A Computational Perspective on the Typology of Agreement

Kenneth Hanson
Stony Brook University

NYU Syntax Brown Bag
September 29, 2023

1 Introduction

[2] 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

[3] 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.)

[4] 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

[5] 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

[6] 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}

[7] 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"

[8] 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?

[9] 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

[10] 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)

[11] Roadmap

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

2 SL and TSL Formal Languages

[13] 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)

Σ = {C, V} G = {VV, CC}

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

Illicit words: C**VV**C, CV**CC**V, C**VV**C**C**V . . .

[14] Strictly Local Languages (2)

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

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

Σ = {C, V} G = {⋊V, VV, CC}

Licit words: ⋊CV⋉, ⋊CVC⋉, ⋊CVCV⋉, ⋊CVCVC⋉, . . .

Illicit words: ⋊**V**CV⋉, ⋊C**VV**⋉, ⋊CV**CC**V⋉, . . .

[15] 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

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

⋊ k u b u l o ⋉ ✓
⋊ k i b i l o ⋉ ✗

[16] Tier-Based Strictly Local Languages (2)

A more complex example

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

Σ = {k, b, l, i, **e**, u, o, **a**}
T = {i, u, o, **a**}
G = {iu, io, oi, ui}

Word	Tier	
k**u**b**u**l**o**	⋊uuo⋉	✓
k**i**bil**o**	⋊i**io**⋉	✗
k**u**bel**o**	⋊uo⋉	✓
k**i**bel**o**	⋊**io**⋉	✗
k**u**b**a**l**o**	⋊uao⋉	✓
k**i**b**a**l**o**	⋊iao⋉	✓

3 Constraints on Syntactic Derivations

[18] EPP Movement

(1) Minimality

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

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

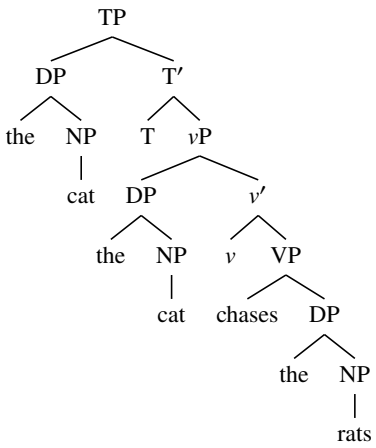
(2) Blocking

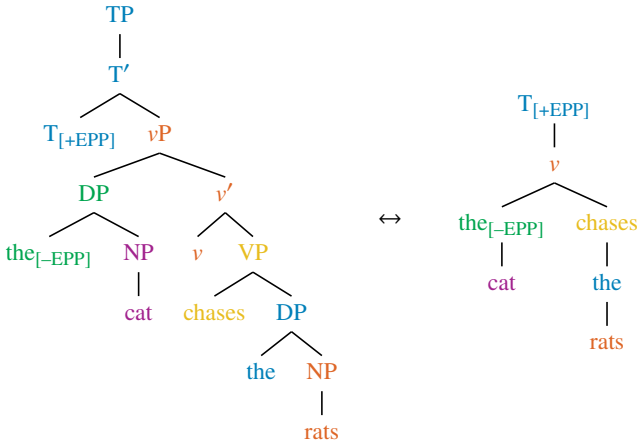
a. This student seems [$_{TP}$ ___ to be a genius].

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

[19] Derivation Trees

'The cat chases the rats.'

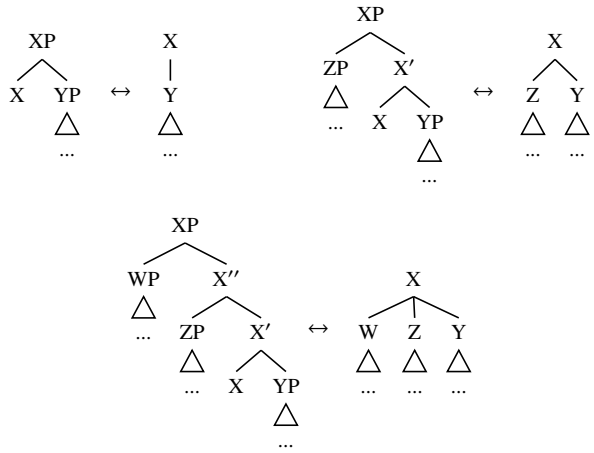




↔

[20] Derivation Trees (2)

