Derived-environment effects: a view from learning

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Keio-ICU Linguistics Colloquium

16 October 2020

Queen Mary University of London

Phonotactics and Alternations

- Phonological alternations often reflect static phonotactic restrictions in the lexicon (e.g. Chomsky & Halle, 1968; Kenstowicz & Kissberth, 1977).

- Navajo harmony prefix+root (Data cited from Martin (2011), originally from Fountain (1998))
  - /ji-s-tiz/ → [ji-s-tiz] 'it was spun'
  - /ji-s-lééʒ/→ [ji-ʃ-lééʒ] 'it was painted'

- Harmonic roots
  - [tʃ'oʒ] 'worm' ([-anterior]…[-anterior]) *[tʃ'oz]
  - [ts'ózí] 'slender' ([+anterior]…[+anterior]) *[ts'óʒí]

Phonotactics and Alternations

- Constraint-based theoretical models (e.g. Optimality Theory; Prince & Smolensky, 1993/2004)

- Generalizations about phonotactics and alternations are encoded using the same constraint

Phonotactics and Alternations

- But sometimes static phonotactic patterns mismatch with alternation pattern at morph. boundaries (See Paster 2013):

- Active alternation, no support from stem phonotactics:
  - (Morphologically) Derived-environment effects (DEE) (Kiparsky, 1973, 1993)
  - A.k.a. non-derived environment blocking (NDEB)

- Stem phonotactic restrictions, but no active alternation (e.g. laryngeal co-occurrence restrictions in many lgs., see Gallager, Gouskova & Camacho, 2019)

Derived-environment effects

Turkish vowel harmony: (e.g. Clements & Sezer, 1982):

Suffixes agree with final vowel of stem in backness:

	Nom.sg	Nom.pl	Gloss
a.	ip	ip-ler	‘rope’
b.	sap	sap-lar	‘stalk’

But roots themselves can be disharmonic:

a. takvim ‘calendar’
b. bobin ‘spool’

Previous analyses of DEEs

- General approach: 'protect' morpheme-internal sequences while allowing same sequences to alternate at morph. boundaries (e.g. Kiparsky, 1993; Burzio, 2000; Lubowicz, 2002; McCarthy, 2003; Wolf, 2008)

- Assumes:
  - **Derived environment condition**: Morphological derivedness is a necessary and sufficient condition for a process to occur (Kiparsky 1982, 1993)

  - (more implicitly) **Phonotactic well–formedness:** Morpheme-internal sequences are phonotactically well-formed (see Chong, 2019)

Previous analyses of DEEs

- Less explicit examination of:
  - ‘Productivity’ of these patterns (though see Inkelas, 2011; Anttila, 2006)
    - What these patterns actually look like ‘under the hood’ (e.g. Bjorkman & Jurgec, 2018)
  - Learnability of these patterns
    - Has implications for our models of phonological learning, and the relationship between phonotactics & alternations in the grammar

Goals for today’s talk

- Examine DEE patterns from two perspectives:

1) **How learnable alternations involved in DEEs relative to ‘across-the-board patterns?** (Chong, under revision)
   - What happens to learning when phonotactics mismatch alternations?

1) **How ‘productive’ are these patterns:**
   - Phonotactic ‘well-formedness’ of stem-internal sequences (Chong, 2019, *Phonology*)

Part I: Learning DEEs in the lab

DEEs – what this has to say about learning?

- Constraint-based models: **learning phonotactic knowledge assists learning of alternations** (Prince and Tesar, 2004; Jarosz, 2006; Tesar and Prince, 2007; Hayes 2004)
  - Shared mechanism - single constraint

- DEEs: **phonotactics mismatch the alternation.**
- **Prediction:** Alternation learning should be more difficult in DEEs

Broader aims – Bigger picture

- Experimental evidence supporting assumption that phonotactics aids alternation learning
  (cf. Pater & Tessier, 2006; Pizzo, 2015; Chong, 2016)

- Using DEEs as a way of examining the **broader question of how phonotactics and alternations interact in learning (grammar)** – able to keep alternation constant, just manipulating stem phonotactics

- If shared mechanism: expect DEEs should be harder

Learning in the lab

- Artificial Grammar Learning (e.g. Pycha at al, 2003; Wilson, 2006; Finley & Badecker, 2009; Kapatsinski, 2010; White, 2014)
  - Adult participants trained on a constructed languages
  - Allows for controlled manipulation of linguistic variables across different miniature languages
  - What is learnt? (or not learnt)
  - Good way of probing potential learning biases
  - Testing a question with adults before examining infants!

