A Computational Perspective on the Typology of Agreement

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September 29, 2023

Variation in Agreement

Focusing on ϕ-agreement...

- Which elements agree?
  - Probes: T/C/v
  - Goals: All DPs/some DPs
- What elements can intervene?
  - Minimality effects
  - Misc. blockers, e.g. finite C
- What are the positions of source and target?
  - Probe c-commands goal
  - Goal c-commands probe

Some Puzzles for AGREE

- Why should visibility vary?
- Why should there be blockers, and why should they vary? (cf. Halpert 2019; Keine 2020)
- Why should directionality vary? Does it really? (cf. Pesetsky and Torrego 2007; Zeijlstra 2012)
- Why does a probe sometimes agree with multiple goals? (cf. Deal 2015, et seq.)

Overview of the Talk

Most long-distance linguistic dependencies are in the formal class **tier-based strictly local (TSL)** (Heinz 2018; Graf 2022a).

- Long-distance phonotactics (Heinz 2018)
- Movement (Graf 2022b)
- Case licensing (Vu et al. 2019; Hanson 2023)

Claim: Syntactic agreement is also TSL.

Why this matters:

- Limits predicted structural configurations
- Provides parameters for variation

Computational Intuitions

Strictly local (SL): constraints on sequences of adjacent elements

- Phonology: local phonotactics
  - No consonant clusters! (*CC)
  - No vowel hiatus! (*VV)
  - No voiceless consonant after a nasal! (*NT)
- Syntax: selection, functional hierarchies
  - Selection: object of *devour* must be a DP!
  - Functional hierarchy: T < (Perf) < (Prog) < (Pass) < V

Computational Intuitions (2)

Tier-based strictly local (TSL): constraints on sequences of adjacent elements. . . *when the irrelevant elements are ignored*

- Phonology: vowel harmony (ignore intervening consonants)
  - ex. front-back harmony

    ✓ k**u**b**u**l**o** ✗ k**i**b**i**l**o**

    *[+back][–back], *[–back][+back]
- Syntax: subject-verb agreement (ignore things other than finite T and D)
  - ex. There **seem** to be **some ducks** in the garden.

    $* \ T_{SG}\ D_{PL},\ *\ T_{PL}\ D_{SG}$

Limits on Structural Configurations

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

- No arbitrary logic — “you can have A…B…C or X…Y…Z, but not both”
- No counting — “you can have A…B…C, but only up to three times”

Parameters for Variation

The space of possible TSL constraints corresponds neatly to variation in long-distance dependencies.

- Visibility: which elements are relevant and which are ignored?
- Blocking: are there elements which block dependency formation?
- Directionality: do we ban XY, YX, or both?

Parameters for Variation (2)

Phenomenon	ϕ-agreement	Vowel harmony
Participants	Probe and most DPs	Most vowels
Invisible	Non-DPs, some DPs	Consonants, some vowels
Blockers	Finite C, some DPs	Some vowels
Directionality	Downward/upward	Progressive/regressive

What Else Can TSL Do?

- Selective opacity
  - probe horizons (Keine 2020)
- One probe sharing multiple goals
  - e.g. interaction/satisfaction theory (Deal 2015)
- Two elements interacting within some domain
  - e.g. dependent case (Baker 2015)
- Conjoined vs independent probes (cf. Lohninger et al. 2022)

Roadmap

- SL and TSL formal languages
- Constraints on syntactic derivations
- Formal typology of agreement
  - Invisibility
  - Blocking
  - Multiple probes
  - Directionality
  - Multiple goals

SL and TSL Formal Languages

Strictly Local Languages

In a **strictly *k*-local** (SL-*k*) language, a string is well-formed iff it does not contain any **forbidden substrings** of some fixed length *k*.

- Σ = "alphabet" = set of all symbols
- G = "grammar" = forbidden substrings

Example: CV alternation (SL-2)

$\Sigma = \{C, V\}$ $\quad G = \{VV, CC\}$

Licit words: CVC, VCV, CVCVC, ...

Illicit words: CVVC, CVCCV, CVVCCV ...

Strictly Local Languages (2)

To model constraints at the start/end of a word, we add **edge markers** $\rtimes/\ltimes$ and use them in the grammar like any other symbol.

Example: CV syllables, optional final C (SL-2)

$\Sigma = \{\mathrm{C}, \mathrm{V}\}$ $\quad G = \{\rtimes\mathrm{V}, \mathrm{VV}, \mathrm{CC}\}$

Licit words: $\rtimes$CV$\ltimes$, $\rtimes$CVC$\ltimes$, $\rtimes$CVCV$\ltimes$, $\rtimes$CVCVC$\ltimes$, ...

