Inductive bias in learning partial reduplication:

Evidence from Artificial Grammar Learning

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(Partial) Reduplication is not that hard to learn!

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- Learning results support the key claims of the theory of Prosodic Morphology (McCarthy and Prince, 1986, et seq.), as opposed to X-slot or CV-skeleton (Marantz, 1982) theories of reduplication.
- Learning differences between training with perfect identity and training with a reduplicant-medial fixed segment are consistent with 'higher-order' faithfulness constraints (Zuraw, 2002).

Roadmap

1. Introduction
   - Typological overview
   - Main questions
2. Experimental method
   - Procedure
   - Design & Materials
   - Participants
3. Analysis & Result
   - Amount of copying
   - Affix shape
4. Discussion and conclusion

Outline

Typological overview

Reduplication is a typologically common type of morphological operation with many attested variants

- Full reduplication

Dyirbal plurals (Dixon, 1972, p. 242):

midi	*'little, small'*	midi-midi	*'lots of little ones'*
gulgiɽi	*'prettily painted men'*	gulgiɽi-gulgiɽi	*'lots of prettily painted men'*

- **Partial reduplication**

Agta plurals (Healey, 1960,7):

labáng	*'patch'*	lab-labáng	*'patches'*
uffu	*'thigh'*	uf-uffu	*'thighs'*

(see Graz Database on Reduplication, 2005; RedType, 2019)

Partial reduplication

Dimensions of attested variation

- Reduplicant shape ✓
- Degree of surface identity ✓
- Fixed segments / melodic overwriting ✓

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- Tonkawa repetitives (Gouskova, 2007, p. 3):

to.poʔs	to-to.poʔs	*I cut it/REP*
sal.koʔs	sa-sal.koʔs	*I pull/REP CONT*
naa.toʔs	na-na.toʔs	*I step on it/REP*

- Unattested: XXX- (copy first three segments), etc.

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- Doka Timur West Tarangan (Nivens, 1993, p. 371; Spaelti, 1997, p. 8):

ˈletna	lit-ˈletna	*'male-3**s**'*
ˈrɔna	rin-ˈrɔna	*'dry-3**s**'*

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- Yoruba Nominalization (Alderete et al., 1999, p. 328, Pulleyblank, 1988, p. 265):

gbóná	*'be warm, hot'*	gbí-gbóná	*'warmth, heat'*
dára	*'be good'*	dí-dara	*'goodness'*

Main questions

When presented with minimal evidence of typologically attested patterns of partial reduplication …

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- Report an artificial grammar learning experiment with the 'Poverty of the stimulus' design (Wilson, 2006) to address these questions

Previous experimental studies

. . . on reduplication, or identity-based patterns

- **Homogeneous inputs**, e.g. all CVCVCV in Marcus et al. (1999)
- **Orthographic materials**: Berent et al. (2016), Berent, Bat-El, and Vaknin-Nusbaum (2017), Haugen, Ussishkin, and Dawson (2022)
- **Forced-choice task**: Berent et al. (2016), Prickett et al. (2021), Haugen, Ussishkin, and Dawson (2022)

Current experiment

Methodological Advantages

- *Homogeneous and therefore highly ambiguous familiarization, heterogeneity in testing to discover participant analytic biases*
- *Auditory stimuli without orthographic support, to minimize any role of conscious letter-based strategies*
- *Free spoken responses: more demanding, ecologically valid, and revealing of variation in participant generalizations*

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   - Listen to **8** singular ~ plural pairs, with pictures provided

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2. Testing phase:
   - Listen to a singular and produce the plural form
   - 7 testing types × 8 trials (all new singulars) = 56 trials in total
   - All trial types tested together, order randomized

Experimental design: Training

- Two between-participant conditions

Perfect identity (A) $C_1V_2C_3C_4V_5 \rightarrow C_1V_2C_3$ - $C_1V_2C_3C_4V_5$

ˈdɔvgə → dɔv-ˈdɔvgə

Fixed segment (B) $C_1V_2C_3C_4V_5 \rightarrow C_1\textit{i}C_3$ - $C_1V_2C_3C_4V_5$

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- Inventories:

C_1	coronal obstruent	/t, d, ʃ, z/
V_2	non-high vowel	/ɛ, æ, ɔ, a/
C_3	labial obstruent	/p b f v/
C_4	other obstruent	→ creates sonority plateau
V_5	other vowels	

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What does it take to learn (partial) reduplication?