- Caveats

Artificial Grammar Learning

- Vowel harmony:
  - Vowel sequences have to agree in backness
  - Alternation pattern is learnable in the lab: (e.g. Pycha et al. ,2003; Finley & Badecker, 2009)
  - Static phonotatic pattern is also learnable in the lab: (Skoruppa & Peperkamp, 2011)

Artificial languages

- Consonants: [p, b, t, d, k, g, m, n]
- Vowels: [i, e, u, o]

Front (unrounded)	Back (rounded)
i	u
e	o

- Singular stems: ˈCVCV (e.g. [ˈbunu])
- Plural suffix: [-mu]/[-mi]

- In all languages, suffix alternated based on backness of the final vowel of the stem:
  - Sg: [ˈpime]~Pl: [ˈpimemi]
  - Sg: [ˈtonu]~Pl: [ˈtonumu]

Artificial languages

- All languages had 100% rate of alternations
- Languages differed in proportion of harmonic stems

Harmonic language		Semi-/Non-Harmonic language	
Sg: [bunu]	Pl: [bunu-mu]	Sg: [bunu]	Pl: [bunu-mu]
Sg: [pime]	Pl: [pime-mi]	Sg: [pime]	Pl: [pime-mi]

No non-harmonic stems	Sg: [boki]	Pl: [boki-mi]

- Total of 32 singulars in each language

Artificial languages

	'Non-harm.'	'Semi-harm.'	'Harmonic'
Alternations:			
No. of harmonizing stems	**32 (100%)**	**32 (100%)**	**32 (100%)**

Stem phonotactics:			
No. Harmonic stems	**16 (50%)**	**24 (75%)**	**32 (100%)**
No. non-harmonic stems	16 (50%)	8 (25%)	0 (0%)

Procedure overview

Training Phase

Blick test – decide which word belongs to lg.