Illicit words: **$\rtimes$V**CV$\ltimes$, $\rtimes$C**VV**$\ltimes$, $\rtimes$CV**CC**V$\ltimes$, ...

Tier-Based Strictly Local Languages

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*.

- T = "tier alphabet" = set of salient/visible symbols

Example: Vowel harmony (TSL-2)

Front-back harmony, 'e' is transparent, 'a' is a blocker

$$\Sigma = \{k, b, l, i, u, o\}$$
$$T = \{i, u, o\}$$
$$G = \{iu, io, oi, ui\}$$

$\rtimes$ k u b u l o $\ltimes$ ✓

$\rtimes$ k i b i l o $\ltimes$ ✗

Tier-Based Strictly Local Languages (2)

A more complex example

Front-back harmony, 'e' is transparent, 'a' is a blocker

$\Sigma = \{$k, b, l, i, **e**, u, o, **a**$\}$

$T = \{$i, u, o, **a**$\}$

$G = \{$iu, io, oi, ui$\}$

Word	Tier	
kubulo	⋊uuo⋉	✓
kibilo	⋊iio⋉	✗
kubelo	⋊uo⋉	✓
kibelo	⋊io⋉	✗
kubalo	⋊uao⋉	✓
kibalo	⋊iao⋉	✓

Constraints on Syntactic Derivations

EPP Movement

(1) Minimality

a. The cat [$_{vP}$ ___ chases the rats].

b. * The rats [$_{vP}$ the cat chase ___].

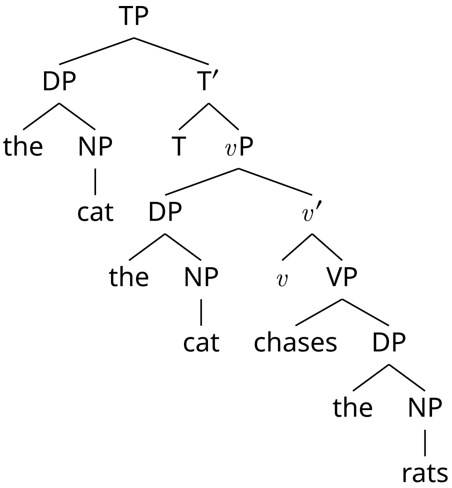
(2) Blocking

a. This student seems [$_{TP}$ ___ to be a genius].

b. * This student seems [$_{CP}$ that ___ is a genius.]

Derivation Trees

‘The cat chases the rats.’



Derivation Trees

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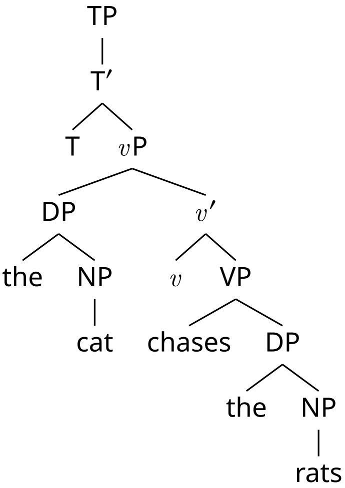

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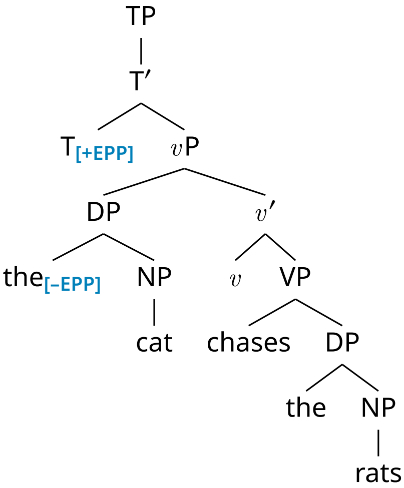

