Regular Reduplication Across Modalities

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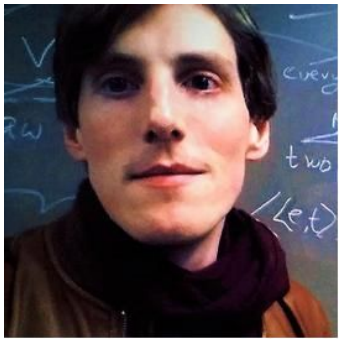


Reduplication: A Morphological Copying Process

- **Cross-linguistically robust** (Rubino 2013)

Attested:	Total (85%)	*buku* → *buku buku* (Indonesian ‘book’ → ‘books’)
	Partial (75%)	*buku* → *bu buku*
	Triplication (rare)	*buku* → *buku buku buku*
Unattested:	Squaring	*buku* → *buku buku buku buku*
	Iterated prefix	*buku* → *b bu buk buku*
	Exponential prefix	*buku* → *b bubu bukbukbuk bukubukubukubuku*
	Even-Odd Reverse	*buku* → *buku ukub buku ukub*

Reduplication: A Morphological Copying Process

- **Cross-linguistically robust**
- **Computationally complex?**
  - **Recognition** $f: \Sigma^* \rightarrow \mathbb{R}$

    $\{ww \mid w \in \Sigma^*\}$ - *well-nested 2-MCFL* (a TAL, Joshi 1985), triplication - *3-MCFL*

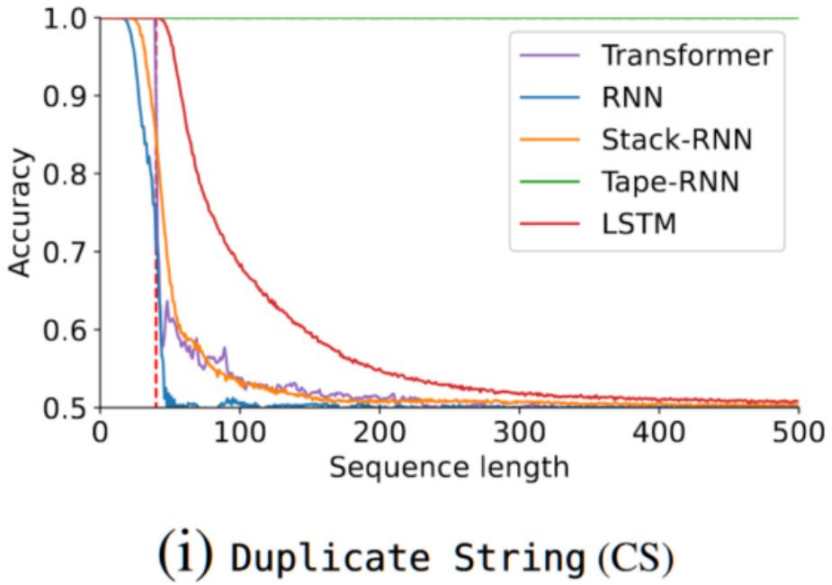
  - **Transduction** $f: \Sigma^* \rightarrow \Sigma^*$

    $w \rightarrow ww^n$ is a *Regular function* (Dolatian & Heinz 2020, Rawski et al 2023)

  - Not discussed today: syntactic copying (Yoruba relatives, Georgian case)

Reduplication: A Morphological Copying Process

- **Cross-linguistically robust**
- **Computationally complex?**
- **Unlearnable** by most neural sequence models
  - Nelson et al 2020
    Deletang et al 2022
    Zhou et al 2024
    a.o.



Reduplication: A Morphological Copying Process

- **Cross-linguistically robust**
- **Computationally complex?**
- **Unlearnable** by most neural sequence models
- **Computable** by (average) hard-attention transformers w/ position encodings
    - (Strobl et al *in review*)