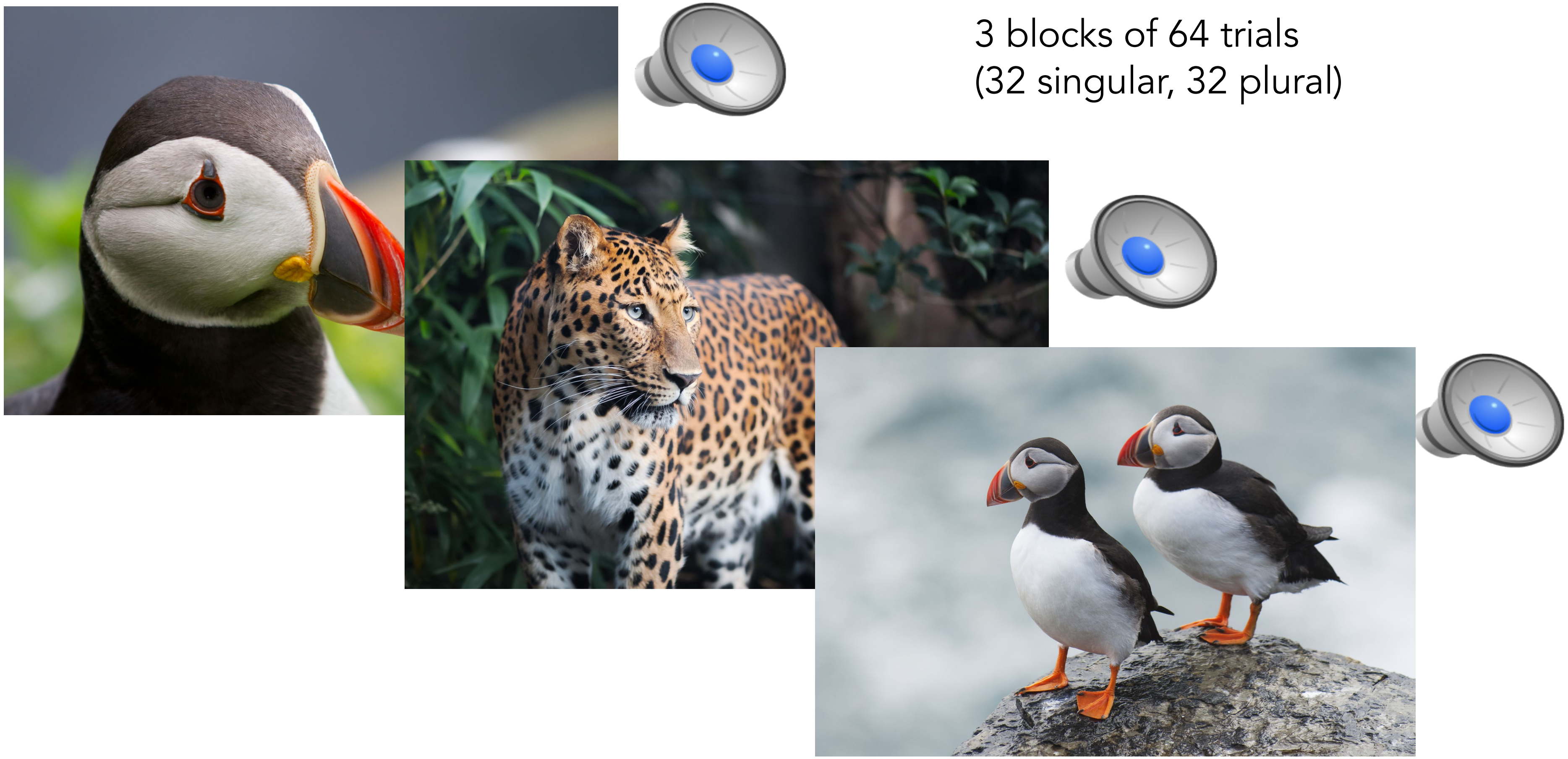
Wug test – decide correct plural

American English adults tested online in Experigen (Becker & Levine, 2014)

Stem phonotactics

Alternation

Training phase



3 blocks of 64 trials
(32 singular, 32 plural)

Blick test: Stem phonotactics
(Halle, 1978)

- 2-Alternative-Forced-Choice task (following Skoruppa & Peperkamp, 2011)
- Heard two possible (singular) words: One harmonic & one non-harmonic stems – with no accompanying images
  - e.g. [ˈgike] *vs.* [ˈgiko]

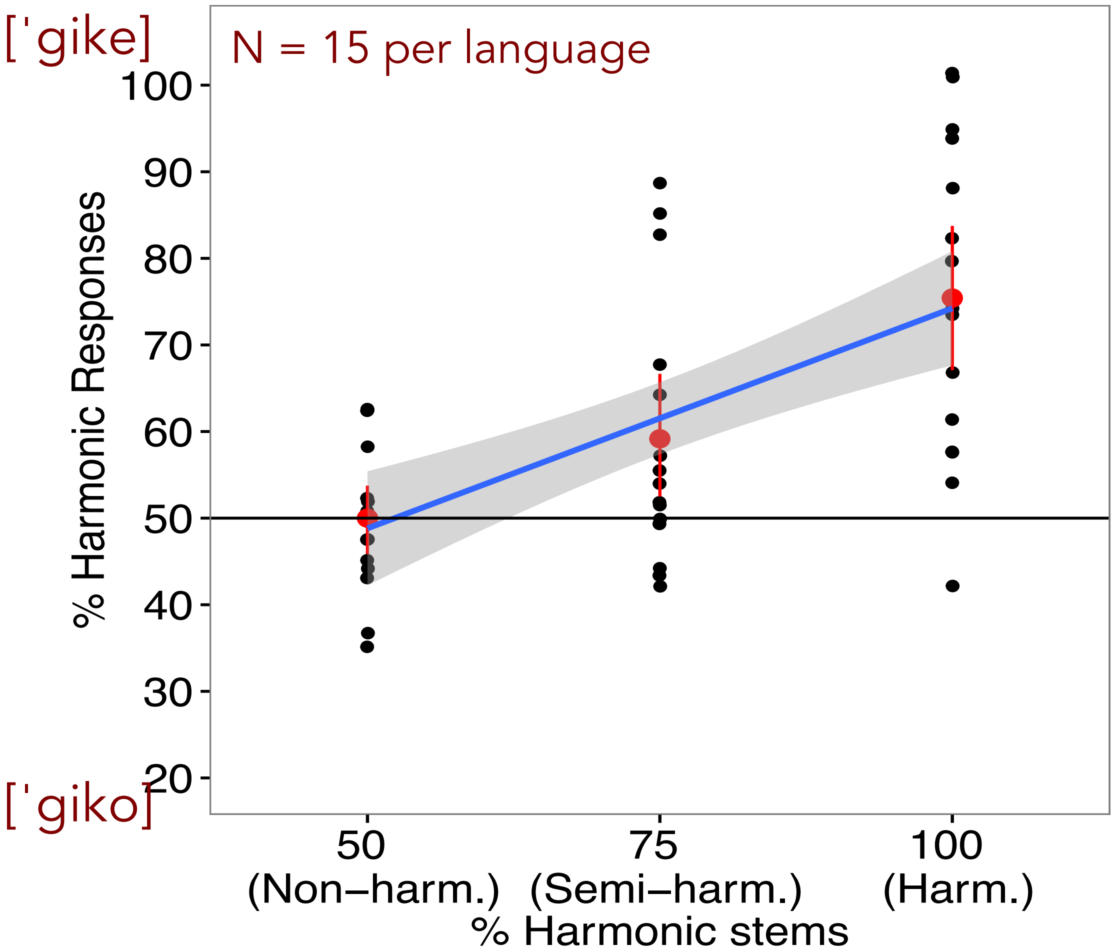

- Asked to decide which word belonged to the language they had just learnt
- 16 novel test pairs (singulars) created in the same way as training items

