

On The Computational Complexity of Syntactic Dependencies

Kenneth Hanson

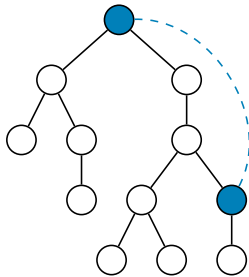
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Language as a computational problem

1. What kinds of computations are needed to build linguistic structures?
2. What can we gain from this knowledge?



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- Local and long-distance **phonological maps**
(Chandlee and Heinz 2018; Burness et al. 2021)

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- Local and long-distance **phonological maps**
(Chandlee and Heinz 2018; Burness et al. 2021)
- Most **syntactic dependencies**

Selection	(Graf 2018)
Functional hierarchies	(Hanson 2023b)
Adjunction	(Hanson under review)
Movement	(Graf 2018, 2022b)
Case	(Vu et al. 2019; Hanson 2023a)
Agreement	(Hanson to appear)

Computational complexity: The old view

Modeled using **surface strings**, syntactic patterns are fairly **complex**

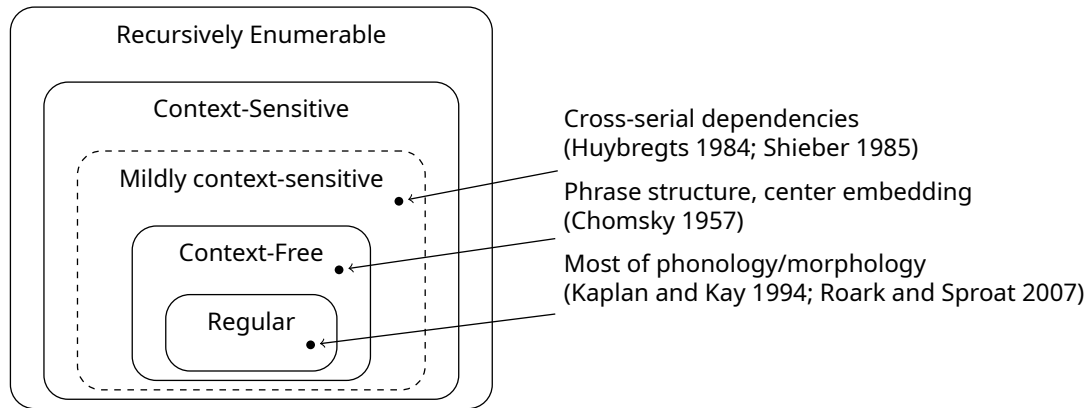


Figure 1: The Chomsky Hierarchy (Chomsky 1959), simplified

Computational complexity: The new view

Modeled using **trees**, syntactic patterns are **subregular**, along with most of phonology and morphology

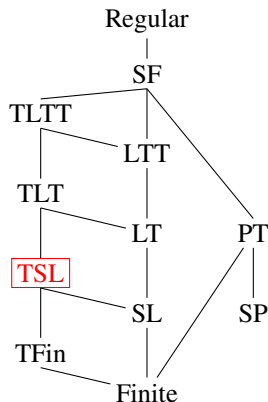


Figure 2: The Subregular Hierarchy (Heinz 2018; Lambert 2023), simplified

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Overall theme:

By focusing on the computational properties of language, we can discover new generalizations and build connections within and beyond linguistic theory.

Roadmap

What is a TSL computation?

A TSL model of agreement

Consequences for typology

Related and ongoing work

- Gradiance in experimental data

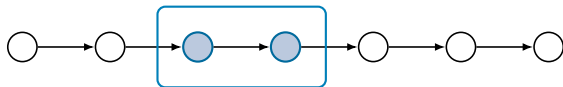
- Other syntactic dependencies

- Open questions

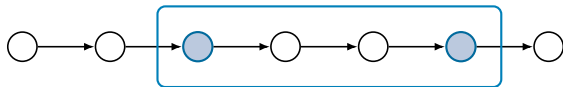
What is a TSL computation?

What does it mean to be local?

Local \rightarrow finitely bounded



(window size 2)



(window size 4)

Long-distance (non-local) \rightarrow no finite bound



Not just local, *strictly local*

Strictly local (SL): permitted/forbidden substrings of fixed size

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

Window: 2

Good: nt, nd, mp, mb, ...

Bad: *np, *nb, *mt, *md, ...

McNaughton and Papert (1971) and Rogers et al. (2013)

Long-distance, but *local over a tier*

Tier-based strictly local (TSL): like SL, but *irrelevant elements are ignored*

Ex. Samala sibilant harmony (Heinz 2018)

✓ p i s o t o n o s i k i w a t

✗ p i s o t o n o ʃ i k i w a t

Window:	2
Visible elements:	s, ʃ
Constraints:	*sʃ, *ʃs



Also see: Heinz et al. (2011) and Lambert and Rogers (2020)

More about TSL

- SL is the **special case** of TSL where the tier contains everything
- TSL is **distinct** from autosegmental phonology (Goldsmith 1976)
 - ▶ Autosegmental tier: true multistratal representation
 - ▶ TSL: extra arcs in the basic string/tree representation

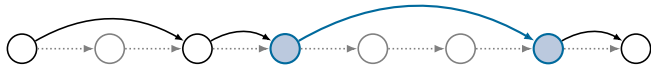


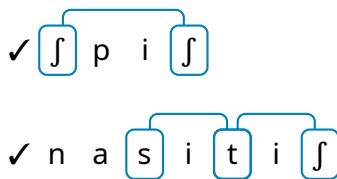
Figure 3: Two adjacent elements on a tier

Model-theoretic view of TSL: see Lambert et al. (2021) and Lambert (2023).

Invisibility and blocking

TSL with a window size of 2 (TSL-2) can handle both invisibility and blocking

Ex. Slovenian sibilant harmony (McMullin and Hansson 2016)



Window:	2
Visible elements:	s, f, t
Constraints:	*sf, *fs

Also see McMullin (2016), Graf (2022b), and Hanson (to appear).

A TSL model of agreement

Locality of syntactic agreement

(1) Minimality (Rizzi 1990)

- a. The cat_{SG} **chases**_{SG} the rats.
- b. * The cat **chase**_{PL} the rats_{PL}.