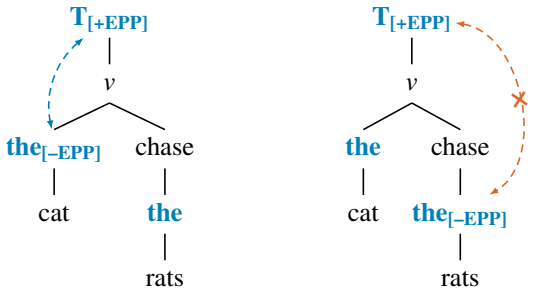
The rightmost child of a node is its complement; others are specifiers.



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

[21] Minimality

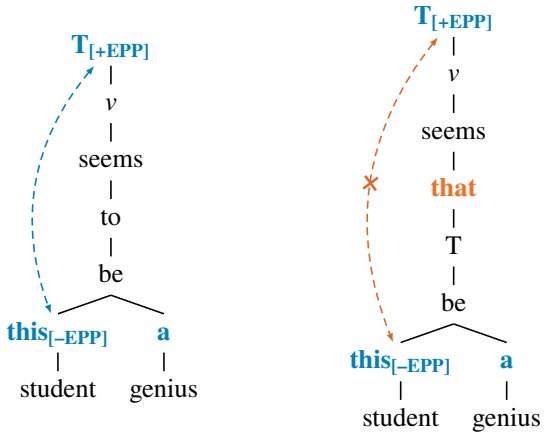
✓ The cat [$_{vP}$ ___ chases the rats]. vs. ✗ The rats [$_{vP}$ the cat chase ___].



[22] Blocking

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

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



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

[24] 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.

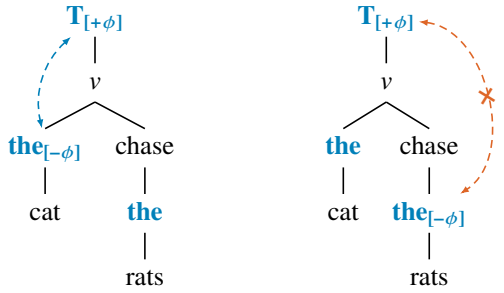
(5) Finite C blocks agreement
  a. It **seems** that there are some ducks in the garden.
  b. * It **seem** that there are some ducks in the garden.

(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.

[25] Agreement and Minimality

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

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



[26] 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.

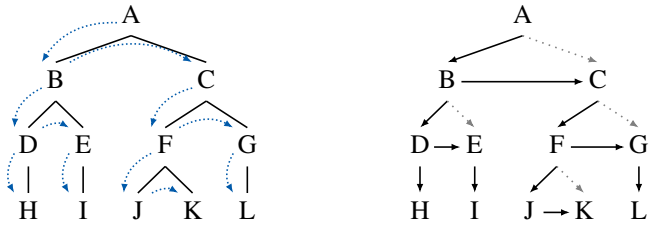
TSL grammar:

- Project a tier with all nodes of categories T/D/C
- Banned substrings: $\left\{ \begin{array}{ll} X_{[+\phi]} \cdot X_{[+\phi]} & X_{[-\phi]} \cdot X_{[-\phi]} \\ X_{[+\phi]} \cdot X & X \cdot X_{[-\phi]} \\ X_{[+\phi]} \cdot \ltimes & \rtimes \cdot X_{[-\phi]} \end{array} \right\}$

[27] Command Strings

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

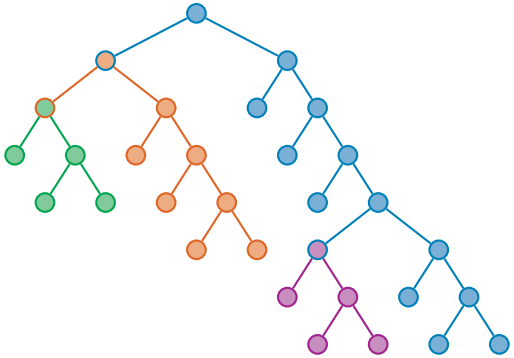
- There is a c-string from the root to each node.
- Among each head and its arguments: Head < Specifier < Complement.



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

[28] Command Strings (2)

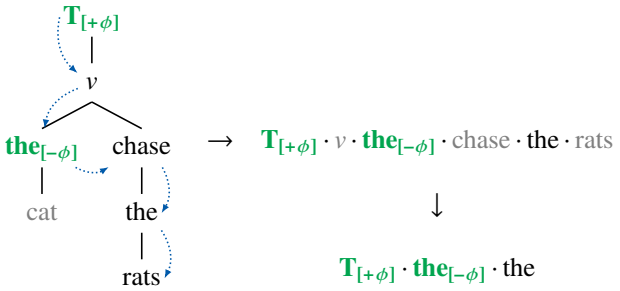
We're interested in c-strings that trace the **complement spine** of the tree, or of a left branch.



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

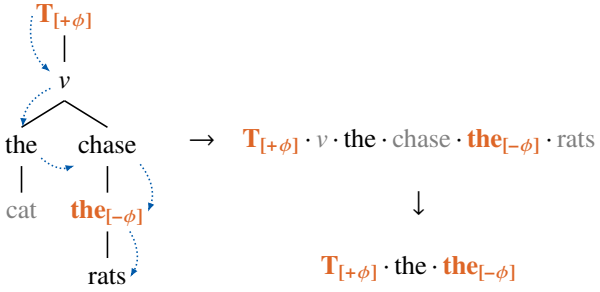
[29] Tiers Over Command Strings

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



[30] Tiers Over Command Strings (2)

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



4 The Typology of Agreement

[32] 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	

[33] 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)

4.1 Invisibility

[35] 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)

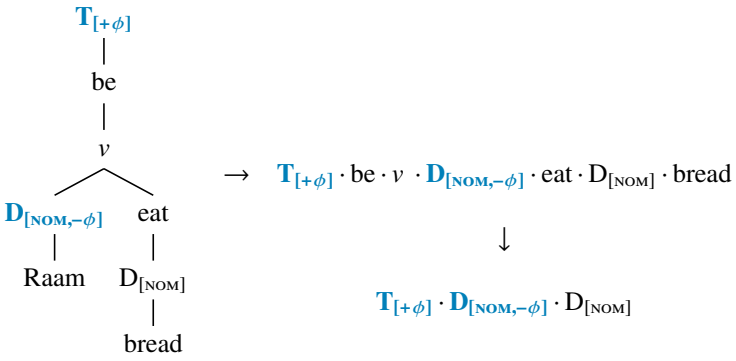
a. Raam roTii khaataa thaa.
Raam.M.NOM bread.F.NOM eat.IPFV.M be.PST.M
'Raam ate bread (habitually).'

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.

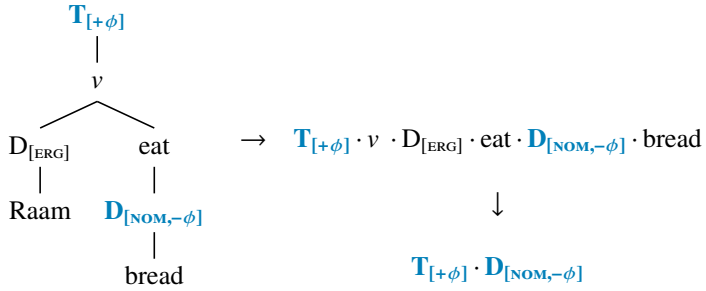
[36] Case-Sensitive Agreement (2)

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



[37] Case-Sensitive Agreement (3)

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



[38] Case-Sensitive Agreement (4)

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

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

[39] 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.

4.2 Blocking

[41] 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.

[42] 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.'

[43] Dative Intervention (2)

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

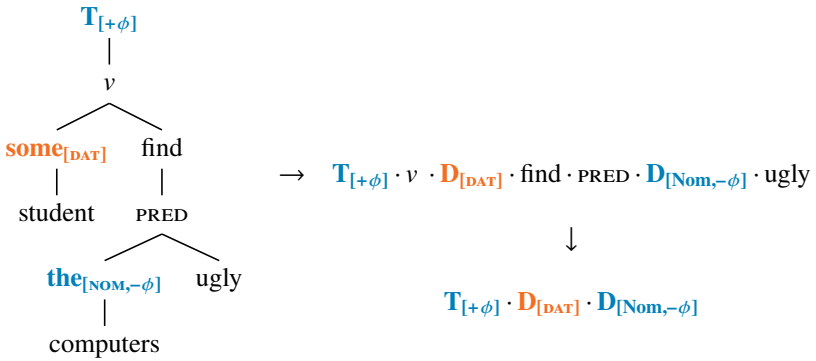
a. Það finnst einhverjum stúdent [tölvurnar ljótar].
EXPL find.DFLT some student.DAT computer.PL.DEF.NOM ugly.NOM

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.)

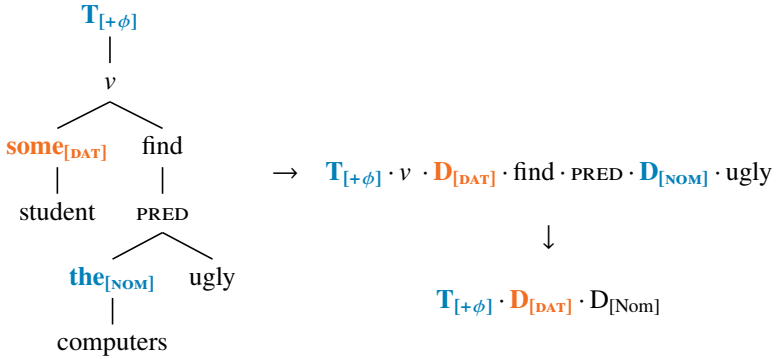
[44] Dative Intervention (3)

✗ 'There find.PL some student the computers ugly.'



[45] Dative Intervention (4)

✓ 'There find.DFLT some student the computers ugly.'



[46] 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 $X_{[+\phi]} \cdot X_{[NOM]}$.

Alternative: Default agreement is agreement with the dative DP.

4.3 Multiple Probes

[48] 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.

[49] 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)

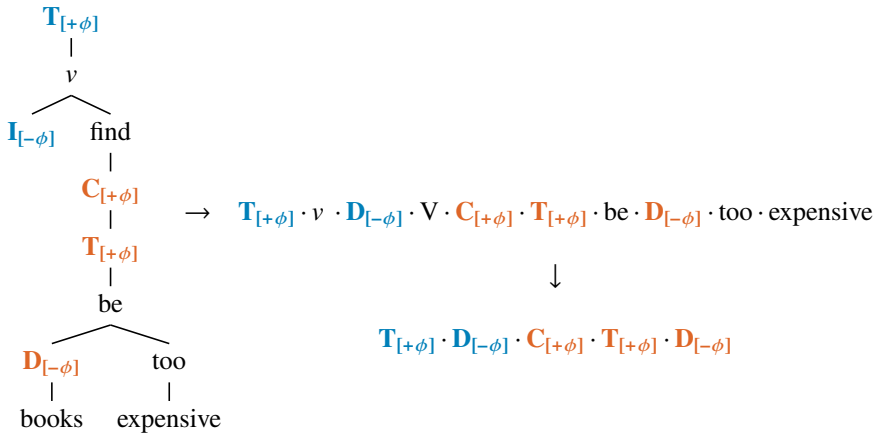
a. Kpeinzen da-j (gie) morgen goat.
I-think **that-you (you)** tomorrow **go**
'I think that you'll go tomorrow.'

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.

[50] Complementizer Agreement (2)

'I find that the books are too expensive.'



[51] 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.

4.4 Directionality

[53] 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.'

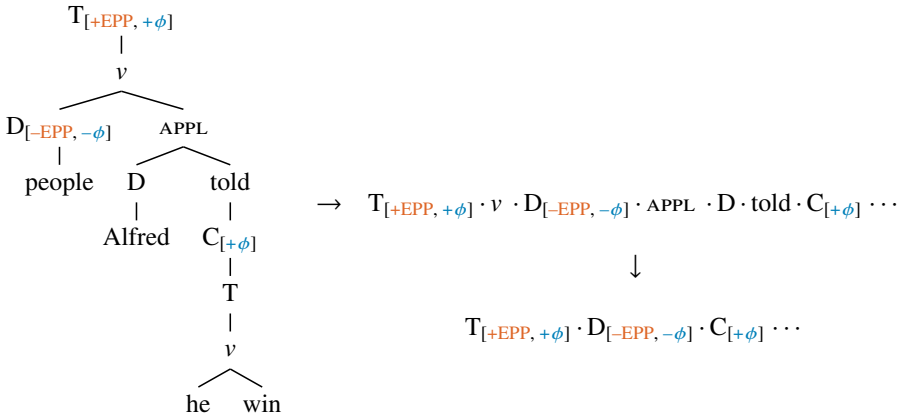
b. Alfredi ka-bolela ba-ba-ndu a-li ba-kha-khile.
C1.Alfred C1-said C2-C2-people **C1**-that C2-FUT-conquer
'Alfred told the people that they will win.'