Blick test: Predictions

- Non-harmonic learners should not learn any phonotactic constraint
  - No strong preference in lexicon for harmonic words
  - **e.g. [ˈgike] = [ˈgiko]**

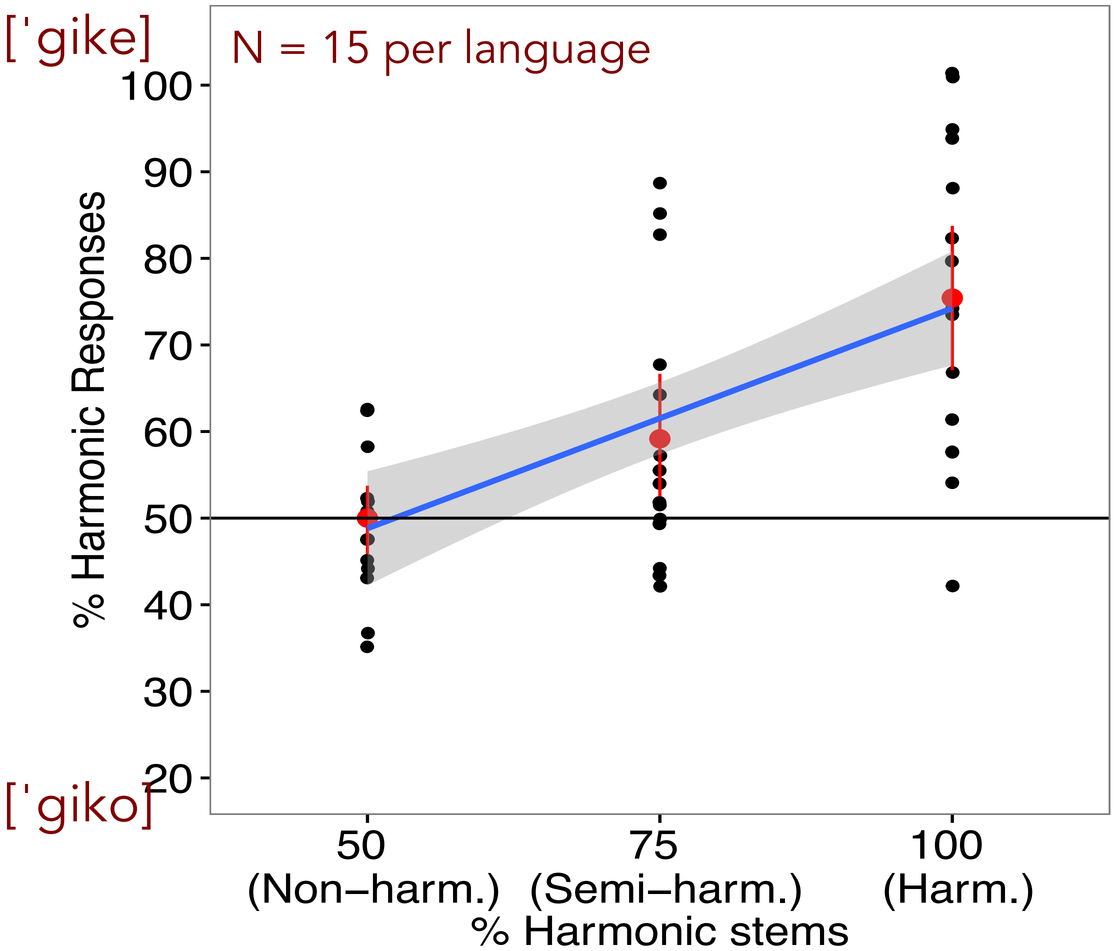
- Harmonic learners should infer some kind of phonotactic constraint
  - Should prefer harmonic words
  - **e.g. Prefer [ˈgike] over [ˈgiko]**

Results: Blick test - phonotactics



- Mixed-effects log. reg.:
  Rate of choosing harmonic word:
  - Linear Predictor =
    % Harmonic Stems (linear)
  - Categorical Predictor
- Harmonic learners inferred phonotactic constraint
- Non-harmonic learners showed no preference

Results: Blick test - phonotactics



- Basic manipulation works: different phonotactic learning outcomes
  - Though difference between Semi-H. and Non-H. not sig.

Wug test: alternations

(Berko, 1958)

[ˈkobo]

[ˈkobomi]

[ˈkobomu]

- Asked to pick the correct word
- 16 novel test words – all were harmonic singulars

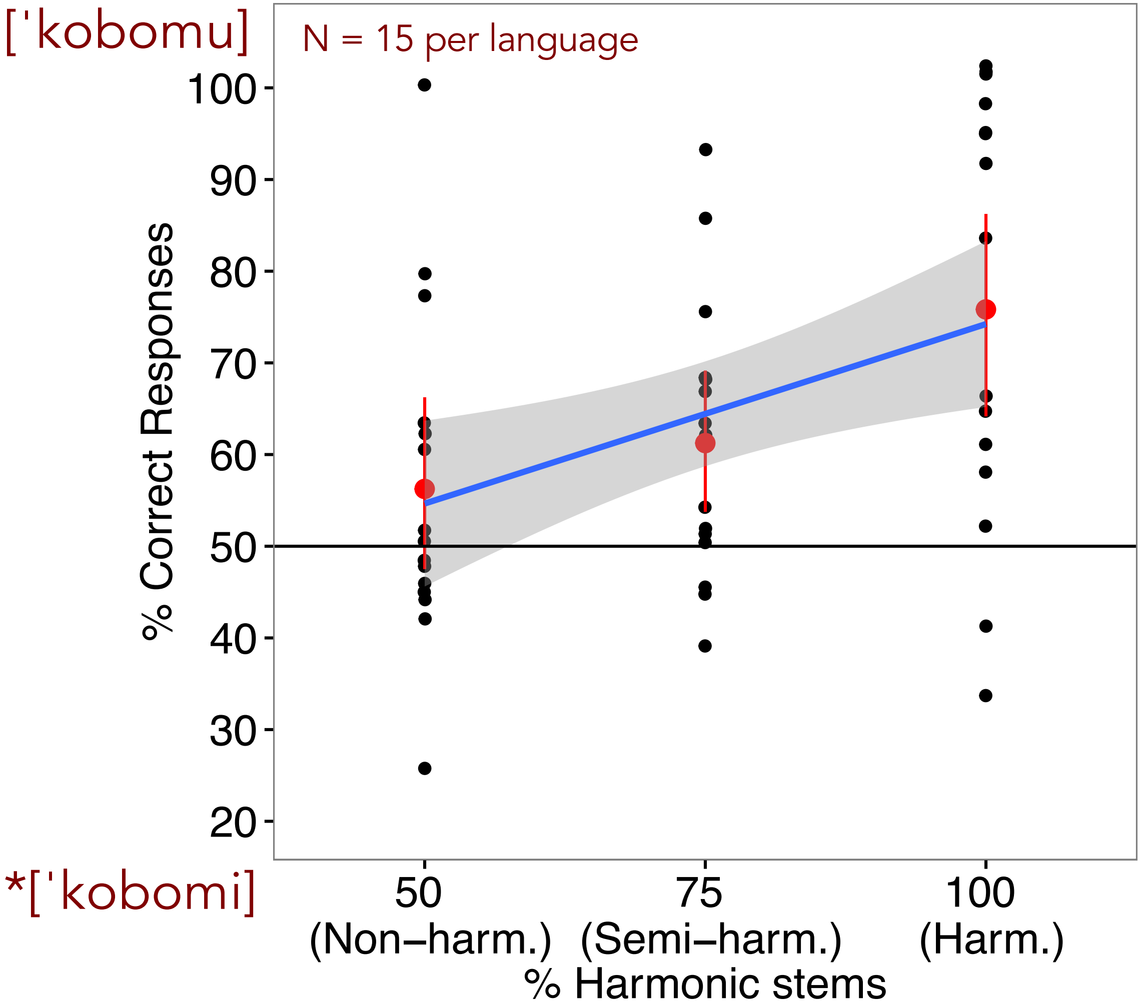
Wug test: Predictions

- 100% evidence for alternations in all languages
- Correct response is always harmonic plural (i.e. [ˈkobomu] (*[ˈkobomi])

1. If phonotactic and alternation learning are completely separate:
   - Learners in all languages should learn alternation equally well

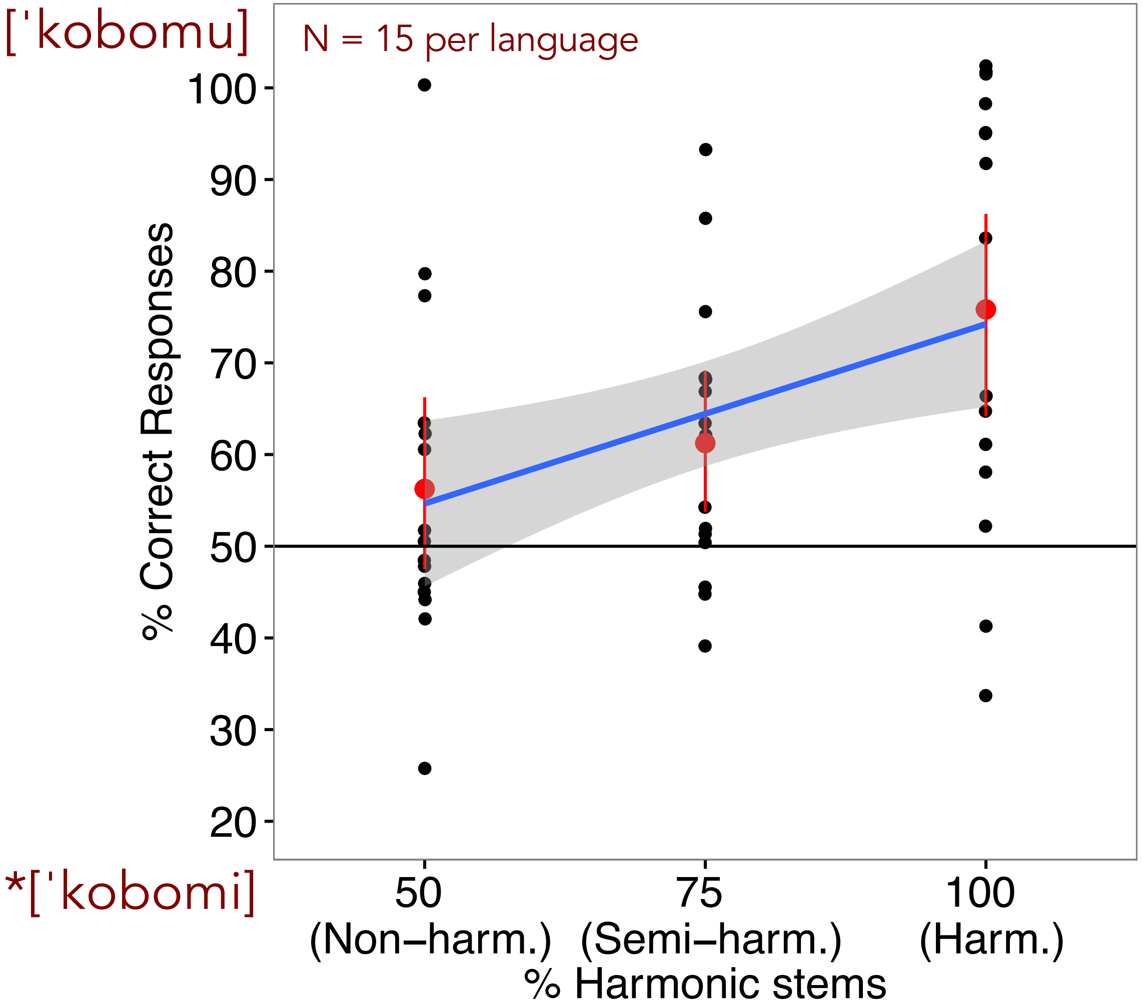
2. If phonotactic learning and alternation learning are linked:
   - Strength of alternation learning should mirror phonotactic learning

Results: Wug test - alternations



- Mixed-effects log. reg.: % Correct plurals selected
  - Linear Predictor = % Harmonic Stems (linear)
  - Categorical Predictor
- Harmonic learners learned alternation
- Non-harmonic learners did not learn the alternation

Results: Wug test - alternations



- 100% evidence for alternations across all languages
- Strength of alternation learning numerically proportional to harmonic stems in the lexicon
  - Difference between Semi-H. and Non-H. not sig.

Interim discussion

- Harmonic language learners learnt a phonotactic constraint and successfully learnt the phonological alternation

- Non-harmonic language learners did not learn a phonotactic constraint (as expected)
  - More importantly did not learn the phonological alternation

Interim discussion

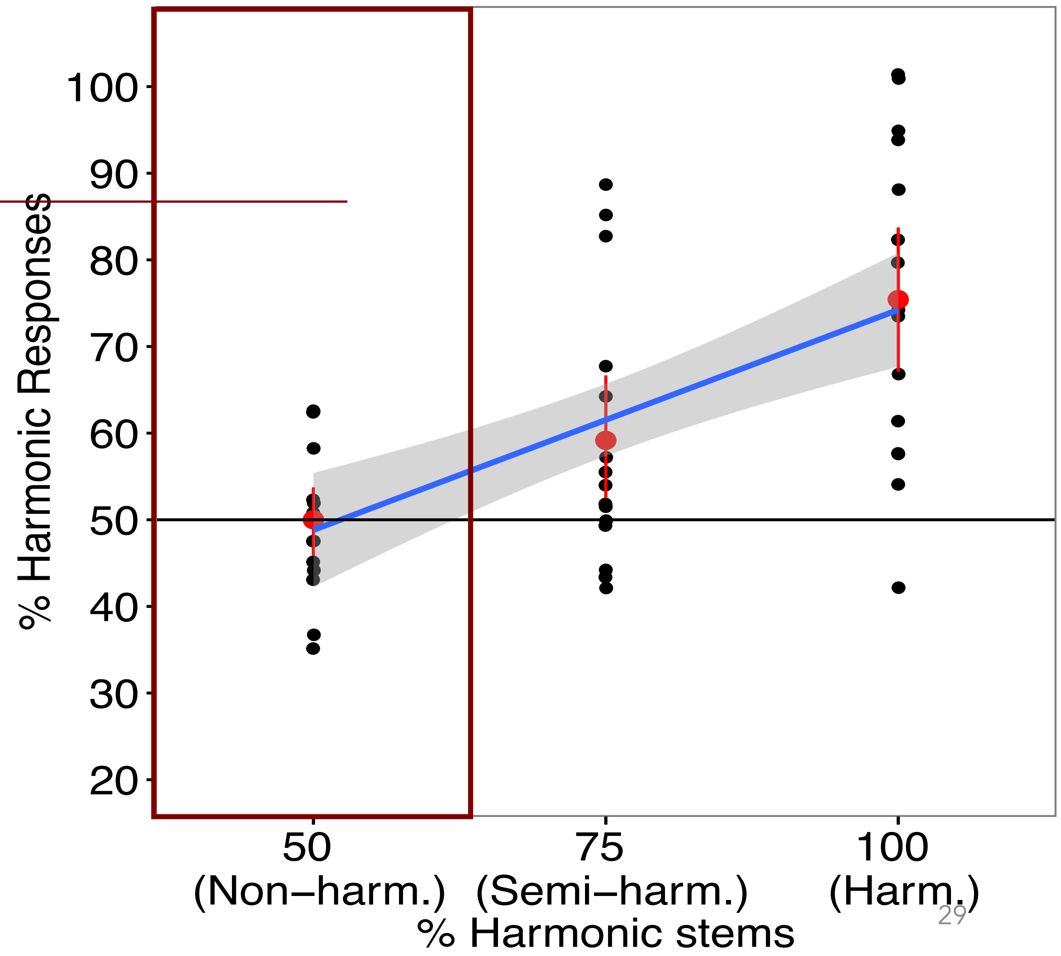
- Results suggest alternations in **DEE patterns (the non-harmonic language) are harder to learn.**

- Results support the claim that there is a **close relationship between phonotactics and alternation learning** (& in the grammar).

Mismatches in the wild

- But, these non-harmonic languages (i.e. DEEs) do exist!

1. Turkish Vowel Harmony
2. Korean Palatalization
3. Finnish assibilation…. Etc.



Part II: Looking more closely at DEEs

Another example: Korean

- Korean palatalization

(e.g. Kiparsky, 1973; Iverson & Wheeler, 1988; T. Cho, 2001; Y. Y. Cho, 2009):

Alternation across morph. boundaries:

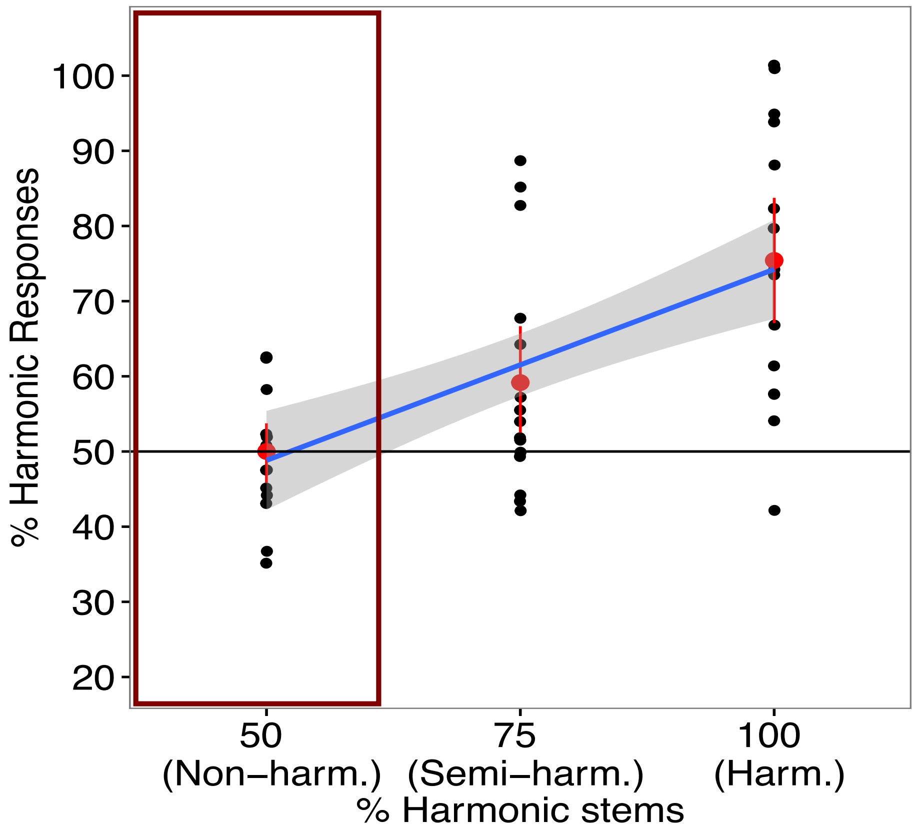
/t, t^h/ → [c, c^h] / __+[i, j] (i.e. *TI)

a. /mat-i/ → [maci] 'eldest-nom'
b. /pat^h-i/ → [pac^hi] 'field-nom'

But [ti] and [t^hi] are attested within stems:

a. /mati/ → [mati] 'knot, joint'
b. /t^him/ → [t^him] 'team'

Mismatches in the wild



- Korean alternation is productive (see Jun & Lee, 2007)
- How much of a mismatch is there between phonotactics and alternations?
- In Korean, are words with [ti] and [tʰi] completely phonotactically well-formed?

Korean corpus

- National Academy of Korean Language (NAKL; 2003) corpus
- ~53,000 commonly used Korean words
- Orthographically transcribed
- Includes native, Sino-Korean and loanwords

- Pre-processed: Kim et al 2002 algorithm
  - Splits up each syllabary into constituent jamos
  - Applies neutralizing phonological processes within words
    - Only if there's an existing orthographic character

Lexicon counts

- How frequent are words with TI (=[t,t^h,t*][i,j]) in the lexicon?
- Total > 53,000 words

CV type	Entire Lex.	Native	Sino-Kor.	Loans
[ti]	208	68	5	135
[t^hi]	167	30	4	133
[t*i]	32	28	4	0
[tjV]	14	5	0	9
[t^hjV]	15	4	4	7
[t*jV]	0	0	0	0
Total	436	135	17	284

Under-representation in the lexicon

- Observed vs. Expected: [Ti] vs. other CVs

O/E = Observed/Expected

	/i/, /jV/	other Vs	Expected % of Cs
/t, t^h, t*/	**454 (5,798)** **1.63% / 1.43%** **O/E = 0.08**	27,424 (22,073) 98.37% / 22.75% O/E = 1.24	18.31%
other Cs	31,247 (25,903) 25.12% / 98.57% O/E = 1.21	93,112 (98,672) 74.87% / 77.25% O/E = 0.95	81.69%
Expected % of Vs	20.82%	79.18%	

- Similar distribution in Child-Directed Speech (corpora: Ghim 2005, Ryu 2016)

Phonotactic learning simulation

- Is the under-representation of TI sequences in the corpus sufficient to learn a phonotactic constraint?
  (see Wilson & Obdeyn, 2009 on issues with relying solely on O/E calcs)

- Computational learning simulation
  - UCLA Hayes-Wilson Phonotactic Learner (Hayes & Wilson 2008)
    - Using weighted constraint models (no strict domination)
    - Maximum Entropy model (Goldwater & Johnson 2003)
    - Assess forms for phonotactic legality – only surface forms

What goes into the learner?

- Given a set of segments (and feature matrices), a data set as input:
  - Generates space of possible constraints based on natural classes
  - Algorithm selects constraints that maximize likelihood of the data
  - Final grammar then assigns a likelihood value (penalty/harmony score) to a given string
  - Quantitative prediction about phonotactic well-formedness
  - Higher weight → higher penalty (more important)

Learning data

- Trained learner on NAKL corpus:
  - Mostly uninflected forms – assuming no morphological parse
  - Contains derivational morphology
    - But: similar results with smaller monomorphemic corpus
  - Included native, Sino-Korean and loanwords
  - >53,000 words

- