

# The syllable in domain generalization: Evidence from artificial language learning

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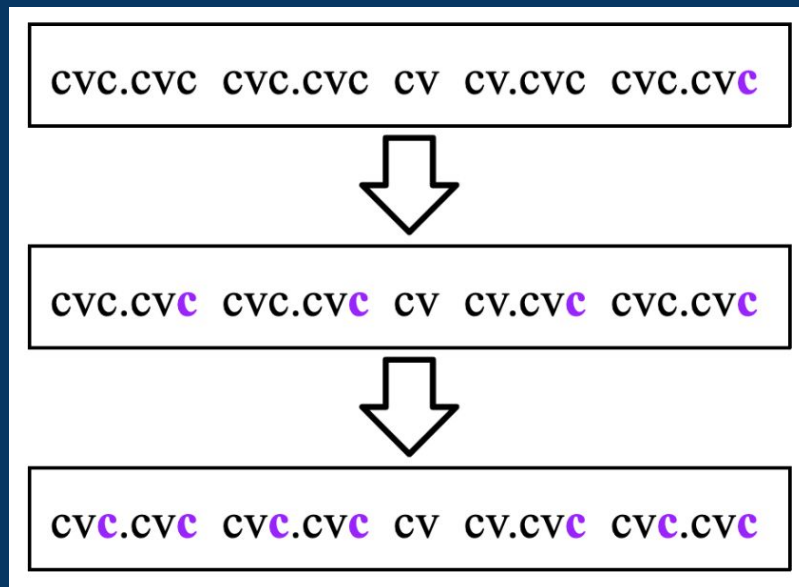
2023 Annual Meeting on Phonology  
October 20, 2023



UNIVERSITY OF CALIFORNIA  
**SANTA CRUZ**

# Domain generalization

- Diachronic origins of certain domain-edge phenomena
  - Final devoicing, high tone retraction, vowel length neutralization...
    - (Phonetic motivation at phrase level)
- A shift in the domain of a distribution pattern from a longer, more inclusive phonological domain (e.g. the utterance) to a shorter, less inclusive one (e.g. the word).



## Myers & Padgett (2014)

- 2 Artificial Language Learning experiments showing learning and generalization of final obs. devoicing from utterance-final to word-final position

## Question: Is the word special?

- Do learners generalize to other (prosodic) domains?
- Is there a preference for word-level phonology?

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**Upshot:** Domain generalization to the syllable is possible.

- Generalization can occur across *phonological* domains
- The syllable is accessible to the grammar/memory for necessary calculations

## In this talk:

- 1) Generalization beyond the word - Why might we (not) expect it?
- 2) Artificial learning experiment
- 3) Discussion/Future directions

# Generalization beyond the word

# Generalization beyond the word

- General preference for word-level phonology?
  - Plenty of syllable-level phonology
    - Neutralizations, Spanish /s/-debuccalization, Tz'utujil approximant devoicing (see additional materials)
- M&P - More words than utterances experienced/stored
  - Ah, but more syllables than words!
- Generalization beyond the word - Zec & Zsiga (2022)
  - High tone retraction in Štokavian varieties of Serbian
  - Generalization to the word and, in some varieties to the foot



# The syllable as different from the word

- Primary difference
  - Words = morphosyntactic, semantic, and phonological units/domains
  - Syllables = phonological
- Two potential points of departure:
  - What structures are accessible in memory/grammar?
  - What type of domains do we generalize over?

# What structures are accessible in memory / grammar?

- Are syllables even phonological domains?
  - Direct reference to syllable structure unnecessary (e.g., Ohala & Kawasaki-Fukumori 1997, Steriade 1999)
  - Some syllable structure in URs/lexicon (e.g., Vaux 2003)
- Do syllables get exemplar clouds? Is syllable structure encoded in stored words?