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(2) Horizons (Keine 2019)

- a. There **seem**_{PL} [_{TP} to be some ducks_{PL} in the garden].
- b. * It **seem**_{PL} likely [_{CP} **for** there to be some ducks_{PL} in the garden].

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Hanson (to appear):

The agreeing items must be adjacent on the relevant tier.

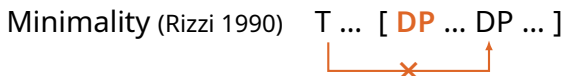
A unified model of locality

Long-distance dependencies are TSL-2 over their respective structures.

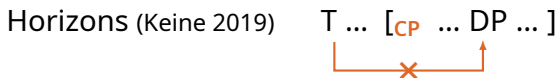
LD phonotactics



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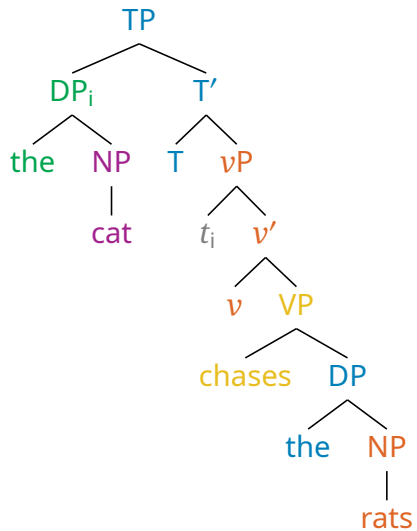
Setup

Key ingredients:

- Hierarchical representation
- Way to indicate long-distance dependencies
- Way to pick out the paths (=strings) which matter

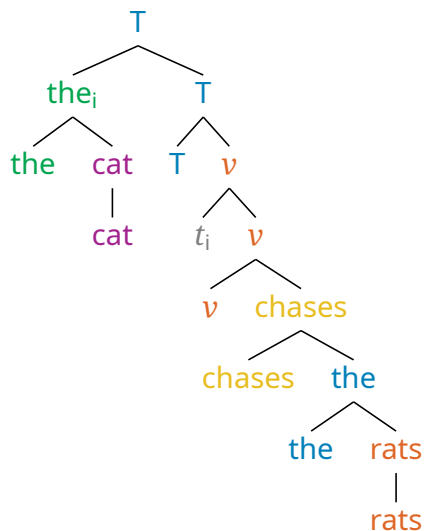
Derivation trees

'The cat chases the rats.'



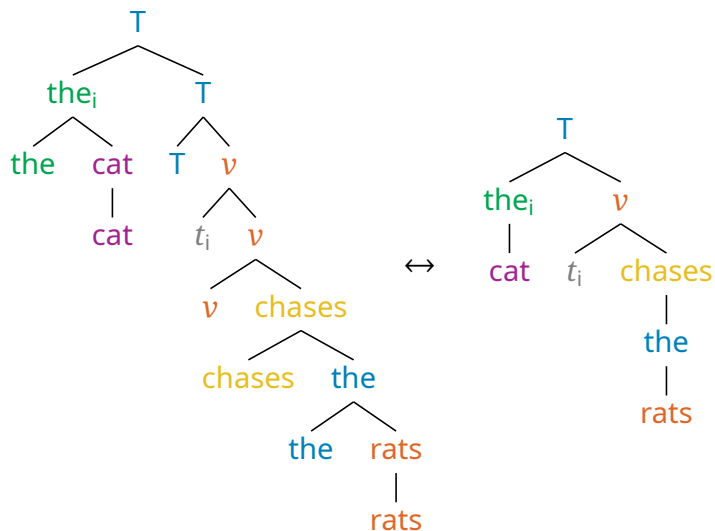
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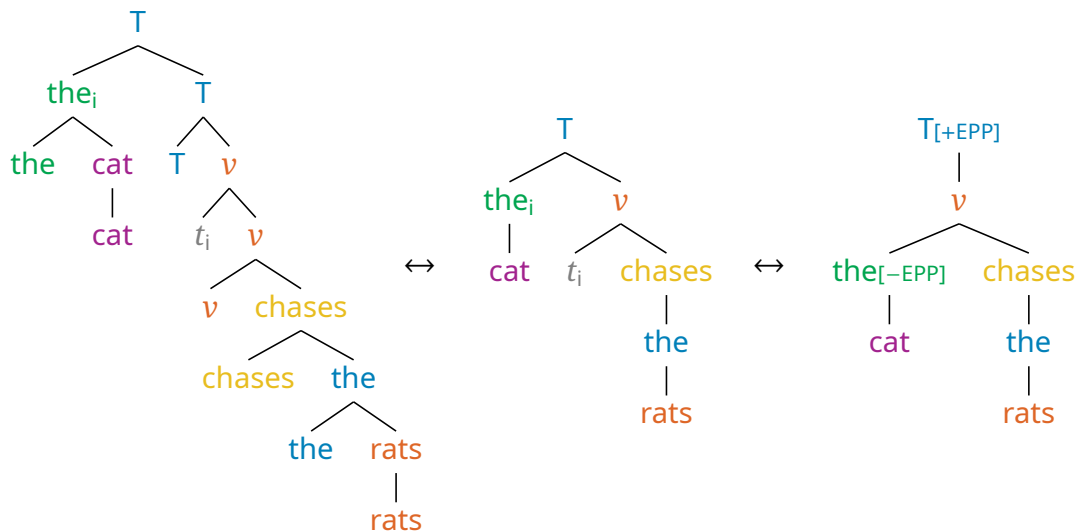
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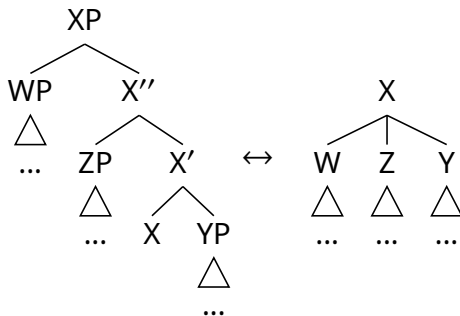
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Derivation trees (2)

The rightmost child is the complement; others are specifiers or adjuncts.



