi$ denote the probe.
- Let $i\phi$ denote a feature in the interaction set *but not* the satisfaction set.
- Let $s\phi$ denote a feature in the satisfaction set.
- Let X stand for a head of any category.
- Allowed pairs: $X_{[p\phi]} \cdot X_{[s\phi]}$, $X_{[p\phi]} \cdot X_{[i\phi]}$, $X_{[i\phi]} \cdot X_{[s\phi]}$
- Banned pairs: everything else

MG derivation trees

- All nodes appear in base position.
- The rightmost child of a node is its complement; others are specifiers.
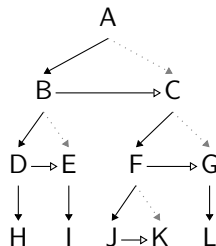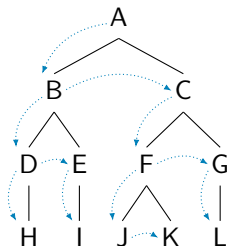- Movement is indicated using feature diacritics.
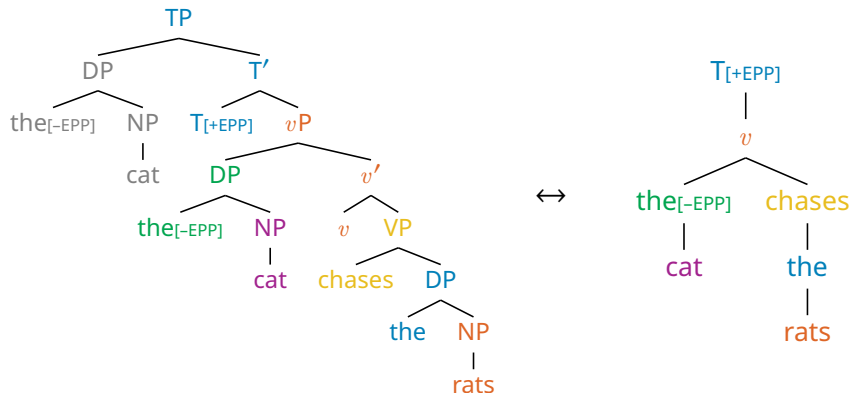
See Graf and Kostyszyn (2021) for a formal definition. Related: Brody (2000).

Command strings

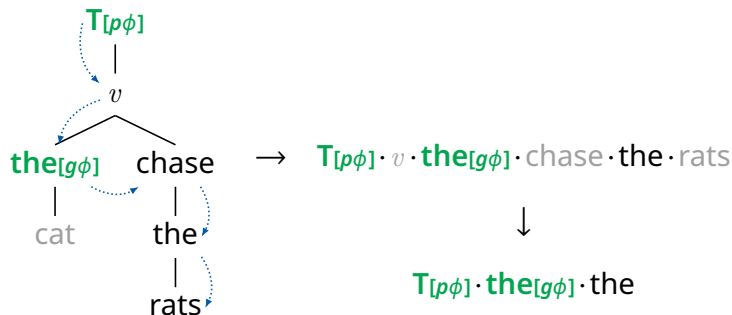A **command string** (c-string) is a derivational ordering of nodes.

- There is a c-string from the root to each node.
- Among each head and its arguments: Head < Specifier < Complement.

See Graf and Shafiei (2019) for details.
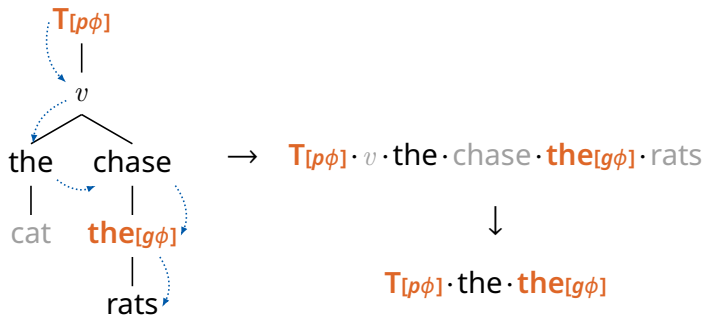
Tiers over command strings

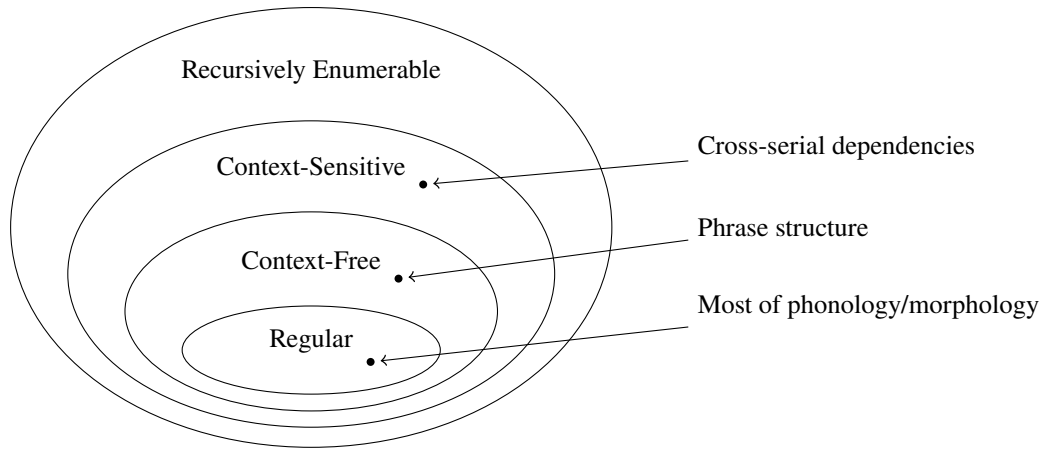✓ The cat **chases** the rats. (subject agreement)

$$\mathsf{T}_{[p\phi]} \cdot v \cdot \mathbf{the}_{[g\phi]} \cdot \text{chase} \cdot \text{the} \cdot \text{rats}$$

$$\downarrow$$

$$\mathsf{T}_{[p\phi]} \cdot \mathbf{the}_{[g\phi]} \cdot \text{the}$$

Tiers over command strings (2)

✗ The cat **chase** the rats. (object agreement)

$T_{[p\phi]} \cdot v \cdot \text{the} \cdot \text{chase} \cdot \textbf{the}_{[g\phi]} \cdot \text{rats}$

↓

$T_{[p\phi]} \cdot \text{the} \cdot \textbf{the}_{[g\phi]}$

The Chomsky Hierarchy

Syntax is "mildly context sensitive" when analyzed over surface strings. It becomes subregular when analyzed over derivation trees.

Recursively Enumerable

Context-Sensitive — Cross-serial dependencies

Context-Free — Phrase structure

Regular — Most of phonology/morphology

The Subregular Hierarchy