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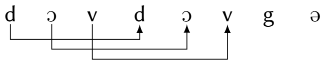

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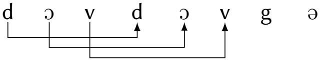

- Recognize effects of copying in the surface forms, namely identical sub-strings!
- Distinguish it from total reduplication
- Construct a hypothesis about the realization of copying
- Relate the hypothesis to the designated operation
  - PL in our case

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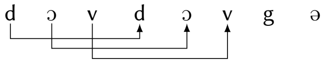
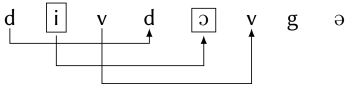


N.B: What hypothesis?

- Heavy syllable template regardless of base? (McCarthy and Prince, 1986, Steriade, 1988)
- CVC-skeleton? (Marantz, 1982)?
- Count-based substring copying (XXX)?
- Featurally-specific template? $C_{[cor]}V_{[-high]}C_{[lab]}$
- Base-dependent syllable copying? (Haugen and Hicks Kennard, 2011)
- . . .

Thinking from a learner's perspective...

As for the fixed segment . . .



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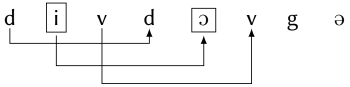

Extra bit: Recognize vowel quality difference!

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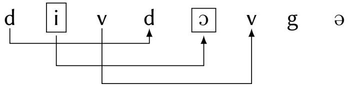

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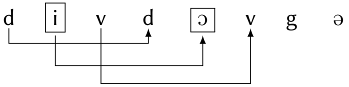

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If test them on high vowels, e.g. ˈʃipne͡ɪ

- ʃip-ˈʃipne͡ɪ?
- or other vowels that would create non-identity

Methodological Advantages

Highly 'impoverished' learning data, compatible with many hypotheses

Design & Materials: test types

Familiar	$C_{[cor]}$	$V_{[-high]}$	$C_{[lab]}$	C	V	ˈzɛvdu
			Segment manipulations			
Lab-Cor	$C_{[lab]}$	$V_{[-high]}$	$C_{[cor]}$	C	V	ˈfædno͡ʊ
High-V	$C_{[cor]}$	$V_{[+high]}$	$C_{[lab]}$	C	V	ˈʃipne͡ɪ
			Shape manipulations			
Singleton	$C_{[cor]}$	$V_{[-high]}$	$C_{[lab]}$	∅	V	ˈdɛbe͡ɪ
Rising	$C_{[cor]}$	$V_{[-high]}$	$C_{[lab]}$	$C_{[son]}$	V	ˈtæpɹe͡ɪ
Complex	$C_{[cor]}$ C	$V_{[-high]}$	$C_{[lab]}$	C	V	ˈstæbgə
Onsetless	∅	$V_{[-high]}$	$C_{[lab]}$	C	V	ˈavdi