Derivation Trees

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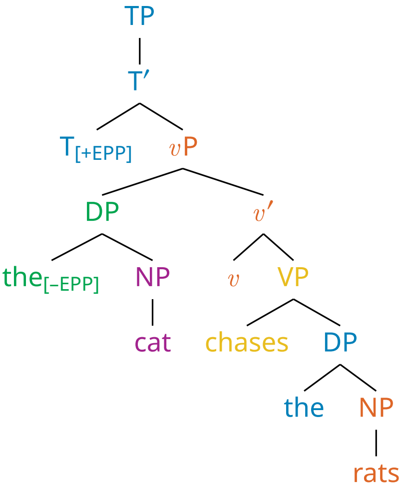
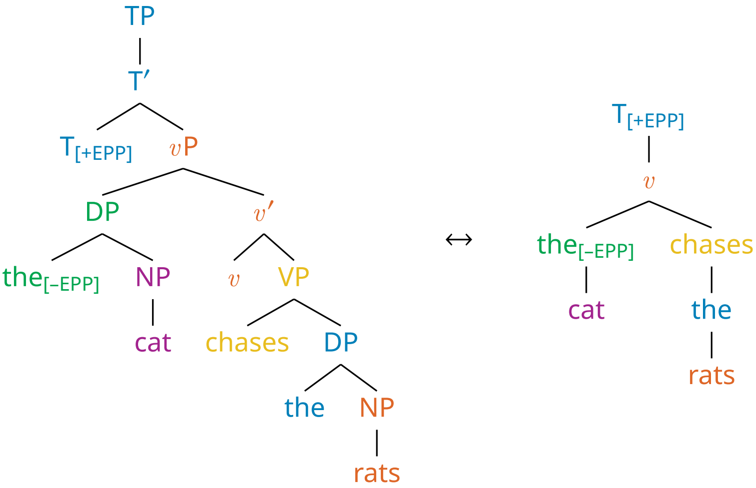


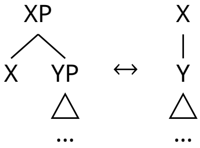
Derivation Trees

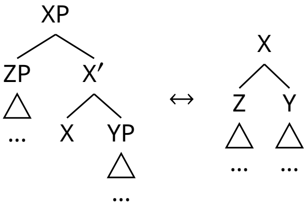
'The cat chases the rats.'

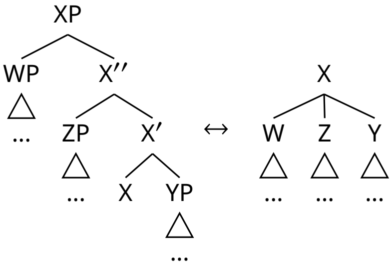


Derivation Trees (2)

The rightmost child of a node is its complement; others are specifiers.



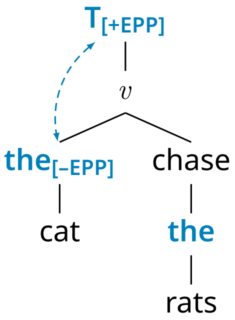


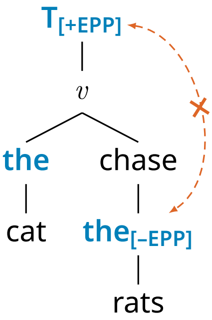


See Graf and Kostyszyn (2021) for details. Related: Brody (2000).

Minimality

✓ The cat [$_{v\text{P}}$ ___ chases the rats]. vs. ✗ The rats [$_{v\text{P}}$ the cat chase ___].

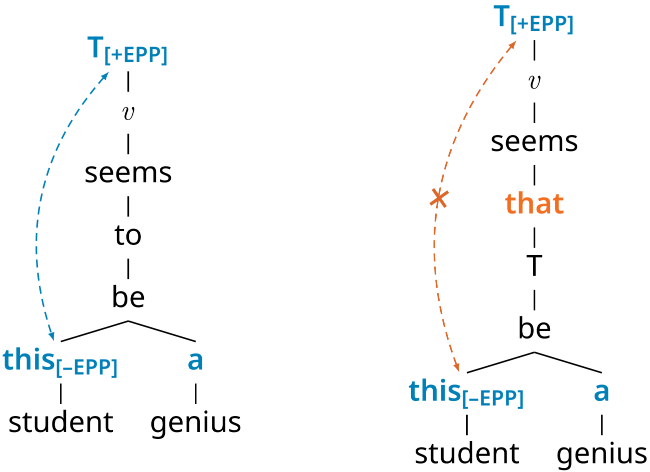




Blocking

✓ This student seems [$_{\text{TP}}$ ____ to be a genius].

✗ This student seems [$_{\text{CP}}$ that ____ is a genius.]



TSL Grammar for EPP Movement

Constraints:

- Every EPP landing site should immediately followed by an EPP mover on the tier, and vice versa.
- No potential EPP-related element may intervene.
- No blocking elements may intervene.

TSL grammar:

- Project a tier with all nodes of categories T/D/C
- Banned substrings:

$$\left\{ \begin{array}{ll} \mathrm{X}_{[+\mathrm{EPP}]} \cdot \mathrm{X}_{[+\mathrm{EPP}]} & \mathrm{X}_{[-\mathrm{EPP}]} \cdot \mathrm{X}_{[-\mathrm{EPP}]} \\ \mathrm{X}_{[+\mathrm{EPP}]} \cdot \mathrm{X} & \mathrm{X} \cdot \mathrm{X}_{[-\mathrm{EPP}]} \\ \mathrm{X}_{[+\mathrm{EPP}]} \cdot \ltimes & \rtimes \cdot \mathrm{X}_{[-\mathrm{EPP}]} \end{array} \right\}$$

Subject-Verb Agreement

(3) Minimality

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

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

(4) Long-distance agreement

a. Some ducks **seem** to be in the garden.

b. There **seem** to be some ducks in the garden.