# What types of domains do we generalize over?

- Bermudez-Otero & colleagues (e.g. Bermudez-Otero & Trousdale 2012)
  - Morphosyntactic-based stratal phonology
  - Phrase stratum → word stratum → stem stratum
  - Syllable is not a domain

# Experiment

# Experiment

- Based closely on Myers & Padgett (2014)
- Artificial language learning
  - Control language material participants are exposed to during a learning phase
  - Test acquisition of linguistic knowledge during a test phase
- Poverty of the stimulus
  - Classes of stimuli present in the test phase that were not included during the learning phase (but related)
    - To test generalization to novel classes

# Experiment design

- Liquid neutralization pattern: /ɹ, ɹ/ → [l]
- Tri-syllabic stimuli with codas in one of two positions:
  - *final*      .CV.CV.CVC.
  - *medial*    .CV.CVC.CV.
- Two learning groups
  - utterance-to-word (UtW)
  - word-to-syllable (WtS)

# Experiment design

- Tri-syllabic stimuli with codas in one of two positions:
  - *final* .CV.CV.CVC.
  - *medial* .CV.CVC.CV.
- C: [t,k,m,n,l,j] , V: [i,a,u]
- Consonants occur with equal frequency (in onsets)
- Learning phase:
  - [l] but not [j] occurs in final position (the neutralization pattern)
  - No liquids ([l,j]) in medial codas (poverty of the stimulus)
- Testing phase:
  - All consonants in all positions - Will participants accept coda [j]?

## Learning phase stimuli:

Block 1. CVVCVC.			Block 2. CVVCVCV.	
<i>nasal-coda</i> ni ni man ki la kam lu ki kan ta ki nim ma nu tin tu la lan ri ka kin ra mi kin ri li kam su ku rin lu na lum la ra num	<i>obst-coda</i> ti nu lut nu ti rak ra ru lak ki ma rut ma ku lik na la nuk mu ti fat ra lu tak ti ku mit mi tu rak ka ru tut mi ri mat	<i>ll-coda</i> ka na nil ta ma mul lu ta nal ra lu mil na ti nil ki ri rut ti mi kil ka ma tal ma ra lal li ni nul mu ta mil lu mu rul	<i>nasal-coda</i> ti mam ki na kin ka la lan ra ku nim li ti kum ka ka run ma ti mum li ma lam tu la tun mu ma run ti ki ram nu nu kam ra	<i>obst-coda</i> ra muk na ru kik mu li nat li mu tat nu li mut ku na nak ta na rik ta mi tat ni ki lok mu ru mit li tu lit ri ru tik ru

## Testing phase stimuli:

Block 1. CVVCVCV.				Block 2. CVVCVCV.			
<i>nasal-coda</i> mu lu tim la nu run nu ta lam ri ki tun ti ti tam li ki nam ma mi mun li li kum ma ra rim li ki rin nu ra nin mu nu lam mi la nin tu nu tum na ru num ku ni ram la li nam ri tu run	<i>obst-coda</i> ta ri kat tu ru lak ji nu tit lu ka muk mi ni nit ri ta mit ma ta kak na ru nak ra mu lut ki na mik su ri tut tu ma mat la ma mit ra ri kik ru la nak ra na lut na ru muk na ka rak	<i>ll-coda</i> ma nu mul ku la nul lu mi ril ka lu kul ta ka lil mu mu kul ra tu ril ka lu kal ji nu kal ki mu kal li ru ral mi mi lil nu ka nul ma mi hul ti lu lil ki ku mil nu na rul	<i>rl-coda</i> ni ki mir ki li tar li ra kar ri ma tir lu la kir na na tar ku ra lar lu ta mur tu mi rir ru ta tar ki tu mur ri mi kas mu ka tir ra ru kir mi ku nar lu ki tar na tu mur ku ti kir	<i>nasal-coda</i> ka tum na nu tam ru ra kin ka li rin ri ru mim ta mu lim tu ni mun tu ru rim lu mu man ti la mun ka ra ram lu la lin ma ta kin la ru rin ri ru mam ru na mam la ti kum lu la kun la	<i>obst-coda</i> ti ruk tu ni lak mu ra tik ri li lut ra ri mik ri ma nat mu na mit ki ra luk ru ti nut ku lu kit ku li nak li lu rak ma nu rik li ru rik li ka muk ta ki kut li ta tit nu ma kak ra	<i>ll-coda</i> ri tal ti li nul mi ki tal ni mu nal ma lu tul ti ru nil ma na tal ni ta lil ta ma nil ku li lul nu mu lak li li mul ku ni nal ma ti ril ma mu lul ri ku nul mu ku lal ri ku tul ri	<i>ll-coda</i> tu tar ni mi rar na mi rur ku ka nar nu ru rik ki ru kir tu mu nur ki mi lur nu na mur ku ki nar la tu mur la na kas ni ka tur la ta nar ma ka kir ti ki kur ma tu kir nu mi lir ma