Stimuli

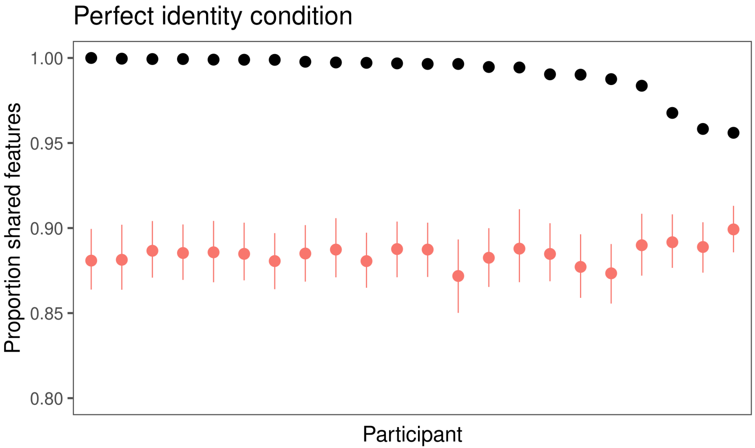
- Nonce singulars (and anticipated reduplicated words) selected to be phonotactically balanced and legal in English.
- Synthesized with Amazon Polly
  - Matthew Voice; 80% speech rate
- All singular forms bear initial stress to enhance noun-likeness.
- No stress shift from singular to plural.

Participants

- English native speakers with no previous language background on reduplication were recruited via Amazon Mechanical Turk
  - **Perfect identity condition**
    22 participants (age 26 – 72 (mean 40); 11 Female)
  - **Fixed segment condition**
    25 participants (age 24 – 61 (mean 39); 15 Female)

Outline

Analysis: Affix faithfulness



Observed (black) vs. Monte Carlo (red, R = 1000, α = 0.01)

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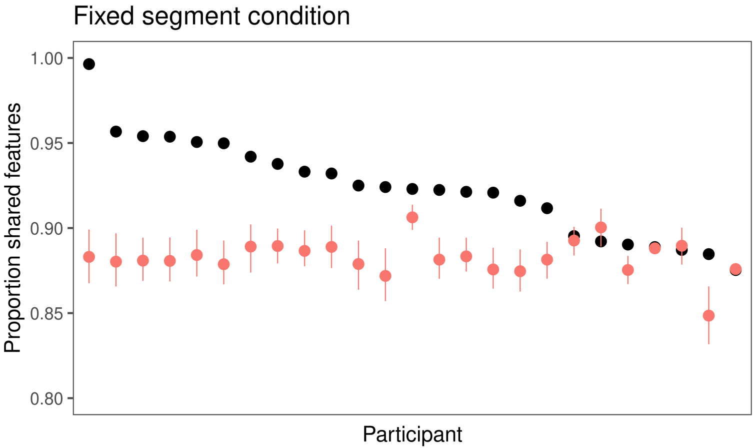

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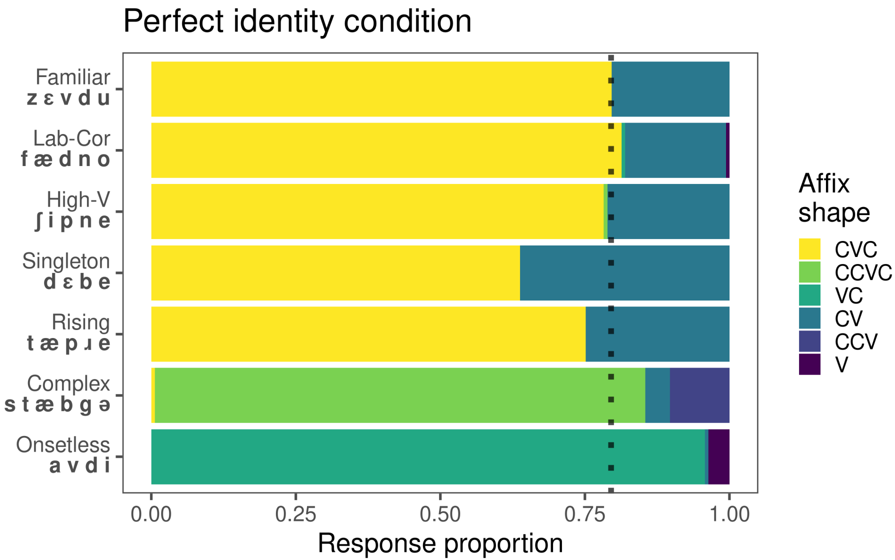
Analysis: Affix shape



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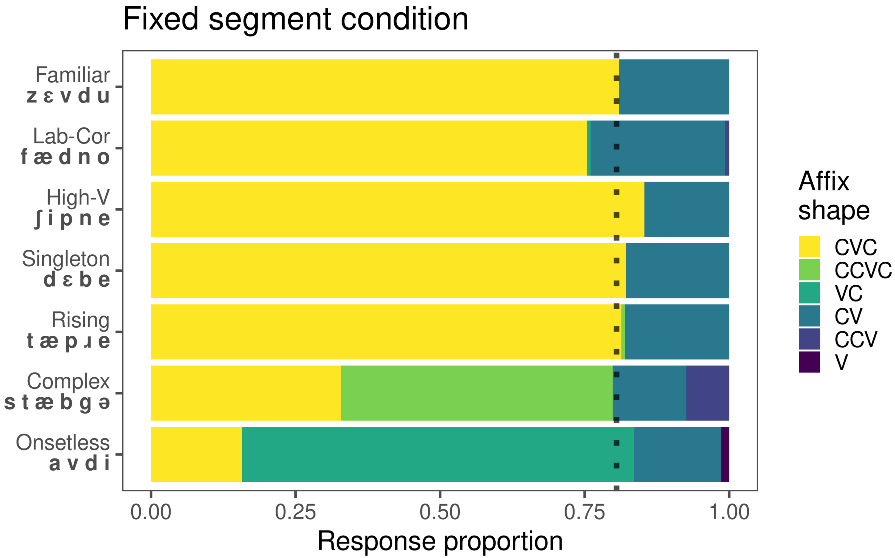


Bayesian statistics of affix shape

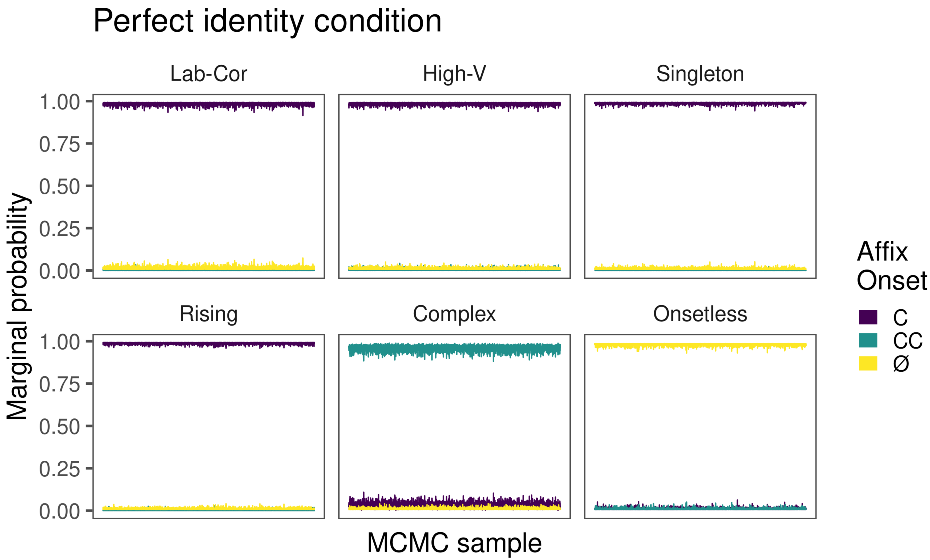
Mixed-effects multinomial logistic regression of affix
Onset (CC, C, ∅) and Rime (VC, V) probabilities