(5) Finite C blocks agreement

a. It **seems** that there are some ducks in the garden.

b. * It **seem** that there are some ducks in the garden.

(6) Finite C is not always opaque

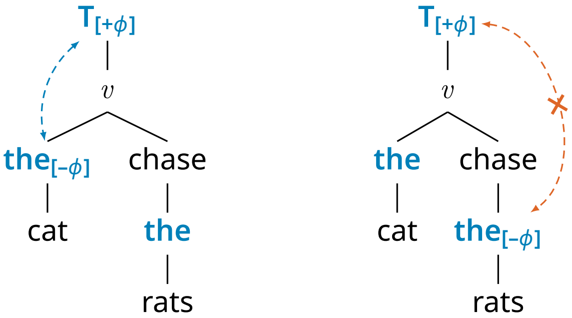
a. Nobody said that there are **any** ducks in the garden.

b. * Somebody said that there are **any** ducks in the garden.

Agreement and Minimality

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

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



TSL Grammar for Subject-Verb Agreement

Constraints:

- Every ϕ-probe site should immediately followed by a ϕ-goal on the tier, and vice versa.
- No potential ϕ-related element may intervene.
- No blocking elements may intervene.

TSL grammar:

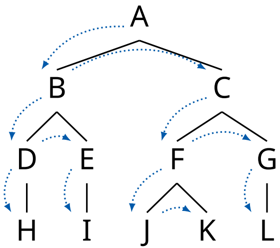
- Project a tier with all nodes of categories T/D/C
- Banned substrings:

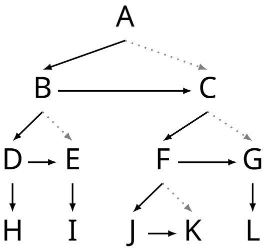
$$\left\{ \begin{array}{ll} X_{[+\phi]} \cdot X_{[+\phi]} & X_{[-\phi]} \cdot X_{[-\phi]} \\ X_{[+\phi]} \cdot X & X \cdot X_{[-\phi]} \\ X_{[+\phi]} \cdot \ltimes & \rtimes \cdot X_{[-\phi]} \end{array} \right\}$$

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.

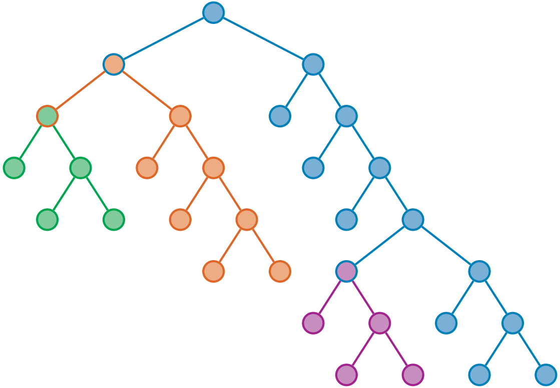




See Graf and Shafiei (2019) for details. Related: Frank and Vijay-Shankar (2001).

Command Strings (2)

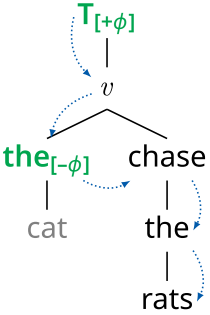
We're interested in c-strings that trace the **complement spine** of the tree, or of a left branch.



See Graf and De Santo (2019) regarding how to distinguish spines.

Tiers Over Command Strings

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



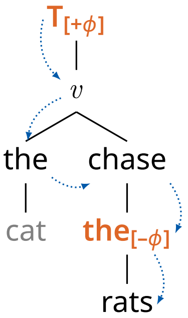
$$\longrightarrow \quad \mathbf{T}_{[+\phi]} \cdot v \cdot \mathbf{the}_{[-\phi]} \cdot \text{chase} \cdot \text{the} \cdot \text{rats}$$

$$\downarrow$$

$$\mathbf{T}_{[+\phi]} \cdot \mathbf{the}_{[-\phi]} \cdot \text{the}$$

Tiers Over Command Strings (2)

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



$\longrightarrow$ $\mathbf{T}_{[+\phi]} \cdot v \cdot \text{the} \cdot \text{chase} \cdot \mathbf{the}_{[-\phi]} \cdot \text{rats}$

$\downarrow$

$\mathbf{T}_{[+\phi]} \cdot \text{the} \cdot \mathbf{the}_{[-\phi]}$

The Typology of Agreement

Parameters for Variation

TSL patterns have two types of parameters:

- Which elements are projected on the tier?
- What are the local constraints on the tier?

Participants	Probe and most DPs	Tier projection
Invisible	Non-DPs, some DPs	
Blockers	Some DPs, finite C	
Directionality	Downward/upward	Tier constraints
Multiple agreement	One/multiple probes/goals	

Case Studies

1. Invisibility: Case-sensitive agreement (Hindi)
2. Blocking: Dative intervention (Icelandic)
3. Multiple Probes: Complementizer agreement (West Flemish)
4. Directionality: More complementizer agreement (Lubukusu)
5. Multiple goals: Existential clauses (English)

Invisibility

Case-Sensitive Agreement

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

(7) 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).’

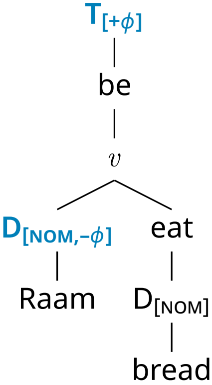
b. Raam-ne roTii khaayii.
Raam.M-**ERG** bread.F.NOM eat.PFV.F

‘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)



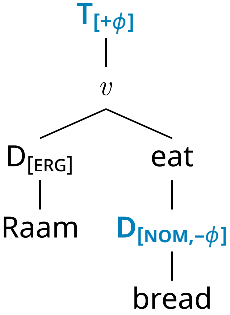
$$\rightarrow \mathbf{T}_{[+\phi]} \cdot \text{be} \cdot v \cdot \mathbf{D}_{[\text{NOM},-\phi]} \cdot \text{eat} \cdot \text{D}_{[\text{NOM}]} \cdot \text{bread}$$

$$\downarrow$$

$$\mathbf{T}_{[+\phi]} \cdot \mathbf{D}_{[\text{NOM},-\phi]} \cdot \text{D}_{[\text{NOM}]}$$

Case-Sensitive Agreement (3)

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



$$\longrightarrow \mathbf{T}_{[+\phi]} \cdot v \cdot \mathrm{D}_{[\mathrm{ERG}]} \cdot \mathrm{eat} \cdot \mathbf{D}_{[\mathrm{NOM},-\phi]} \cdot \mathrm{bread}$$

$$\downarrow$$

$$\mathbf{T}_{[+\phi]} \cdot \mathbf{D}_{[\mathrm{NOM},-\phi]}$$

Case-Sensitive Agreement (4)

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

Subject Case	T agrees w/	✓	Tier
Nominative	Subject	✓	$T_{[+\phi]} \cdot D_{[\text{NOM},-\phi]} \cdot D_{[\text{NOM}]}$
	Object	✗	$T_{[+\phi]} \cdot D_{[\text{NOM}]} \cdot D_{[\text{NOM},-\phi]}$
Ergative	Subject	✗	$T_{[+\phi]} \cdot D_{[\text{NOM}]}$
	Object	✓	$T_{[+\phi]} \cdot D_{[\text{NOM},-\phi]}$

Ergative ≠ Invisible

Oblique case-marked DPs are not necessarily invisible.

(8) Case-insensitive agreement 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.'

Analysis: Exactly as in English.

Blocking

Blocking and Defaults

In principle, there are two possible outcomes when agreement is blocked (cf. Preminger 2014):

1. The derivation crashes.
2. Default agreement occurs.

We will look at a case of default agreement.

Dative Intervention

Often, datives are invisible (like ergatives in Hindi).
In Icelandic, they are usually invisible, but not always.

(9) Optional agreement across dative subject (Holmberg and Hróarsdóttir 2003)

a.	Einhverjum	stúdent	finnst	[tölvurnar	ljótar].
	some	student.SG.DAT	find.SG	computer.PL.DEF.NOM	ugly.NOM
b.	Einhverjum	stúdent	finnast	[tölvurnar	ljótar].
	some	student.SG.DAT	find.PL	computer.PL.DEF.NOM	ugly.NOM

‘Some student finds the computers ugly.’