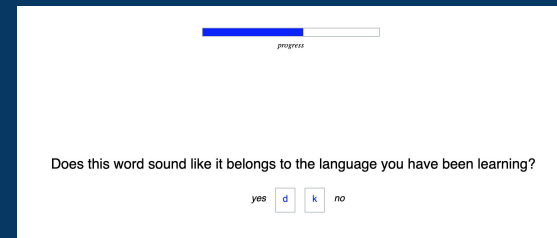
# Participants

- UCSC undergrad participant pool
- English-dominant
- 71 participants (35 UtW, 36 WtS)



# Procedure

- Online - PClbex
  - Stimuli presented auditorily through headphones (no orthographic representation)
- Self-paced
- Learning phase: Listening to [3-syllable words | 3-word sentences] in a made-up language. Listen and repeat aloud.
  - Stimuli presented in blocks by coda position (final/medial)
  - Each block presented 3 times - random order within block
- Testing phase: New items, again presented in blocks (1x each)
  - *Does this [word | sentence] sound like it belongs to the language you have been learning?*
- 18 observations per condition per participant
  - 18 final [ɹ], 18 medial [ɹ], 18 final [l], 18 medial [l]

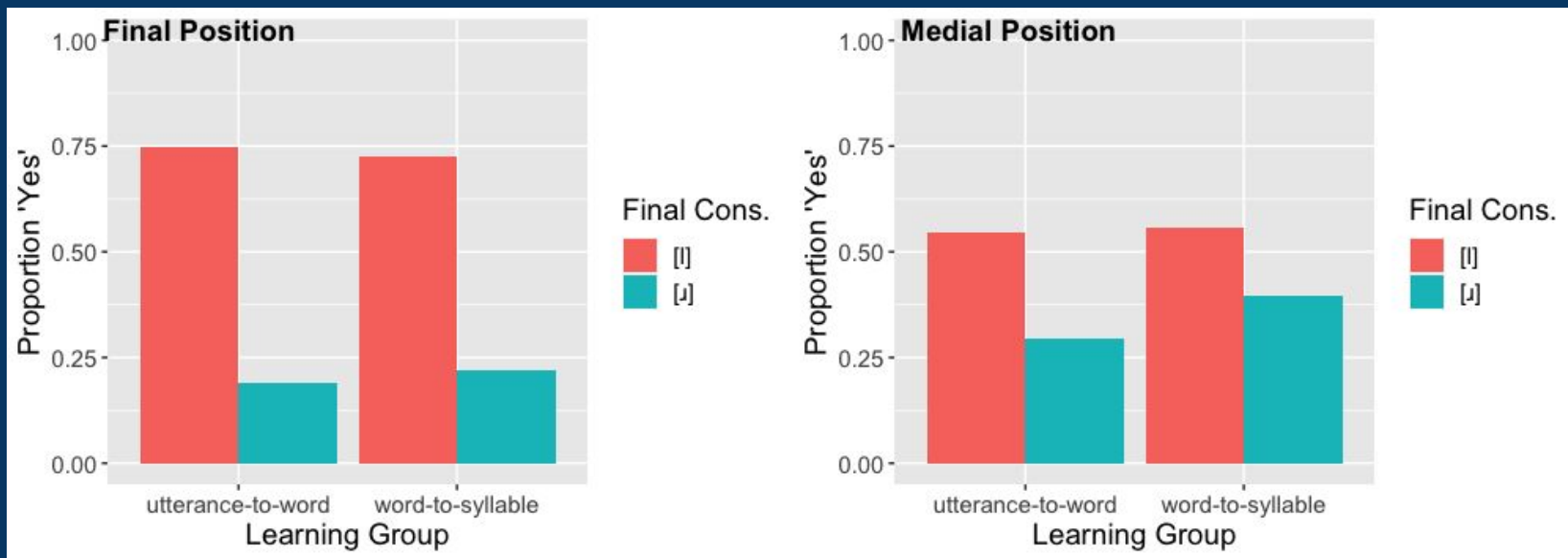


# Hypotheses

1. **Learning** - Participants will show a preference for [l] over [ɹ] in *final* codas in the testing phase.
2. **Generalization** - Participants will show a preference for [l] over [ɹ] in *medial* codas.
3. **Syllable as domain** - If the syllable is a potential domain for domain generalization, then both groups should similarly generalize to non-final codas.

# Results

- 10 participants (5 in each group) did not learn the pattern (and therefore could not generalize it to the smaller domain)
  - Remaining participants: 30 UtW, 31 WtS



# Results

- Mixed effects logistic regression analysis
  - Dependent variable: response ('no'/reject or 'yes'/accept)
  - Fixed effects: liquid coda consonant ([l]/[ɹ]), coda position (final/medial), learning group (UtW/WtS)
- Significant main effects of coda consonant and coda position but not learning group
- Evidence of both *learning* and *generalization* in both groups

# Discussion

# Discussion

- Evidence of learning and generalization in both groups
  - Generalization to the word level *and* generalization to the syllable level
- Do we believe that the two groups were really doing different tasks?
  - Exit survey responses indicate yes
  - Subsequent experiment - only words, no sentences
  - Future experiment - images

# Discussion

- Generalization from word → syllable or utterance → syllable?
  - Stimuli = single-word utterances, therefore word-final = utterance-final
  - Future work could tease apart word → syllable vs. utterance → syllable generalization
    - Is generalization (necessarily) stepwise?
- Utterance/word → non-prevocalic?
  - Still a type of generalization
  - May be difficult to test with artificial learning

# Thank you!

Special thank you to Jaye Padgett for sharing his research and insight and guiding me through this project, Ryan Bennett, Grant McGuire, and Rachel Walker for their ongoing support and mentorship, and Eric Baković and Scott Myers for taking time to provide insight to this banana slug. Also to Amanda Rysling, 2022 LING 290 participants, all my classmates and colleagues who have heard me discuss this research at many stages and provided fantastic questions and feedback, and to my Tz'utujil friends and collaborators who have shared their language and so much more with me and inspired much of my work. Maltyoox!



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# Additional materials

# Syllable-level phenomena: Spanish [s] debuccalization

## (1) Spanish /s/-debuccalization

	<u>orthography</u>	<u>non-debuccalizing</u>	<u>debuccalizing varieties</u>	
a.	<i>español</i>	[es'paɲol]	[eh'paɲol]	‘Spanish’
b.	<i>sostener</i>	[sos'tener]	[soh'tener]	‘sustain’
c.	<i>feliz cumpleaños</i>	[fe'lis kumple'aɲos]	[fe'lih kumple'aɲoh]	‘happy birthday’

## Syllable-level phenomena: Tz'utujil devoicing

### (2) Approximant devoicing in Tz'utujil (Dayley 1985)

a.	<i>way</i>	[waj]	'tortilla'
b.	<i>Moysees</i>	[mɔjse:s]	'Moses'
c.	<i>kow</i>	[kɔϕ]	'hard'
d.	<i>tewlaj</i>	[tɛϕlax]	'very cold'
e.	<i>uleew</i>	[ule:ϕ]	'land'
f.	<i>jul</i>	[xɔ!]	'hole'
g.	<i>elnaq</i>	[ɛ!naq <sup>h</sup> ]	'he has left'
h.	<i>q'or</i>	[q'ɔɾ]	'lazy'
i.	<i>warnaq</i>	[waɾnaq <sup>h</sup> ]	'he has gone to sleep'

# Stimuli - Learning phase

Block 1 .CV.CV.CVC.			Block 2 .CV.CVC.CV.	
<u>nasal-coda</u>	<u>obs-coda</u>	<u>[[ ]-coda</u>	<u>nasal-coda</u>	<u>obs-coda</u>
.ni.ni.man	.ti.nu.lut.	.ka.na.nil.	.ti.mam.ki.	.ra.muk.na.
.ki.la.kum.	.nu.ti.rak.	.ta.mu.mul.	.na.kin.ka.	.ru.kik.mu.
.lu.ki.kan.	.ra.ru.lak.	.lu.ta.nal.	.la.lan.ra.	.li.nat.li.
.ta.ki.nim.	.ki.ma.rut.	.ra.lu.mil.	.ku.nim.li.	.mu.tat.nu.
.nu.nu.tin.	.mu.ku.lik.	.na.ti.nil.	.ti.kum.ka.	.li.nut.ku.
.tu.la.lan.	.na.la.tuk.	.ki.ri.rul.	.ka.run.ma.	.na.nak.ta.
.ri.ka.kim.	.mu.ti.tat.	.ti.mi.kil.	.ti.mun.li.	.na.rik.ta.
.ra.mi.kin.	.ra.lu.tak.	.ka.ma.tal.	.ma.lum.tu.	.mi.tat.ni.
.ri.li.kam.	.ti.ku.mit.	.mu.ra.lal.	.la.tun.mu.	.ki.lik.mu.
.nu.ku.rin.	.mi.tu.ruk.	.li.ni.nul.	.mu.run.ti.	.ru.mit.li.
.lu.na.lum.	.ka.ru.tut.	.mu.ta.mil.	.ki.ram.nu.	.tu.lit.ri.
.la.ra.num.	.mi.ri.mat.	.lu.mu.rul.	.nu.kam.ra.	.ru.tik.ru.

# Stimuli - Testing phase

Block 1 .CV.CV.CVC.			
<u>nasal-coda</u>	<u>obst-coda</u>	<u>[l]-coda</u>	<u>[r]-coda</u>
.mu.lu.tim.	.ta.ti.kat.	.ma.nu.mul.	.ni.ki.mir.
.la.nu.run.	.tu.ri.lak.	.ku.la.nul.	.ki.li.tar.
.nu.ta.lan.	.ti.nu.tit.	.lu.mi.ril.	.li.ra.kar.
.ri.ki.tun.	.lu.ka.muk.	.ka.la.kul.	.ri.ma.tir.
.ti.ti.tam.	.mi.ni.nit.	.ta.ka.lil.	.lu.la.kir.
.li.ki.nam.	.ri.ta.mit.	.mu.mu.kul.	.na.na.tur.
.ma.mi.mun.	.ma.ta.kak.	.ra.tu.ril.	.ku.ra.lar.
.li.li.kum.	.na.ru.nak.	.ka.lu.kal.	.lu.ta.mur.
.ma.ra.rim.	.ra.mu.lut.	.ti.nu.kal.	.tu.mi.rir.
.li.ki.rin.	.ki.na.mik.	.ki.mu.kal.	.ru.ta.tar.
.na.ra.nin.	.nu.ri.tut.	.ti.ru.ral.	.ki.tu.mur.
.mu.nu.lam.	.tu.mi.mat.	.mi.mi.lil.	.ri.mi.lar.
.mi.la.nin.	.la.mu.mit.	.tu.ka.rul.	.nu.ka.tir.
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.na.ru.nun.	.ru.la.nak.	.ku.li.nul.	.mi.ku.nar.
.ku.ni.ram.	.ra.na.lut.	.ti.lu.lil.	.lu.ki.tar.
.la.li.nam.	.na.ru.nuk.	.ki.ku.mil.	.na.tu.mur.
.ri.tu.run.	.na.ka.rak.	.nu.na.rul.	.ku.ti.kir.

Block 2 .CV.CVC.CV.			
<u>nasal-coda</u>	<u>obs-coda</u>	<u>[l]-coda</u>	<u>[r]-coda</u>
.ka.tum.na.	.ti.ruk.tu.	.ri.tal.ti.	.tu.tar.ni.
.ni.tan.ru.	.ni.lak.mu.	.li.tul.mi.	.mi.mar.na.
.ra.kim.ku.	.ta.tik.ri.	.ki.tal.ni.	.mi.rur.ku.
.li.rin.ri.	.li.lut.ra.	.mu.ral.ma.	.ka.nar.nu.
.ru.mim.ta.	.ri.mik.ri.	.lu.tul.ti.	.nu.rir.ki.
.mu.lim.tu.	.ma.nat.mu.	.ru.nil.ma.	.ru.kir.tu.
.ni.mun.tu.	.na.mit.ki.	.na.tal.ni.	.mu.nur.ki.
.ru.rim.lu.	.ra.luk.ru.	.ta.lil.ta.	.mi.lur.nu.
.mu.man.ti.	.ti.nut.ku.	.ma.nil.ku.	.na.nur.ku.
.la.mun.ka.	.lu.kit.ku.	.li.lul.nu.	.ki.nar.la.
.ra.ram.lu.	.li.nak.li.	.nu.lal.ti.	.tu.mar.la.
.la.lin.ma.	.lu.rat.ma.	.li.mul.ku.	.na.kar.ni.
.ta.kim.la.	.nu.rik.li.	.ni.nal.na.	.ka.tur.la.
.ru.rin.ri.	.ru.rit.ki.	.ti.ril.ma.	.ta.nar.ma.
.ru.mam.ru.	.ka.muk.ta.	.mu.lul.ri.	.ka.kir.ti.
.na.man.la.	.ki.kut.li.	.ku.nul.mu.	.ki.kur.ma.
.ti.kum.lu.	.ta.tit.nu.	.ku.lal.ri.	.tu.kir.na.
.la.kun.la.	.ma.kak.ra.	.ku.tul.ri.	.mi.lir.ma.

# Fixed effects in a logistic regression model of responses

Significant values ( $p < 0.05$ ) are indicated by \*

	<i>b</i>	<i>z</i>	<i>p</i>
Intercept	1.2457	6.307	2.84e-10*
Coda consonant ([ɹ])	-3.0106	-10.518	< 2e-16*
Coda position (medial)	-1.0295	-5.222	1.77e-07*
Learning group (WtS)	-0.1021	-0.427	0.669
Coda consonant × Coda position	1.7204	5.980	2.23e-09*
Coda consonant × Learning group	0.1912	0.550	0.582
Coda position × Learning group	0.1454	0.743	0.458
Coda consonant × Coda position × Learning group	0.2198	0.754	0.451

# Effects of Coda consonant in data subsets defined by Coda position and Learning group

Significant values ( $p < 0.05$ ) are indicated by \*

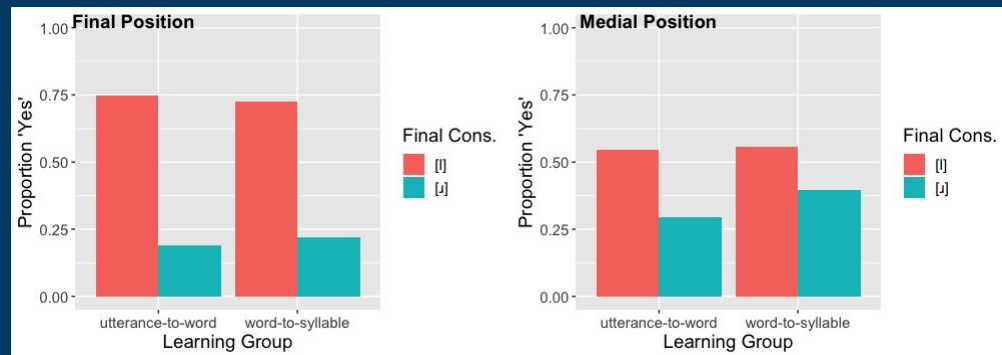
Coda position	Learning group	<i>b</i>	<i>z</i>	<i>p</i>
final	UtW	-2.8886	-10.387	$< 2e-16^*$
final	WtS	-2.9561	-7.583	$3.37e-14^*$
medial	UtW	-1.3102	-4.856	$1.2e-06^*$
medial	WtS	-0.9029	-4.076	$4.57e-05^*$



# Correctness

- Coded for “correctness”
  - Accept [l] = correct
  - Reject [ɹ] = correct

	final	medial
UtW	78%	63%
WtS	75%	58%



- Difference between groups not statistically significant