Implemented in Stan (https://mc-stan.org/) with broad prior distributions

Plot posterior distributions marginalized over participants

Monte Carlo comparison of response probabilities within/across test types

Bayesian statistics of affix shape: onset



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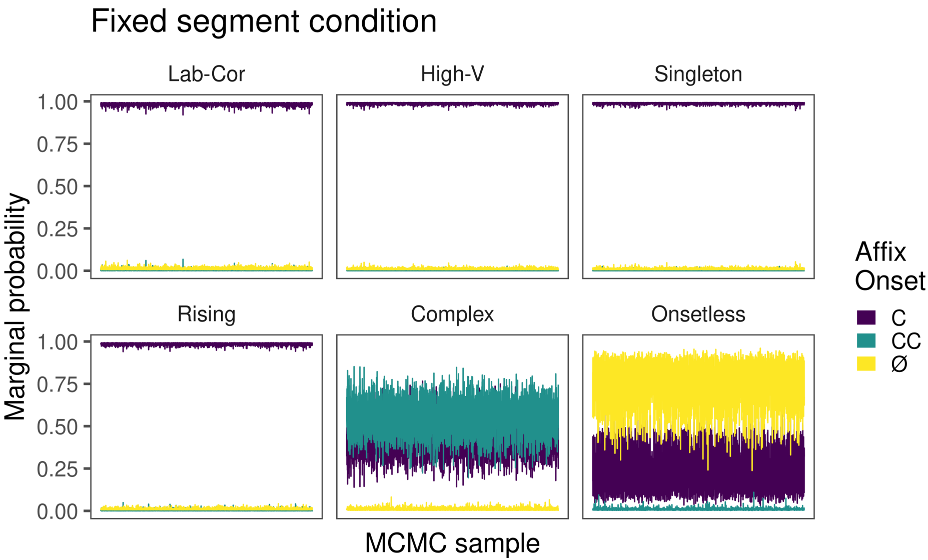


Bayesian statistics of affix shape: onset

Perfect identity condition

	C > CC, ∅	for all test types *except*
Complex:	CC > C, ∅	
Onsetless:	∅ > C, CC	
Lab-Cor:	C > ∅ > CC	

Fixed segment condition

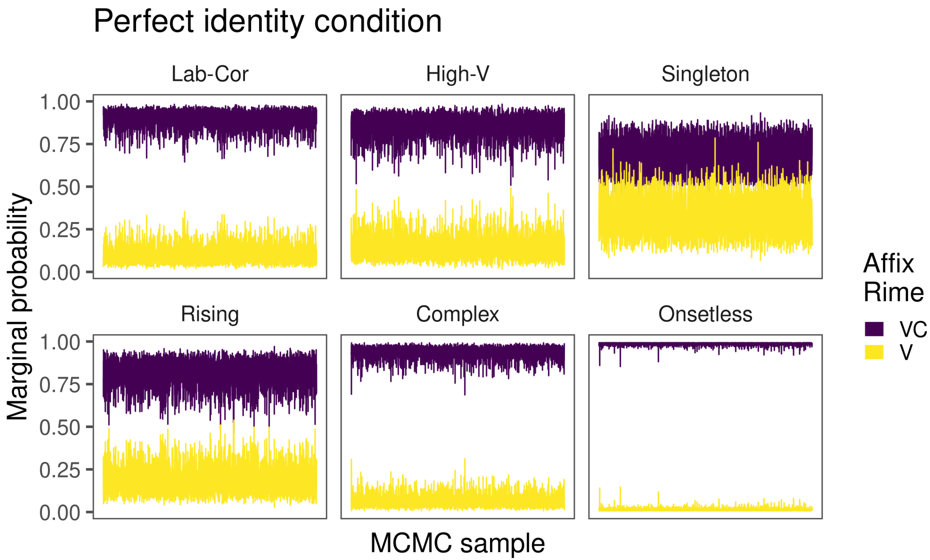
	C > CC, ∅	for all test types *except*
Complex:	C, CC > ∅	
Onsetless:	C, ∅ > CC	

Onset shape (within each condition)

C:	*other* > Complex, Onsetless
CC:	Complex > *other*
∅:	Onsetless > *other*

Pairwise posterior comparisons, $\alpha = 0.01$

Bayesian statistics of affix shape: rime



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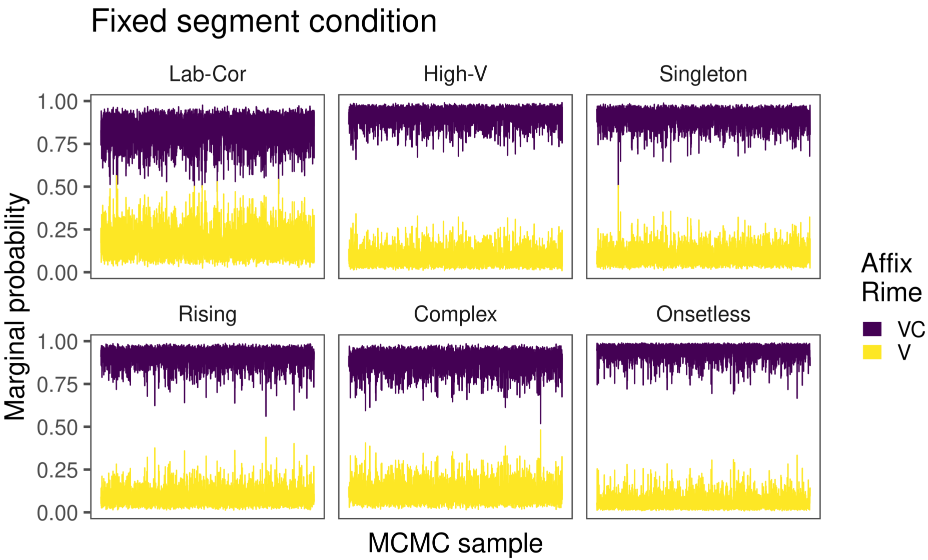

Bayesian statistics of affix shape: rime

Perfect identity condition

VC > V   for all test types

VC:	Onsetless > *other*	(hiatus avoidance)
	Complex > Singleton	(why?)

Fixed segment condition

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Pairwise posterior comparisons, $\alpha = 0.01$

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    Consistent with Prosodic Morphology weight-/rime- based templatism
  - XXX-slot, counting based ✗
    No evidence of VCC reduplicants given VCCV bases, no preference for CCV reduplicants given CCVCCV bases
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Converging evidence from results of *artificial-grammar experiments* and attested typological variation in partial reduplication

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  - Yes, the rate of copying application differs, as we already saw in feature faithfulness: some participants in fixed segment condition actually have memorized prefix(es) instead of active copying

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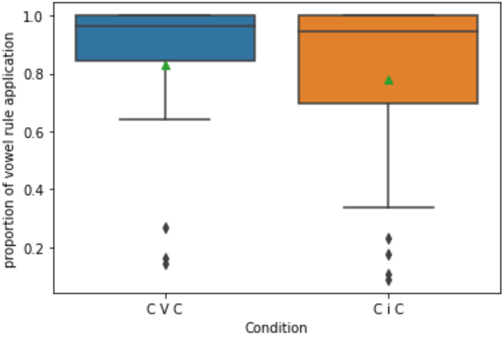
  - Different slot in reduplicant show different levels of copying/corresponding rule application



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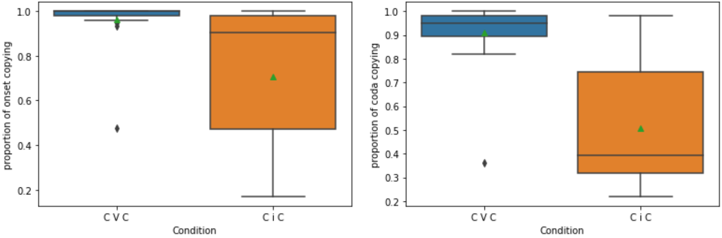

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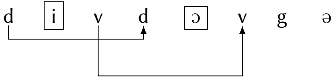

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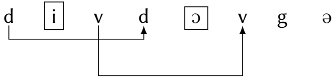

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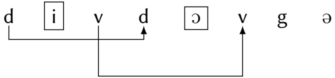

  - Copying gets interrupted by non-identity between the fixed /-i/ and the base vowel.
  - Any theory can predict such learning difference?
    - REDUP in Zuraw (2002), which motivates aggressive reduplication, urges *contiguous* sub-string correspondence

Acknowledgments

Thank you!

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Appendix I: Training items

Singular	Perfect identity (A)	Fixed segment (B)
ˈdɔvgə	dɔv-ˈdɔvgə	div-ˈdɔvgə
ˈdɛfkeɪ	dɛf-ˈdɛfkeɪ	dif-ˈdɛfkeɪ
ˈtabneɪ	tab-ˈtabneɪ	tib-ˈtabneɪ
ˈtæfku	tæf-ˈtæfku	tif-ˈtæfku
ˈzapmoʊ	zap-ˈzapmoʊ	zip-ˈzapmoʊ
ˈzɔvgi	zɔv-ˈzɔvgi	ziv-ˈzɔvgi
ˈʃæpmə	ʃæp-ˈʃæpmə	ʃip-ˈʃæpmə
ˈʃɛbnoʊ	ʃɛb-ˈʃɛbnoʊ	ʃib-ˈʃɛbnoʊ

Appendix II: Affix Shape

Fixed Segment condition:

CV shapes	freq
CCVC	63
CV	287
CVC	624
VC	91
CCV	12
CVCC	2
V	1
VCC	1
VVC	3
i:	1
VCCV	4
CVCCV	10
CCVCCV	2
CVCV	1

Perfect identity condition:

CV shapes	freq
CCVC	133
CV	191
CVC	597
VC	150
CCV	16
CVCCV	1
CVCV	3
V	7
VCCV	1

Appendix II: Affix shape

Affix Onset shape $\in \{C, CC, \varnothing\}$ Rime shape $\in \{VC, V\}$

$$P(\text{Onset shape } k \mid \text{participant } i \text{ \& test type } j) = \text{softmax}(\beta_j^{onset} + \lambda_{ij}^{onset})_k$$

$$P(\text{Rime shape } l \mid \text{participant } i \text{ \& test type } j) = \text{softmax}(\beta_j^{rime} + \lambda_{ij}^{rime})_l$$

Fixed effects

$$\beta_j^{onset} = [\beta_j^{onset}(C), \beta_j^{onset}(CC), \beta_j^{onset}(\varnothing) = 0]$$

$$\beta_j^{rime} = [\beta_j^{rime}(VC), \beta_j^{rime}(V) = 0]$$

$$\beta_{jk}^{onset} \sim N(0, \sigma_\beta^{onset}) \qquad \sigma_\beta^{onset} \sim \text{Inv-Gamma}(2, 1)$$

$$\beta_{jl}^{rime} \sim N(0, \sigma_\beta^{rime}) \qquad \sigma_\beta^{rime} \sim \text{Inv-Gamma}(2, 1)$$

Random effects

$$\lambda_{ij}^{onset} = [\lambda_{ij}^{onset}(C), \lambda_{ij}^{onset}(CC), \lambda_{ij}^{onset}(\varnothing) = 0]$$

$$\lambda_{ij}^{rime} = [\lambda_{ij}^{rime}(VC), \lambda_{ij}^{rime}(V) = 0]$$

$$\lambda_{ijk}^{onset} \sim N(0, \sigma_\lambda^{onset}) \qquad \sigma_\lambda^{onset} \sim \text{Exponential}(1/2)$$

$$\lambda_{ijl}^{rime} \sim N(0, \sigma_\lambda^{rime}) \qquad \sigma_\lambda^{rime} \sim \text{Exponential}(1/2)$$

Appendix III: Onset simplification in fixed segment condition

For complex onset ...