Dative Intervention (2)

(10) Icelandic transitive expletive construction (Holmberg and Hróarsdóttir 2003)

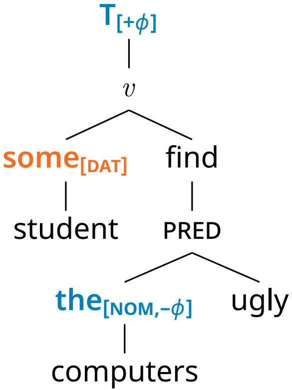
a.		Það	finnst	einhverjum	stúdent	[tölvurnar	ljótar].
		EXPL	find.**DFLT**	some	student.**DAT**	computer.**PL**.DEF.NOM	ugly.NOM
b.	*	Það	finnast	einhverjum	stúdent	[tölvurnar	ljótar].
		EXPL	find.**PL**	some	student.**DAT**	computer.**PL**.DEF.NOM	ugly.NOM

‘Some student finds the computers ugly.’

Analysis of blocking data: Dative DPs do project. Probe can be followed by a non-agreeing dative. (The full pattern also TSL.)

Dative Intervention (3)

✗ ‘There find.**PL** some student the computers ugly.’



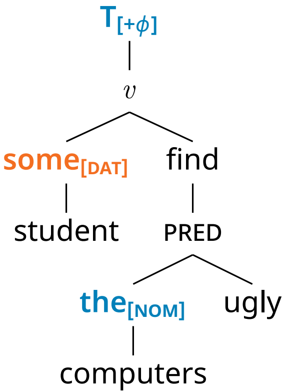
$$\longrightarrow \; T_{[+\phi]} \cdot v \cdot D_{[\text{DAT}]} \cdot \text{find} \cdot \text{PRED} \cdot D_{[\text{Nom},-\phi]} \cdot \text{ugly}$$

$$\downarrow$$

$$T_{[+\phi]} \cdot D_{[\text{DAT}]} \cdot D_{[\text{Nom},-\phi]}$$

Dative Intervention (4)

✓ ‘There find.**DFLT** some student the computers ugly.’



$$\longrightarrow \quad T_{[+\phi]} \cdot v \cdot D_{[DAT]} \cdot \text{find} \cdot \text{PRED} \cdot D_{[NOM]} \cdot \text{ugly}$$

$$\downarrow$$

$$T_{[+\phi]} \cdot D_{[DAT]} \cdot D_{[Nom]}$$

Dative Intervention (5)

Analysis: Dative DPs do project. Probe can be immediately followed by a non-agreeing dative.

- Tier projection is as in English.
- Don't ban all $X_{[+\phi]} \cdot X$, only $X_{[+\phi]} \cdot X_{[\text{NOM}]}$.

Alternative: Default agreement is agreement with the dative DP.

Multiple Probes

Multiple Probes

- So far we've only dealt with a single ϕ-probe in a clause.
- In general, each probe gets its own tier with its own constraints.
- It is possible, and sometimes necessary, for two probes to share a tier.

Complementizer Agreement

In some languages with agreeing complementizers, both C and T agree with the same DP.

(11) Complementizer Agreement in West Flemish (Diercks 2013)

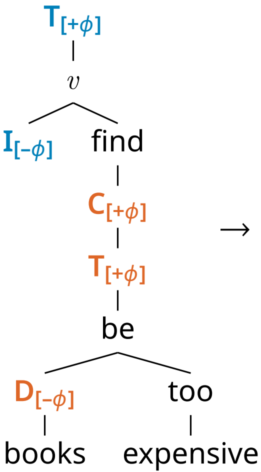
a. Kpeinzen da-j (gie) morgen goat.
I-think **that-you (you)** tomorrow **go**
'I think that you'll go tomorrow.'

b. Kvinden dan [die boeken] te diere zyn.
I-find **that-PL** [**the books**] too expensive **are**
'I find those books too expensive.'

Single-tier analysis: Relax the constraint against sequential probes.

Complementizer Agreement (2)

‘I find that the books are too expensive.’



$\longrightarrow \mathrm{T}_{[+\phi]} \cdot v \cdot \mathrm{D}_{[-\phi]} \cdot \mathrm{V} \cdot \mathrm{C}_{[+\phi]} \cdot \mathrm{T}_{[+\phi]} \cdot \text{be} \cdot \mathrm{D}_{[-\phi]} \cdot \text{too} \cdot \text{expensive}$

$\downarrow$

$\mathrm{T}_{[+\phi]} \cdot \mathrm{D}_{[-\phi]} \cdot \mathrm{C}_{[+\phi]} \cdot \mathrm{T}_{[+\phi]} \cdot \mathrm{D}_{[-\phi]}$

Complementizer Agreement (3)

Analysis: Relax the constraint against sequential probes.

- Tier projection: as in English.
- Constraints: as in English, but don't ban $X_{[+\phi]} \cdot X_{[+\phi]}$
    - Or at least, don't ban $C_{[+\phi]} \cdot T_{[+\phi]}$

Alternative: Each type of ϕ-probe (C, T, etc.) gets its own tier.

Directionality

Upward Complementizer Agreement

(12) Complementizer Agreement in Lubukusu (Diercks 2013)

a. Ba-ba-ndu ba-bolela Alfredi ba-li a-kha-khile.
C2-C2-people **C2**-said C1.Alfred **C2**-that C1-FUT-conquer
'The people told Alfred that he will win.'

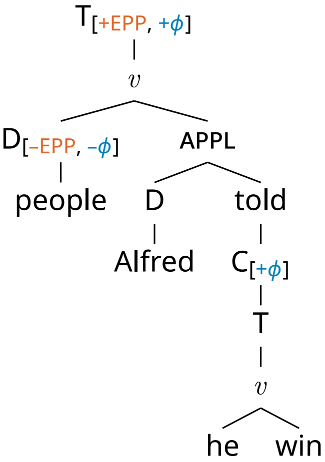
b. Alfredi ka-bolela ba-ba-ndu a-li ba-kha-khile.
C1.Alfred C1-said C2-C2-people **C1**-that C2-FUT-conquer
'Alfred told the people that they will win.'

Analysis:

- Allow ϕ-probe on C follow its goal.
- Agreement on C is subject oriented, so project only DPs with –EPP.

Upward Complementizer Agreement (2)

‘The people told Alfred that he will win.’



$$\longrightarrow \quad \mathrm{T}_{[+\mathrm{EPP},\ +\phi]} \cdot v \cdot \mathrm{D}_{[-\mathrm{EPP},\ -\phi]} \cdot \mathrm{APPL} \cdot \mathrm{D} \cdot \mathrm{told} \cdot \mathrm{C}_{[+\phi]} \cdots$$

$$\downarrow$$

$$\mathrm{T}_{[+\mathrm{EPP},\ +\phi]} \cdot \mathrm{D}_{[-\mathrm{EPP},\ -\phi]} \cdot \mathrm{C}_{[+\phi]} \cdots$$

Upward Complementizer Agreement (3)

Analysis: Allow ϕ-probe on C follow its goal. Project DPs only if [–EPP].

- Project: all T, D if [–EPP], all C
- Constraints: as in English, but allow $D_{[-\phi]} \cdot C_{[+\phi]}$

Multiple Goals

Multiple Goals

- Sometimes a single elements seems to get its features from several different goals, e.g. omnivorous agreement (cf. Nevins 2011).
- The interaction-satisfaction theory (Deal 2015) modifies the AGREE algorithm as follows:
  - We distinguish two sets of features, the **interaction set** and the **satisfaction set**.
  - A probe copies features from elements in the interaction set, but only stops once it finds an element in the satisfaction set.
  - The morphology can realize the features of any/all of the elements the probe has acquired.
- The theory has many other uses, including some cases of optionality.

Optionality

(13) Optional agreement in English existential clauses

a. There seem(s) to be some squirrels in the attic.

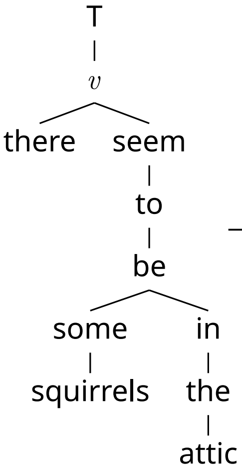
b. Some squirrels seem(*s) to be in the attic.

Analysis:

- Singular/default agreement is agreement with *there*, whose ϕ-features are in the interaction set but not the satisfaction set.
- Allow sequence of goals between the probe and the goal that ‘satisfies’ it.

Optionality (2)

‘There seem(s) to be some squirrels in the attic.’



$$\longrightarrow \quad \mathrm{T}_{[+\phi]} \cdot v \cdot \mathrm{there}_{[-\phi]} \cdot \mathrm{seem} \cdot \mathrm{to} \cdot \mathrm{be} \cdot \mathrm{some}_{[-\phi]} \cdot \mathrm{in} \cdot \mathrm{the} \cdot \mathrm{attic}$$

$$\downarrow$$

$$\mathrm{T}_{[+\phi]} \cdot \mathrm{there}_{[-\phi]} \cdot \mathrm{some}_{[-\phi]}$$

Optionality (3)

Analysis: Allow sequence of goals between the probe and the goal that ‘satisfies’ it.

- Tier alphabet: as usual
- Constraints: as usual, but allow there$_{[-\phi]} \cdot$ D$_{[-\phi]}$

Note: We could also use this analysis for dative intervention.

Summary

Phenomenon	Example	Tier Projection	Tier Constraints
Minimality	Subject-verb agreement	All T/D/C	Strict matching of $+\phi$ and $-\phi$
Invisibility	Case-sensitive agreement	All T/C D only if right case	—
	Subject-oriented agreement	All T/C D only if –EPP	—
Blocking	Dative intervention	—	Non-agreeing dative may follow $+\phi$
Multiple probes	Agreeing T & C	—	Allow sequential $+\phi$
Directionality	Upward agreement	—	Swap order of $+\phi/-\phi$
Multiple goals	Optionality	—	Allow sequential $-\phi$

Summary (2)

- Agreement patterns in syntax are TSL over c-strings.
- If we vary the tier projection and constraints slightly, we can account for variation across languages and constructions.
- The range of variation is similar to other phenomena, especially phonologyical harmony.
- Most of the logical possibilities of TSL are realized just within ϕ-agreement — this is not necessarily expected!

Open Questions

- Any TSL-3 patterns? TSL-4?
- To what extent are multiple tiers required?
  (subfeatures of ϕ, subject+object agreement)
- Are there patterns that are not TSL under any reasonable analysis?
- To what extent do other kinds of agreement (e.g. negative concord) look like ϕ agreement?
- To the extent that movement/case/agreement are not alike, why?
- How far can we take the parallel with harmony in phonology?

Acknowledgments

This work was partly supported by NSF Grant BCS-1845344 and by the Institute for Advanced Computational Science at Stony Brook University.

Thanks to Thomas Graf, Sandhya Sundaresan, and Tom McFadden for comments and feedback.

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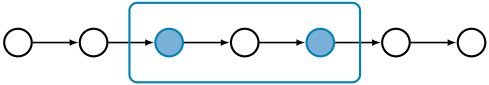
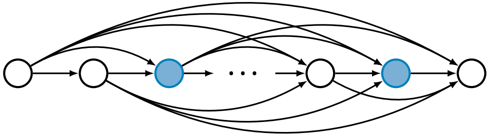
Extras

Three Models of Locality

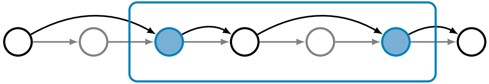
Finitely bounded



Unbounded



Finitely bounded with invisibility



Computing SL/TSL Patterns

Some ways to determine whether a string satisfies a SL/TSL grammar:

1. Collect the set of length-k (tier) substrings, and intersect it with the grammar. The string is well-formed iff this intersection is the empty set.
2. Read one symbol at a time, keeping track of the most recent $k - 1$ (tier) symbols. Check for violations at each step. The string is well-formed if we reach the end with no violations.

Computational Complexity

(T)SL languages are efficient to process.

- The size of the grammar is at most $|\Sigma|^k$, where Σ is the set of symbols.
- Testing or generating a string takes linear time, e.g. when implemented as a finite state machine.

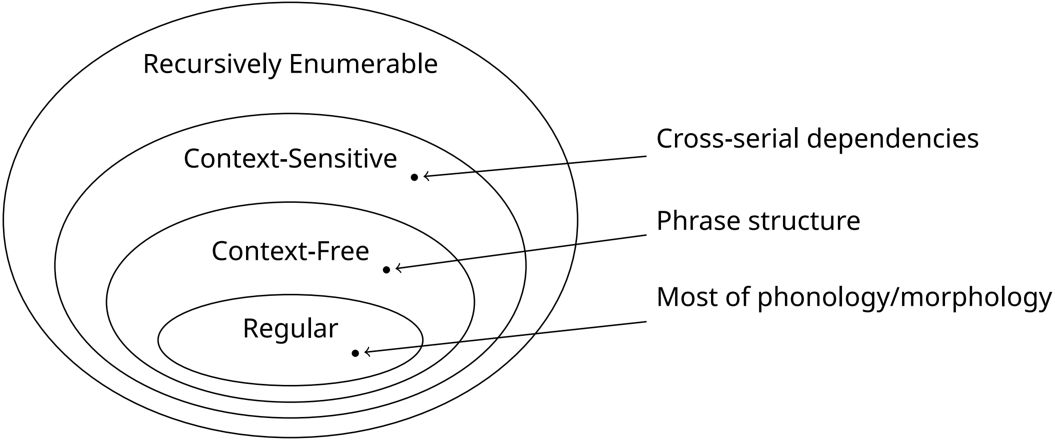
Computational Complexity (2)

(T)SL languages are easy to learn.

- Just keep track of all attested (tier) substrings of size k.
  $\longrightarrow$ *string extension learning* (Garcia et al. 1990; Heinz 2010)
- The time to process the input data is linear.
- Very little data is needed (compared to more expressive classes).

The Chomsky Hierarchy

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



The Subregular Hierarchy