See Graf and Kostyszyn (2021). Related: Brody (2000) and Kobele (2002, 2012).

Modeling long-distance dependencies

Diacritics mark items which *actually* move/agree/etc. in the current derivation, as in Minimalist Grammars (MGs, Stabler 1997, 2011).

Operation	Feature Type	Example
Move	Landing site	+EPP
	Mover	−EPP
Agree	Probe (valuee)	+ ϕ
	Goal (valuer)	− ϕ



Agreement diacritics: see Hanson (to appear). Related: Ermolaeva and Kobele (2022).

Paths, spines

Individual syntactic dependencies don't make use of the entire tree at once.

Also see: Kayne (1984), Uriagereka (1999), Adger (to appear), and Graf and Hanson (under review).

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What path (=string) do we need for agreement?

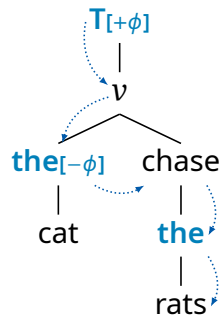
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What path (=string) do we need for agreement?

- Nodes ordered by **derivational prominence**
≈ reverse order of external Merge
(Graf and Shafiei 2019)
 - ▶ Head < (Spec) < Comp
- At each branching point, follow the **complement spine** (Graf and De Santo 2019)



Also see: Kayne (1984), Uriagereka (1999), Adger (to appear), and Graf and Hanson (under review).

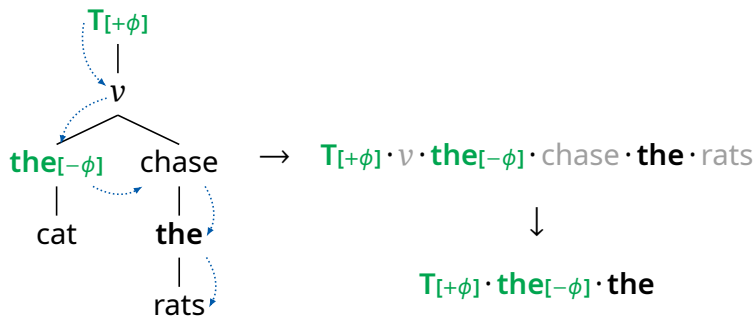
Tiers over spines

TSL grammar for English subject-verb agreement:

- **Tier contents:**
all agreement participants (finite T, D) and blockers (C)
- **Tier constraints:**
every ϕ -probe is immediately followed by a ϕ -goal, and vice versa

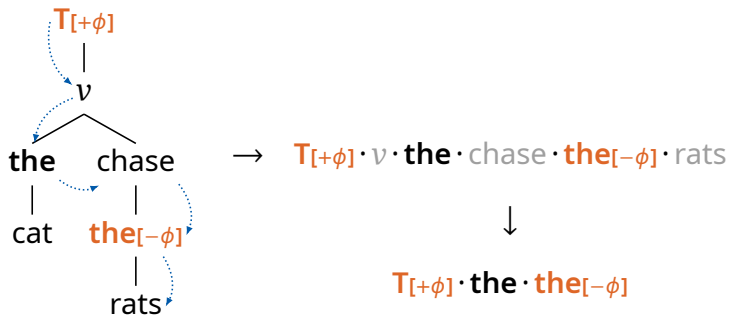
Minimality

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



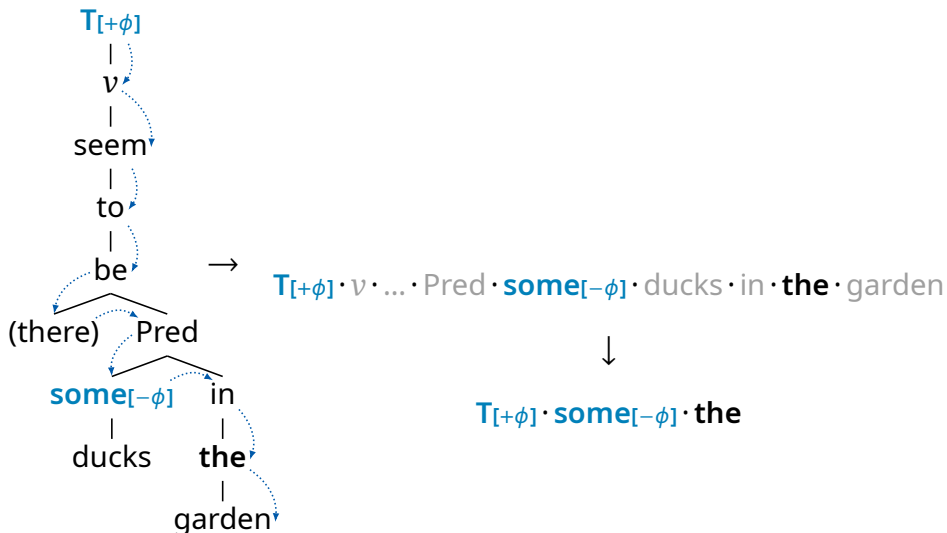
Minimality (2)

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



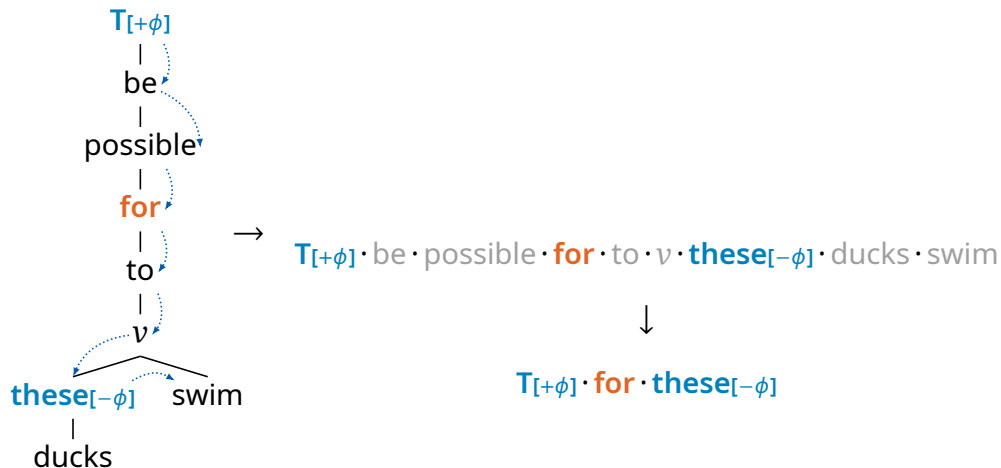
Invisibility

✓ There **seem** to be some ducks in the garden. (no blockers)