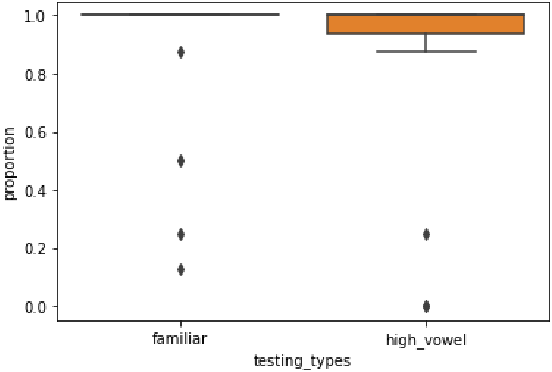
- Within all data, 159 responses in complex onset testing type
- onset clusters: 39 dr, 43 ʃr, 38 st, 39 sl
- We got 83 responses with single-consonant onset, 45 of which copies some Cs in the base,
- 6 sl→ s, 15 ʃr → ʃ, 21 dr → d

Appendix IV: Consonant insertion in fixed segment

For onset-less . . .

- 60 responses with a onset
- 48 of them are the coronal obstruent appearing in the training

Appendix V: identity vs. non-identity



- No differences among test types
- No evidence of identity avoidance, preference to always produce [i]
- Prefer first-order (fixed) generalization over second-order/non-identity

Appendix VI: variable syllable copying?

- Variable syllable copying versus base-independent template copying?
  - We manipulated on the shapes of the base
    - CVCV
    - CVCCV with sonority rise.

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  - Or, the CVC-copier had C as medial coda, while CV-copier syllabified as CV.CV. (All difference are from differences of syllabification.)

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  - Or, the CVC-copier had C as medial coda, while CV-copier syllabified as CV.CV. (All difference are from differences of syllabification.)

Inconclusive, a follow-up experiment directly targeting on this question.

Appendix VII: Syllabification and ambisyllabicity

- Ambisyllabic consonant in English: a stressed vowel+word-medial consonants+a stressless vowel, the consonants could be linked to both syllables.

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- Our testing types are all disyllabic, initially stressed.
  - $C_{[cor]}V_{[-high]}C_{[lab]}V$ ˈdɛbe͡ɪ
  - $C_{[cor]}V_{[-high]}\ C_{[lab]}C_{[son]}V$ ˈtæpɹe͡ɪ

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- Treiman and Danis (1988): disyllabically, when the initial syllable vowel was tense and the single medial consonant was an obstruent, people placed the medial consonant in the second syllable about 79% of the time. When the vowel was lax, the second-syllable rate was 58%.

  → Our experiment copies CVC more than 50% in CVCV case.

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- Experiment 4 in Treiman and Zukowski (1990), for trochaic $V_1C_2C_3V_4$, when the medial cluster is a stop + liquid, when V_1 lax, people show ambisyllabicity about 50% of the time, and 31% of the time, people placed the C_2 into the second syllable. For tense V_1, ambisyllabicity is 21% of the time and $[C_2C_3$ is 72% of the time.
- Assuming their distribution, if our participants are merely repeating the first syllable (taking ambisyllabicity into account), for lax vowel, they would do CVC shape 67% of the time, for tense vowel, they would do CVC shape for 27% of the time.
- While our participants are repeating CVC about 75% of the time...

Appendix VII: Syllabification and ambisyllabicity

- Ambisyllabic consonant in English: word-medial consonants following a stressed vowel, and a stressless vowel, belong to both syllables, with a status of blurred syllabification.
- Our testing types are all disyllabic, initially stressed.
  - $C_{[cor]}V_{[\text{-high}]}C_{[lab]}V$ ˈdɛbe͡ɪ
  - $C_{[cor]}V_{[\text{-high}]}\ C_{[lab]}C_{[son]}V$ ˈtæpɹe͡ɪ
- We take the result from this experiment and also the result of previous syllabification task together as a possible hint that speakers **largely** show a general tendency of heavy syllable copying given our input.
- but no conclusion to be made about base-dependent syllable copying