Analysis:

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

[54] Upward Complementizer Agreement (2)

'The people told Alfred that he will win.'



[55] 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 $D_{[-\phi]} \cdot C_{[+\phi]}$

4.5 Multiple Goals

[57] 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.

[58] Optionality

(13) Optional agreement in English existential clauses

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

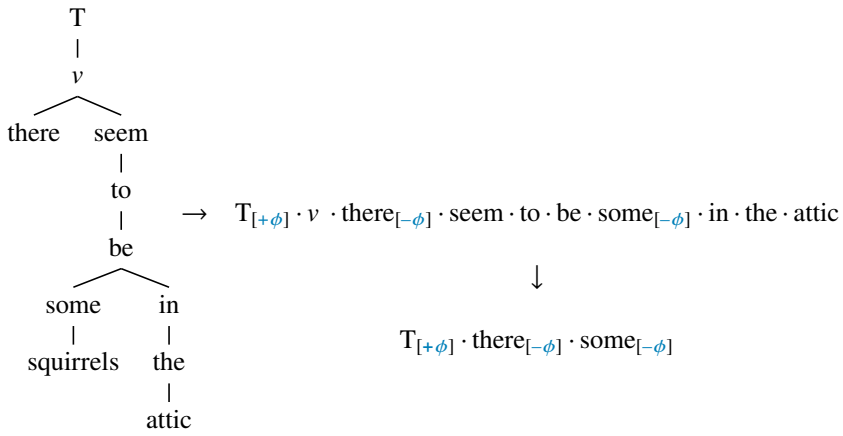
b. Some squirrels seem(*s) to be in the attic.

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.

[59] Optionality (2)

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



[60] 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 $\text{there}_{[-\phi]} \cdot \text{D}_{[-\phi]}$

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

5 Conclusion

[61] 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 $-\phi$

[62] 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!

[63] 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?

[64] 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.

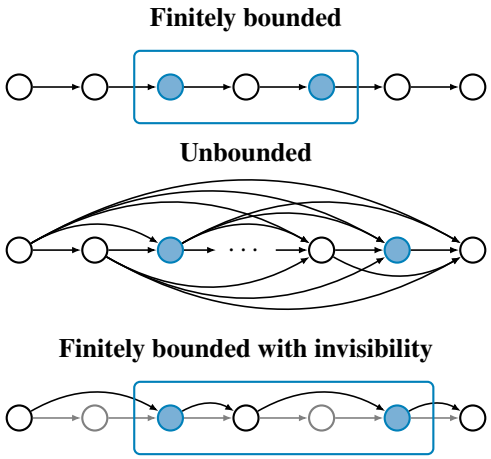
[65] References

Baker, Mark (2015). *Case*. Cambridge University Press.
Brody, Michael (2000). "Mirror theory: Syntactic representation in perfect syntax". In: *Linguistic inquiry* 31.1.
Coon, Jessica and Clint Parker (June 2019). *Case Interactions in Syntax*.
Deal, Amy Rose (2015). "Interaction and satisfaction in ϕ-agreement". In: *Proceedings of NELS 45*. Amherst, MA: GLSA Publications.
Diercks, Michael (2013). "Indirect agree in Lubukusu complementizer agreement". In: *Natural Language & Linguistic Theory* 31.2.
Frank, Rober and K. Vijay-Shankar (2001). "Primitive c-command". In: *Syntax*.
Garcia, Pedro et al. (1990). "Learning Locally Testable Languages in the Strict Sense". In: *Proceedings of the Workshop on Algorithmic Learning Theory*.
Graf, Thomas (2022a). "Subregular linguistics: bridging theoretical linguistics and formal grammar". In: *Theoretical Linguistics* 48.3–4.
— (2022b). "Typological implications of tier-based strictly local movement". In: *Proceedings of the Society for Computation in Linguistics 2022*.
Graf, Thomas and Aniello De Santo (2019). "Sensing Tree Automata as a Model of Syntactic Dependencies". In: *Proceedings of the 16th Meeting on the Mathematics of Language*. Toronto, Canada: Association for Computational Linguistics.
Graf, Thomas and Kalina Kostyszyn (2021). "Multiple Wh-Movement is not Special: The Subregular Complexity of Persistent Features in Minimalist Grammars". In: *Proceedings of the Society for Computation in Linguistics 2021*. Association for Computational Linguistics.
Graf, Thomas and Nazila Shafiei (2019). "C-command dependencies as TSL string constraints". In: *Proceedings of the Society for Computation in Linguistics 2019*.
Halpert, Claire (2019). "Raising, unphased". In: *Natural Language & Linguistic Theory* 37.1.
Hanson, Kenneth (2023). "A TSL Analysis of Japanese Case". In: *Proceedings of the Society for Computation in Linguistics 2023* (University of Massachusetts Amherst, Amherst, MA).
Heinz, Jeffrey (2010). "String Extension Learning". In: *Proceedings of the 48th Annual Meeting of the Association for Computational Linguistics*. Uppsala, Sweden: Association for Computational Linguistics.
— (2018). "The computational nature of phonological generalizations". In: *Phonological Typology*. Phonetics and Phonology 23. De Gruyter Mouton.
Holmberg, Anders and Thorbjörg Hróarsdóttir (2003). "Agreement and movement in Icelandic raising constructions". In: *Lingua* 113.10.
Keine, Stefan (2020). *Probes and their horizons*. MIT Press.
Lohninger, Magdalena et al. (2022). "From Prolepsis to Hyperraising". In: *Philosophies* 7.2.
Mahajan, Anoop Kumar (1990). "The A/A-bar distinction and movement theory". PhD thesis. Massachusetts Institute of Technology.
Nevins, Andrew (2011). "Multiple agree with clitics: Person complementarity vs. omnivorous number". In: *Natural Language & Linguistic Theory* 29.

Pesetsky, David and Esther Torrego (2007). "The Syntax of Valuation and the Interpretability of Features". In: *Phrasal and Clausal Architecture: Syntactic Derivation and Interpretation*. Amsterdam: Benjamins.
Preminger, Omer (2014). *Agreement and its failures*. Vol. 68. MIT press.
Vu, Mai Ha et al. (2019). "Case assignment in TSL syntax: A case study". In: *Proceedings of the Society for Computation in Linguistics 2019*.
Zeijlstra, Hedde (2012). "There is only one way to agree". In: *The Linguistic Review* 29.3.

6 Extras

[67] Three Models of Locality



[68] 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.

[69] 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.

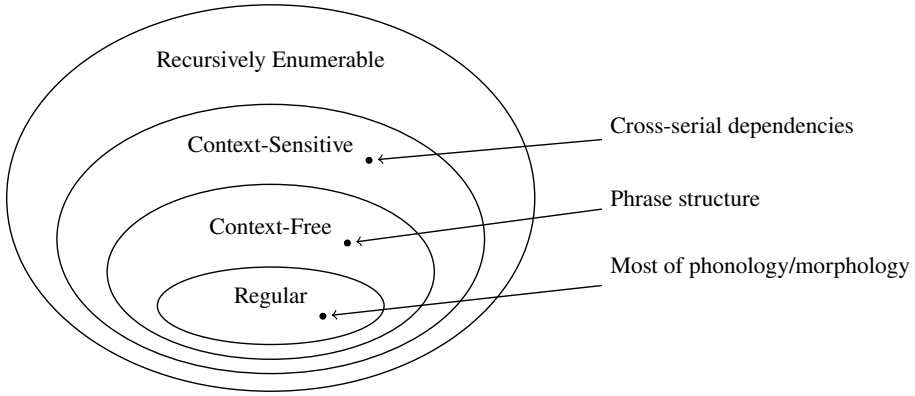
[70] Computational Complexity (2)

(T)SL languages are easy to learn.

- Just keep track of all attested (tier) substrings of size k. → *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).

[71] The Chomsky Hierarchy

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



[72] The Subregular Hierarchy