Blocking

✗ It are possible **for** these ducks to swim. (C is a blocker)



TSL grammar for subject-verb agreement

Window: 2

Tier: finite T, all D, all C

Constraints: $\left\{ \begin{array}{ll} X[+\phi] \cdot Y[+\phi] & X[-\phi] \cdot Y[-\phi] \\ X[+\phi] \cdot Y & X \cdot Y[-\phi] \\ X[+\phi] \cdot \times & \times \cdot Y[-\phi] \end{array} \right\}$

Consequences for typology

A unified model of locality

TSL-2 captures the pattern of invisibility and blocking which is characteristic of long-distance linguistic dependencies.

LD phonotactics



Islands (Ross 1967)



Minimality (Rizzi 1990)



Horizons (Keine 2019)



Parameters of variation

In general, syntactic dependencies have different visibility conditions, and therefore require distinct tiers.

Dependency	Participants	Blockers
ϕ -agreement	T _{FIN} , all D	all C
EPP movement	T _{FIN} , all D, <i>there</i>	all C
<i>wh</i> -movement	C _{wh} , all <i>wh</i> -movers	if, because, ...

Table 1: Visibility conditions for English

See Preminger (2014), Deal (2015), and Keine (2019), a.o.

Parameters of variation (2)

The contents of a given tier also vary across languages.

Language	Participants	Blockers
English	T_{FIN} , all D	all C
Hindi	T_{FIN} , D _[NOM]	all C, T_{INF}

Table 2: Verbal agreement in English vs. Hindi

Case-sensitive agreement

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

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

- a. Raam roṭii khaat-**aa** th-**aa**.
Raam.**M.NOM** bread.F.NOM eat-IPFV.**M** be-PST.**M**

'Raam ate bread (habitually).'

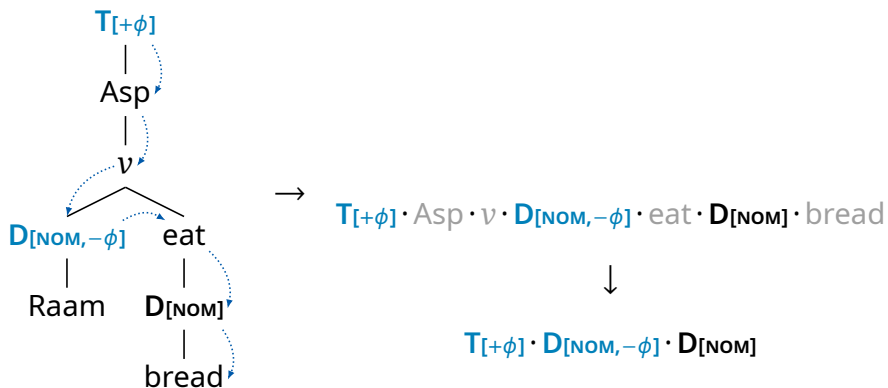
- b. Raam-ne roṭii khaay-**ii**.
Raam.M-**ERG** bread.**F.NOM** eat-PFV.**F**

'Raam ate bread.'

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

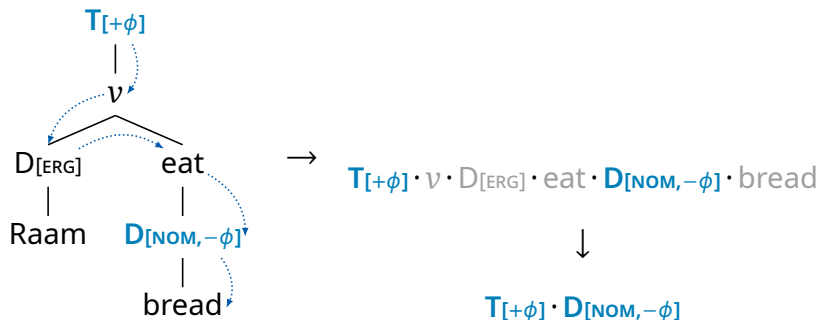
Case-sensitive agreement (2)

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



Case-sensitive agreement (3)

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



Long-distance agreement

In Hindi, agreement can extend into vP, but not TP (Keine 2019).

(4) Hindi LDA and default agreement (Bhatt 2005)

- a. Ram-ne [_{vP} roṭii khaa-**nii**] chaah-**ii**
Ram-ERG bread.F eat-INF.F want-PFV.FSG
'Ram wanted to eat bread.'
- b. Ram-ne [_{TP} roṭii khaa-**naa**] chaah-**aa**
Ram-ERG bread.F eat-INF.M want-PFV.MSG
'Ram wanted to eat bread.'

Analysis: T_{INF} appears on the tier, but v does not.

Limits of variation

Ergative DPs are not necessarily invisible:

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- Case-visibility hierarchy (Bobaljik 2008):
Unmarked (Nom/Abs) < Marked (Erg/Acc) < Oblique (Dat, Gen)
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Higher position of probe ↔ Fewer possible horizons

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When we consider the full range of variation, TSL-2 gets the right fit.

More parameters

Phenomenon	Change to baseline grammar
Invisibility	Some D's fail to project
Blocking	Some non-agreeing items project
Upward agreement	Swap order of $+\phi/-\phi$
Chain agreement	Allow sequential $+\phi$
Multiple agreement	Allow sequential $-\phi$
Independent subfeatures of ϕ	Each probe gets its own tier/constraints

Table 3: Parameters for agreement (Hanson to appear)

More parameters (2)

Even seemingly complex agreement patterns can be handled:

See appendix for details.

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- Upward complementizer agreement (Lubukusu, Diercks 2013)
→ Only project EPP-movers, $-\phi$ precedes $+\phi$

$D[-\text{EPP}, -\phi] \dots C[+\phi]$

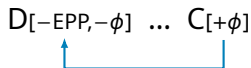


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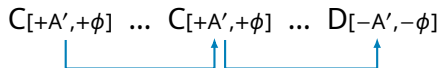
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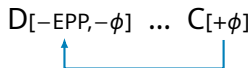
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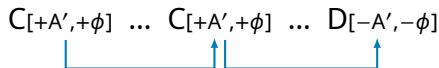
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- Parasitic agreement (Hindi, Bhatt 2005)

→ Second “concord tier” allows parasitic elements between $+\phi$ and $-\phi$



See appendix for details.

Impossible patterns

Logically possible patterns which are not TSL-2 are generally unattested.

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/OTSL	Unattested	—

Table 4: Typology of consonant harmony (adapted from McMullin and Hansson 2016)

Impossible patterns (2)

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

- Gang-up islands: A mover can escape n islands, but not $n + 1$.
- Cowardly islands: XP is an island iff there are at least n XPs in the same clause.
- ...

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Non-TSL-2 and unattested verbal agreement patterns:

- T agrees with the subject unless there is a temporal adjunct, in which case it agrees with the object.
- Only DPs which contain a relative clause which contains two PPs can agree.
- ...

The big picture

- TSL computations are **extremely restricted**
 - ▶ No boolean logic
 - ▶ No counting of violations
 - ▶ Tier contents determined solely by the element labels
- Observed typology emerges from this **highly structured** logical space
- Syntax is revealed to be **much more similar** to phonology and morphology than previously thought (Graf 2022a)
 - ▶ Different structures, different features, but same computations

$$\text{FIN} \subseteq \text{SL} \subseteq \boxed{\text{TSL}} \subseteq \dots \subseteq \text{REG} \subseteq \dots \subseteq \text{CFL} \subseteq \dots \subseteq \text{CS} \subseteq \dots \subseteq \text{RE}$$

Related and ongoing work

Islands and gradient acceptability

- We have been treating islands and other blockers as being **categorical**

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- **Experimental studies** have found that judgments of island violations are often **gradient** (Chaves 2022)
- Can this be incorporated into the TSL model?

Probabilistic TSL

Gradient blocking be captured via **probabilistic tier projection** (Mayer 2021).

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Torres, Hanson, Graf, and Mayer (2023):

Applied pTSL to syntactic islands, modeling data from Sprouse et al. (2016)



Charles Torres
UC Irvine



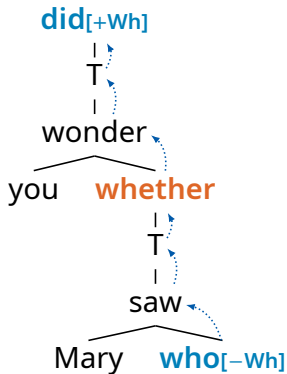
Connor Mayer
UC Irvine



Thomas Graf
Stony Brook

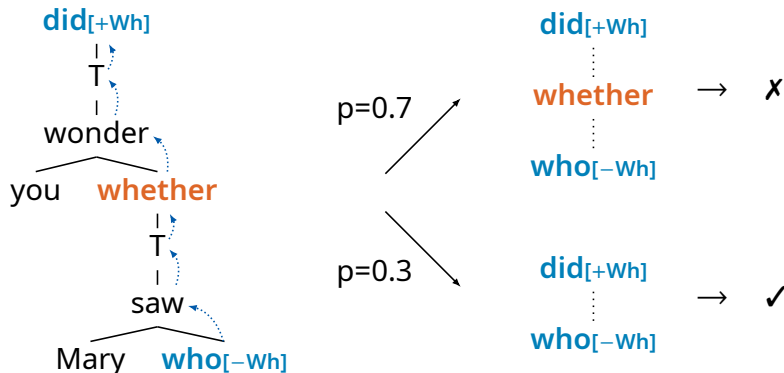
Probabilistic TSL: Example

'Who did you wonder whether Mary saw?'



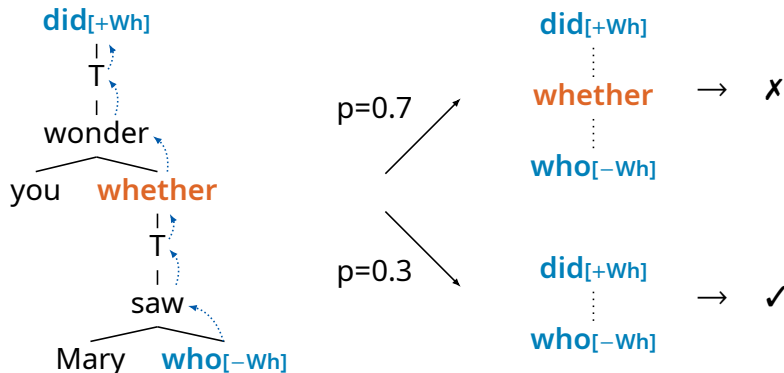
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$$\begin{aligned} \text{Score}(\text{tree}) &= p(\text{tier1}) * \text{licit}(\text{tier1}) + p(\text{tier2}) * \text{licit}(\text{tier2}) \\ &= 0.7 * 0 + 0.3 * 1 \\ &= 0.3 \end{aligned}$$

Probabilistic TSL: Modeling Study

- Data from Sprouse et al. (2016)

Probabilistic TSL: Modeling Study

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- Three island types and four conditions

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 - ▶ other nodes fixed to 1 (movers/landing sites) or 0 (others)

Probabilistic TSL: Results

Node	Projection probability
that	.46
complex NP	.63
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- Projection probabilities mirror relative badness of each island type
- Replicated **superadditivity effect** – extraction from an island is worse than (i) extraction from non-island plus (ii) mere presence of an island
- Model does not capture relative badness of matrix clause movement

Probabilistic TSL: Discussion

- The TSL model is perfectly compatible with gradient in the grammar
 - ▶ categorical tier projection \leftrightarrow categorical output
 - ▶ probabilistic tier projection \leftrightarrow gradient output
- Further extensions:
 - ▶ Can add probabilities to the constraints to produce a stochastic grammar, which can be fit to corpus data in the same manner as a PCFG

Other syntactic dependencies

Local	Selection	Graf (2018); Hanson (2023b)
	Functional hierarchies	Hanson (2023b)
	Adjunction	Hanson (under review)
Long-distance	Movement	Graf (2018, 2022b)
	Case	Vu et al. (2019); Hanson (2023a)
	Agreement	Hanson (to appear)

Other syntactic dependencies

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Functional hierarchies

Hanson (2023b): modeling local dependencies with spines

Functional hierarchies

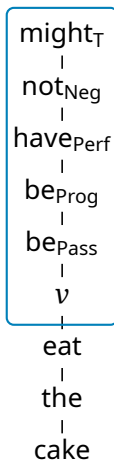
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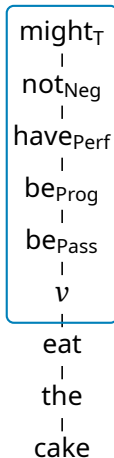
- TSL grammar**

Tier elements: all symbols

Window size: 2

Good substrings:

{	T Neg				
	T Perf	Neg Perf			
	T Prog	Neg Prog	Perf Prog		
	T Pass	Neg Pass	Perf Pass	Prog Pass	
	T v	Neg v	Perf v	Prog v	Pass v
}					



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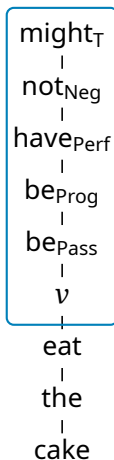
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	T Prog	Neg Prog	Perf Prog		
	T Pass	Neg Pass	Perf Pass	Prog Pass	
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}					



Case dependencies

- **Hanson (2023a):** in-depth analysis of case in Japanese*
 - ▶ Three tiers: verbal domain, nominal domain, lexical case
 - ▶ Valency alternations, nominative objects, long-distance case

*See appendix for an example.

Case dependencies

- **Hanson (2023a):** in-depth analysis of case in Japanese*
 - ▶ Three tiers: verbal domain, nominal domain, lexical case
 - ▶ Valency alternations, nominative objects, long-distance case
- **Current research:** to what extent do the parameters of a TSL-2 model account for cross-linguistic variation in case assignment?
 - ▶ Case spreading / multiple assignment
 - ▶ Dependent case
 - ▶ Accusative/ergative/split alignment
 - ▶ Differential argument marking

*See appendix for an example.

Some open questions

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- How does the computational system interact with **other factors**, such as the feature system?
- Can we view the mapping from syntax to morphology as a TSL function?

Wrapping up

Summary

- To a large extent, linguistic structures can be built with TSL computations: Local or long-distance, trees or strings, harmony or agreement or movement.

By separating out the computational factors underlying language, we can learn many things that we could not otherwise!

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Summary

- To a large extent, linguistic structures can be built with TSL computations: Local or long-distance, trees or strings, harmony or agreement or movement.
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- Theory can be connected to experiment via the underlying mathematics of TSL

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- To a large extent, linguistic structures can be built with TSL computations: Local or long-distance, trees or strings, harmony or agreement or movement.
- Syntax and phonology are similar by virtue of their shared computational basis
- Theory can be connected to experiment via the underlying mathematics of TSL
- Many new questions

By separating out the computational factors underlying language, we can learn many things that we could not otherwise!

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Appendices

More agreement case studies

- Upward agreement

- A' agreement

- Parasitic agreement

Learning tiers from positive data

Avoiding overgeneration in the category system

Miscellaneous

More agreement case studies

Upward agreement

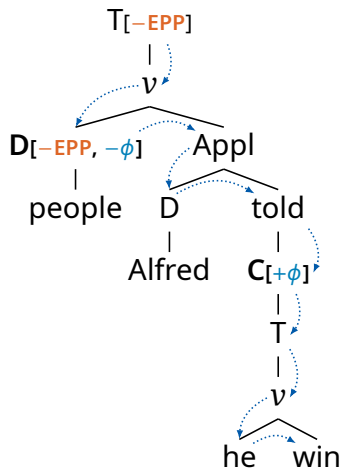
- (5) Complementizer Agreement in Lubukusu (Diercks 2013)
- a. Ba-ba-ndu ba-bolela Alfredi ba-li a-kha-khile.
c2-c2-people c2-said c1.Alfred c2-that c1-FUT-conquer
'The people told Alfred that he will win.'
- b. Alfredi ka-bolela ba-ba-ndu a-li ba-kha-khile.
c1.Alfred c1-said c2-c2-people c1-that c2-FUT-conquer
'Alfred told the people that they will win.'

Analysis:

- Agreement is upward → allow $C_{[+\phi]}$ to follow $D_{[-\phi]}$.
- Agreement on C is subject oriented → project only DPs bearing –EPP.

Upward agreement (2)

'The people told Alfred that he will win.'



→ $T[-EPP] \cdot v \cdot D[-EPP, -\phi] \cdot Appl \cdot D \cdot told \cdot C[+\phi] \cdot \dots$

↓

$D[-EPP, -\phi] \cdot C[+\phi]$

Analysis: Project DPs only if $[-EPP]$. Allow $C[+\phi]$ follow $D[-\phi]$.

Syntactic counterfeeding

Agreeing C is impossible in hyperraising structures.

- (6) Agreeing complementizer incompatible with hyperraising

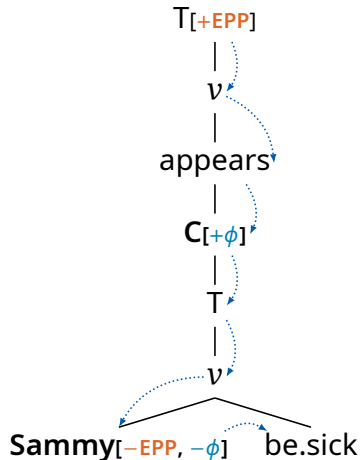
Sammy a-lolekhana **mbo** (*a-li) a-likho a-lwala.
c1.Sammy c1-appears **that** (*c1-that) c1.PROG c1-be.sick

‘Sammy appears to be sick.’ (lit. ‘Sammy seems that is sick.’)

This follows immediately from the TSL analysis!

Syntactic counterfeeding (2)

The hyperraised subject is below C in the derivation tree and cannot agree.



$$\rightarrow T_{[+EPP]} \cdot v \cdot V \cdot C_{[+\phi]} \cdot T \cdot v \cdot D_{[-EPP, -\phi]} \cdot V$$

↓

$$\begin{aligned} & * C_{[+\phi]} \cdot D_{[-EPP, -\phi]} \\ & \text{(should be } D_{[-EPP, -\phi]} \cdot C_{[+\phi]}) \end{aligned}$$

A' agreement

(7) Dinka verbal agreement with Spec-CP

a. Mòc à-cé yîin tîiŋ.

man 3SG-PRF.SV you see.NF

'The man has seen you.'

(Van Urk 2015, ch. 4, 19b)

b. Yîin Ø-cí môc tîiŋ.

you 2-PRF.OV man.GEN see.NF

'You, the man has seen.'

(Van Urk 2015, ch. 4, 20a)

(8) Agreement in both matrix and embedded clause

Yè kôɔc-kó [CP Op é-kè-yá ké tàak [CP è ____

be **people**.CS-which PST-**PL**-HAB.2SG 3PL think.NF C

é-kè-cí Áyèn ké gâam gàlàŋ]]?

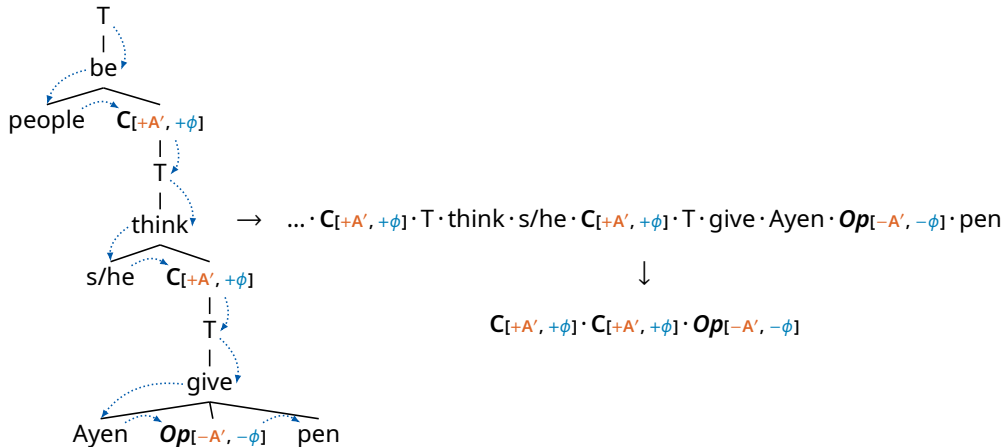
PST-**PL**-PRF.OV Ayen.GEN 3PL give.NF pen

'Which people did (s)he think that Ayen had given a pen to?'

(Van Urk 2015, ch. 5, 14a)

A' agreement (2)

'Which people did (s)he think that Ayen had given a pen to?'



Analysis: Project all D bearing $[-A']$, allow $C_{[+φ]}$ to iterate.

Parasitic agreement

- (9) Hindi participles and infinitives agree iff the main verb does
- a. Shahrukh-ne [_{VP} tehnii kaaṭ-**nii**] chaah-**ii** **thii**
Shahrukh-ERG branch.F cut-**INF.F** want-**PFV.F** be.**PST.FSG**
'Shahrukh had wanted to cut the branch.'
- b. Shahrukh-ne [_{TP} tehnii kaaṭ-**nāa**] chaah-**aa** **thaa**
Shahrukh-ERG branch.F cut-**INF.M** want-**PFV.MSG** be.**PST.MSG**
'Shahrukh wanted to cut a/the branch.'

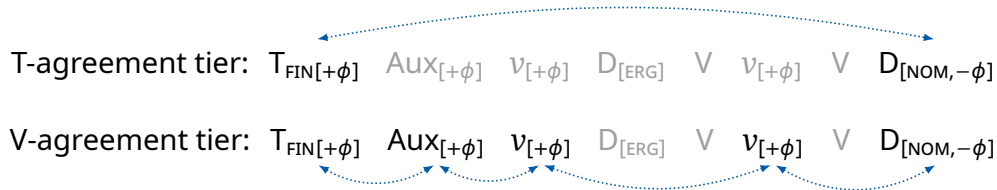
Analysis: Verbs agree iff they occur along a chain from $T_{[+\phi]}$ to $D[-\phi]$.

Complication:

T-agreement and V-agreement must be regulated on separate tiers.

Parasitic agreement (2)

If T agrees with DP, then all verbs along the path also agree.



Why isn't one tier enough?

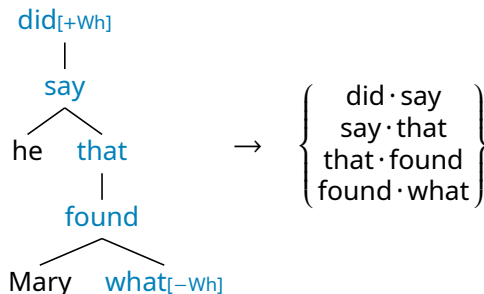
- Agreement can fail, so non-agreeing pairs $T \cdot Aux$, $Aux \cdot v$, etc., must be allowed.
- Once you do this, agreement is incorrectly predicted to always be optional.

Learning tiers from positive data

Learning tiers from paths

Heuser et al. (2024): track *licit bigrams along a movement path*, and generalize to categories when allowed by the Tolerance Principle (Yang 2016)

Hanson (2024): this algorithm already tracks the information needed by a formal TSL learner → we can adapt it to produce a TSL-2 grammar!



See appendix for details.

Learnability considerations

TSL constraints are easy to learn if the tier is already known (Lambert et al. 2021)...

But identifying the tier itself is not trivial

- If there are n symbols, then there are 2^n possible tiers

Current formal learners can do efficiently this for pure TSL-2 languages (Jardine and McMullin 2017; Lambert 2021)...

But natural language always involves intersecting tiers

Starting point

Let's assume that:

- The learner already knows the basics of constituency and selection
- The learner can identify the dependent elements, e.g. mover and landing site, probe and goal

The dependent elements must appear on the tier, and must be adjacent

Next step: identify the blockers

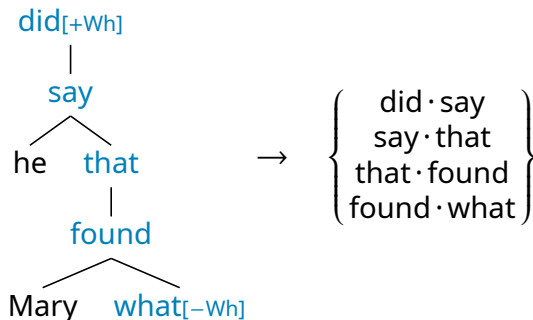
cf. Clark and Yoshinaka 2016; Liang et al. 2022; Li and Schuler 2023

Blockers for *wh*-movement

- ✓ **What** did Mary find ____?
- ✓ **What** did he say that Mary found ____?
- ✗ **What** did he wonder **whether** Mary found ____?
- ✗ **What** did he **mutter** that Mary found ____?

Learning blockers from paths

Heuser et al. (2024): learn movement blockers by tracking **licit bigrams along a movement path** (plus generalization to categories as in Yang 2016)



Key point: Bigrams like {wonder · **whether**, **whether** · found, ...} will not be attested along any *wh*-movement path

Learning blockers from paths (2)

Hanson (2024): the path grammar contains everything we need to construct a TSL-2 grammar

- Extract the elements from the set of path bigrams for movement type X
- The elements which are conspicuously missing are just the tier blockers

$$\left\{ \begin{array}{c} \text{that} \\ \text{whether} \\ \text{say} \\ \text{mutter} \\ \dots \end{array} \right\} - \left\{ \begin{array}{c} \text{that} \\ \text{say} \\ \dots \end{array} \right\} = \left\{ \begin{array}{c} \text{whether} \\ \text{mutter} \\ \dots \end{array} \right\}$$

Learning blockers from paths (3)

Advantages to the combined system:

- Combines the typological merits of TSL-2 with an empirically-motivated acquisition model
- Produces a version of the Height-Locality Connection (Keine 2019), which is not inherent to the TSL-2 model
- Could be adapted for learning constraints on agreement

Summary

- The space of possible tiers is too large to search exhaustively, but we don't actually need to do this
- When learning non-local constraints, the local constraints should be factored out
- Some empirical generalizations may derive from the details learning process rather than the grammar formalism itself

Avoiding overgeneration in the category system

Collaborators



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The problem with subcategorization

- There is a LI of category V that selects a CP
- ...only if that CP contains an AP
- ...and also contains three VPs, none of which contain one another
- ...but only if the LI does not also select a PP
- ...in which case the three VPs must instead be self-embedded
- ...and CP must also contain a non-finite TP
- ...

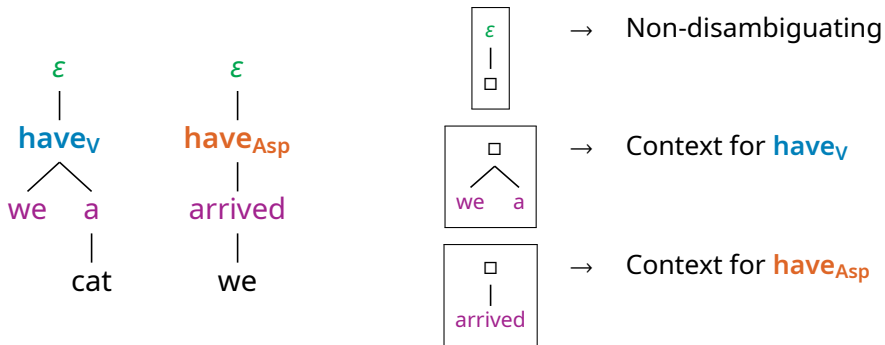
Without further restrictions, any system of category selection can do this

Reining in category features

- Any regular tree constraint can be indirectly implemented via selection
- Selection is SL-2 over trees
 - Massive overgeneration
 - All subregular distinctions are lost
- **Conjecture:** category and subcategorization features must be inferable from the local tree context → **ISL-recoverable** (Graf 2020)
- **This project:** test this conjecture against MGBank (Torr 2017, 2018)

ISL-Recoverability

It should be possible to infer the category of every lexical item based only on the phonological features of its **selector** or its **selectees** (or maybe both).



Results

Forms with ambiguous category:	8369
ISL-2 recoverable in all contexts:	79–86%
ISL-2 recoverable in at least one context:	95–97%

- Most errors are due to empty heads or misparsed sentences (good!)
- Subcategorization features are recoverable at a similar rate (good!)
- Movement features are recoverable at a similar rate (not good!)

Discussion

- It should not be possible to accurately identify all movement features from the local context
- Simulations suggest that a Zipfian distribution of feature specifications over phonetic exponents produces similar quantitative results
→ ISL inferrability might be epiphenomenal
- In any case, local inferrability makes a good heuristic for learning: identical items in the same context must have the same category

Miscellaneous

What makes a possible tier?

We know that the tier elements can be fairly arbitrary, but they can't be completely arbitrary.

- $T = \{\text{the}_{[\text{Nom}]}, \text{all}_{[\text{Acc}]}, \text{for}_C, \text{smile}_V, \text{already}_{\text{Adv}}, \dots\}$
- $\bar{T} = \{\text{the}_{[\text{Acc}]}, \text{all}_{[\text{Nom}]}, \text{that}_C, \text{wash}_V, \dots\}$

Usually, we want entire classes of items:

- all D, all $D_{[\text{NOM}]}$, all $D_{[-\text{EPP}]}$, ...

A couple of possibilities:

- a tier must be defined in terms of natural classes
(insert your favorite theory of syntactic features here)
- unnatural tiers are never posited by the learner under realistic conditions

Case in Japanese

Hanson (2023a): in-depth analysis of case in Japanese, relativizing both dominance and precedence to a tier → **tree tier**

- (10) Mearii **no** imooto **ga** Jon **ni** ringo **o** ageta.
Mary **GEN** sister **NOM** John **DAT** apple **ACC** gave
'Mary's sister gave John an apple.'