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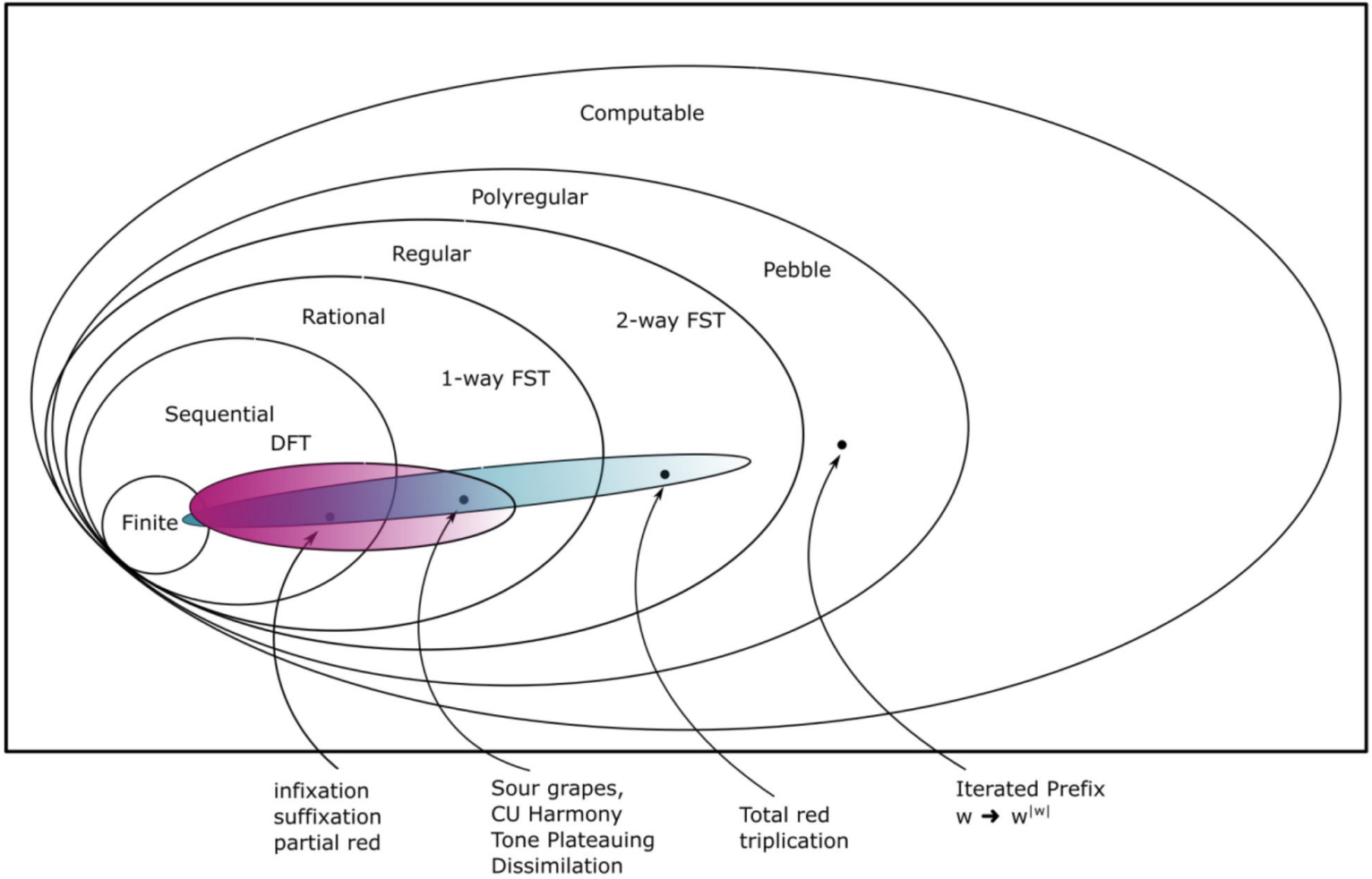
Today: Do **complexity bounds** hold across modalities (i.e. in sign)?



The Computational Landscape (Rawski et al 2023)

Regular vs Polyregular (Bojanczyk 2022)

Properties of regular functions

- Linear growth: $|f(w)| = O(|w|)$
- Closed under composition (if $f : \Gamma^* \to \Sigma^*$ and $g : \Sigma^* \to \Pi^*$ are regular then so is $g \circ f$)
- L regular $\implies f^{-1}(L)$ regular

Properties of polyregular functions

- *Polynomial* growth: $|f(w)| = O(|w|^k)$
- L regular $\implies f^{-1}(L)$ regular; closed under composition

Questions

Reduplication in Signed Languages - is it regular?

At issue: lower bounds on morphological computation

Non-regularity implies a modality effect in either of 2 directions (Sandler 1993)

- Regular boundary may be an artifact of the spoken modality
- Signed modality may allow supra-regular operations on top of amodal ones

Our claim: it’s still regular

Reduplication Typology (Signed)

- Partial, total, triplication (widespread), two-handed, etc (Pfau & Steinbach 2006)
- pluralization, reciprocals, **aspectual modification**, etc (Wilbur 2005)

ASL GIVE

(a) GIVE [distrib]

‘give to each of them’

(b) GIVE [iterative]

‘give over and over again’

a. GIVE+dur

‘keep on giving’

‘Embedded’ Reduplication (Klima & Bellugi 1979, Wilbur 2009)

b. [GIVE + dur] + distrib]

‘keep on giving to each person, one after another’

(c) [[GIVE+distrib] iterative]

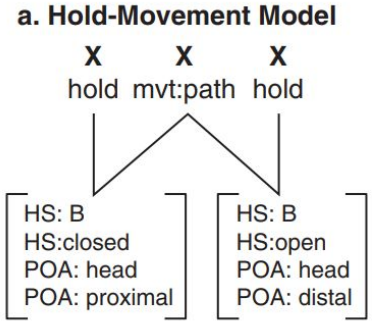
‘give to each of them over and over again’

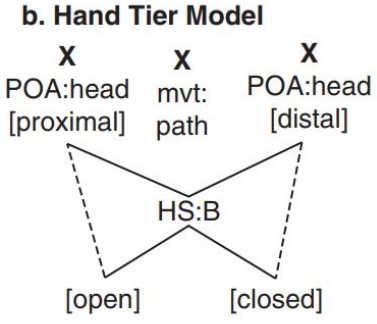
c.[[GIVE+dur]+distrib]+ iterative]

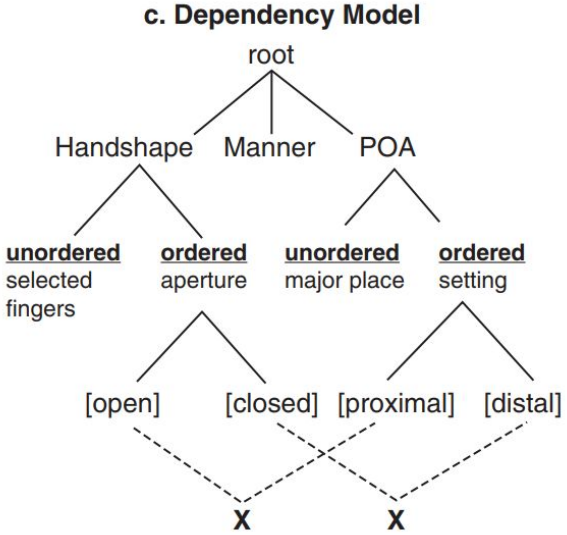
‘keep on giving to each person, one after another, this event sequence recurring regularly over expanses of time’

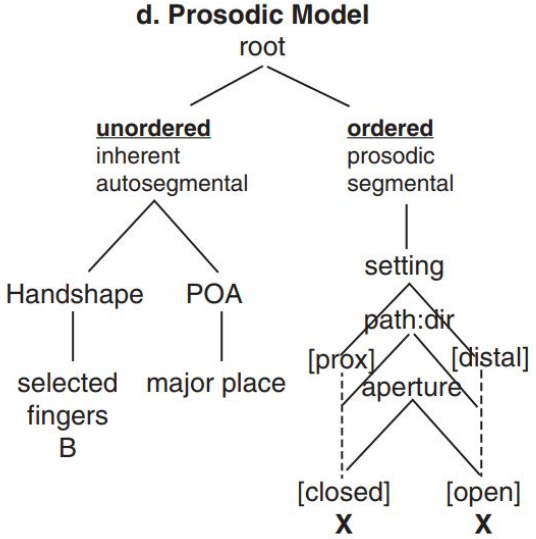
What's a model of a sign?

Brentari (2019)









Sandler's Hand Tier Model as a Finite Relational Model

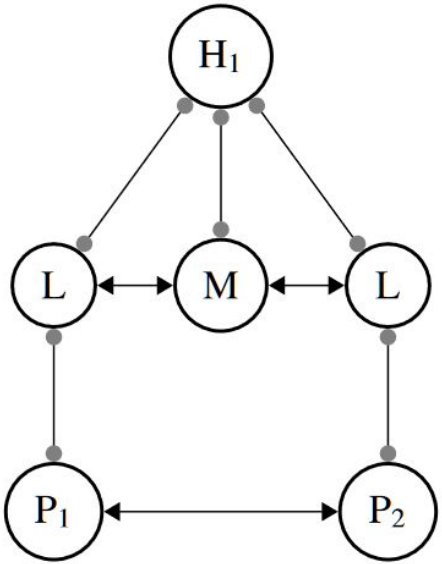
Finite model signature: $\langle D, R \rangle$

D - domain: finite set of nodes

R - relations: finite set

- Unary: node labels
- Binary: successor, association

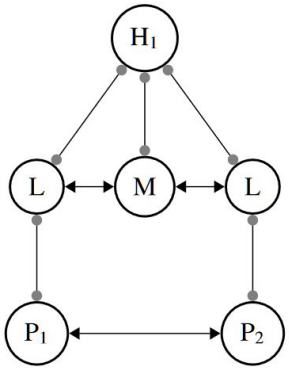
ASL 'GIVE'

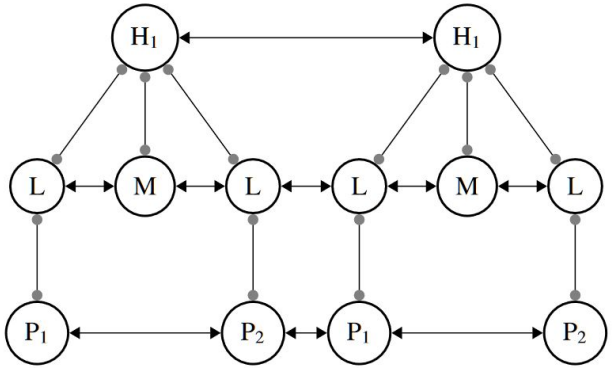


MSO Transductions & Total Reduplication

MSO Transducer: define output model *in terms of* input model

- Finite # of **copies** of the domain
- **Relation Formulas** define the output labels, successor, and association, for all copies
  - $\varphi^{c}_{L}(x) \stackrel{\text{def}}{=} L(x)$ “position is *L* in copy *c* if it’s *L* in input”
- **Domain formula**: which nodes survive (or are deleted)
- MSOT iff all formulas are MSO (set quantification)





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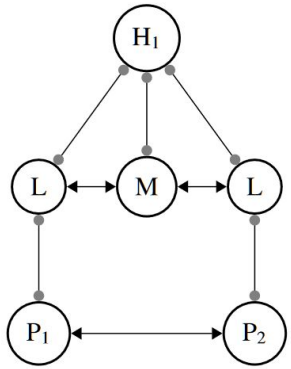

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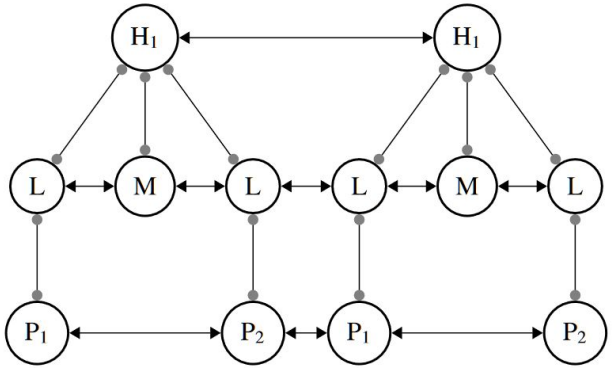


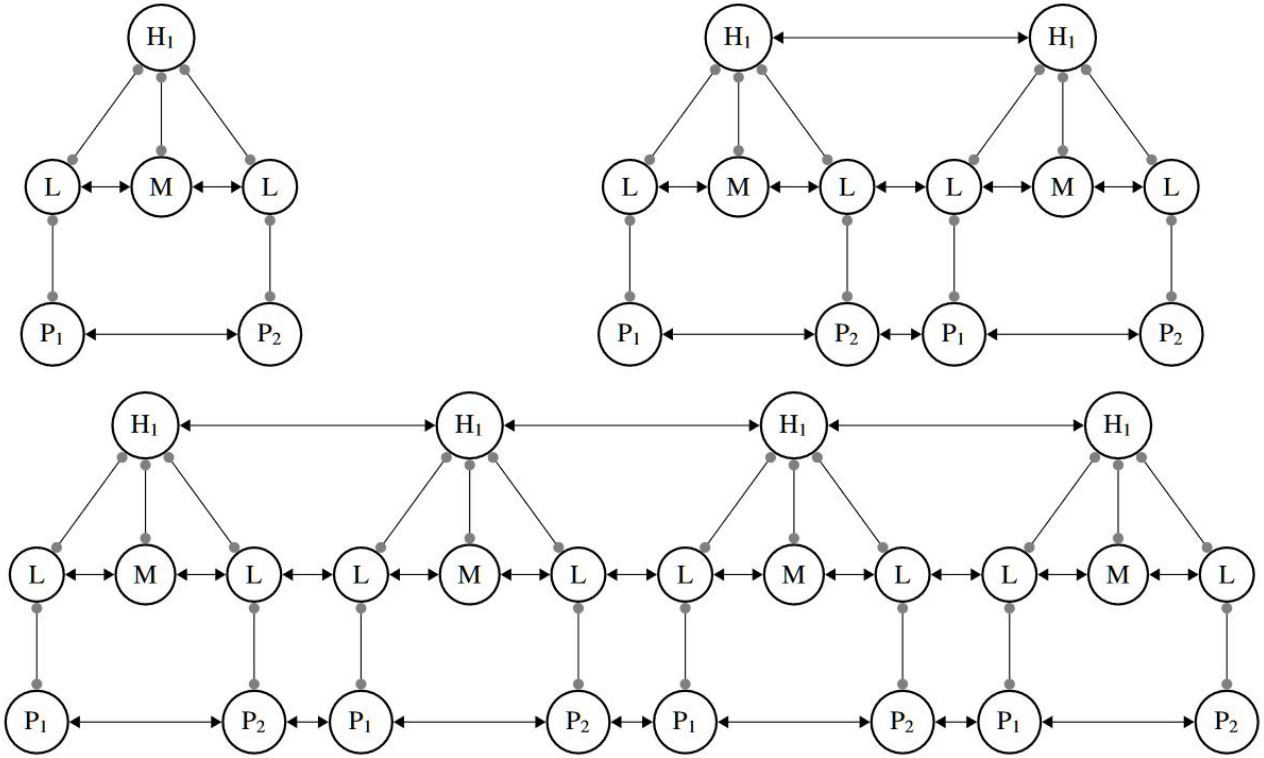
Theorem: MSO = DFA = Regular languages (BEEVT)

Theorem: MSOT = 2DFT = Reg (Engelfriet & Hoogeboom 2002)

Theorem: FOT = Aperiodic 2DFT = Ap. Reg (Carton & Dartois 2021)

Embedded Reduplication

g(f(w)): w → ww → wwww



First Summary

Signed reduplication is regular because…

- Each reduplication process copies a finitely bounded number of times
  - an MSO transduction with a finite copy set
- Regular functions are closed under finite composition
- Number of copies is independent of input size

Comparing to Spoken Multiple Reduplication

Guébie reduplication (Sande 2017; 2021)

- Reciprocalization: *w* → *ww*
- Nominalization: *w* → *ww*
- Nominalization applies to the output of reciprocalization: *w* → *ww* → *wwww*

Runyankore reduplication (Hyman 2020)

- Frequentativity: *w* → *ww* ‘to *w* a lot’
- Root can reduplicate further to mark greater degrees of freq: *w* → *www**
- Like English contrastive *salad salad* reduplication (Ghomeshi et al. 2004)
- Each application of reduplication is regular

Issues for Embedded Reduplication in Sign (Rawski et al 2023)

Cyclicity?

- [[[GIVE + dur] + dist] + iter] more like Guebie than Runyankore
- Typology: is there Runyankore-esque iterative reduplication in SLs?

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Bounds on copies?

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Cyclicity?

Bounds on copies?

- In citation form, each reduplication has finitely bounded copies.
- Van Boven (2021): individual variation via NGT corpus and elicitation data

	Number of repetitions						
	Total	**<One**	**One**	**Two**	**Three**	**Four**	**Unclear**
Simple reduplication	133	19	90	14	2	1	7
Sideward reduplication	197	1	78	44	4	1	69

Issues for Embedded Reduplication in Sign (Rawski et al 2023)

Cyclicity?

Bounds on copies?

[[[GIVE + dur] + dist] + iter]	okay (all unique)
[[[[GIVE + dur] + dist] + dur] + dur]	??

- Direct evidence? murky
- Indirect evidence: Wilbur et al 1983 - not all embeddings work
    - 35% spatial-spatial, 50% temporal-temporal

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How do signers represent the semantic input?

Issues for Embedded Reduplication in Sign (Rawski et al 2023)

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How do signers represent the semantic input?

- **Feature** as mapping $w \rightarrow www$ regular (word-formation, base copying)
- **Feature** as input $wFF \rightarrow www$ polyregular (BRCT, template-filling)

Conclusion

Reduplication is regular across speech and sign (and maybe pro-tactile)

Insights:

- The number of copies per reduplication AND their composition is bounded
- The input does not contain information about number of copies

Predictions:

- no [[[[GIVE + dur] + dist] + dur] + dur] …
- no squaring, iterative prefix, exponential prefix, etc.

Signed languages are a rich laboratory to study bounds on linguistic computation

Questions?

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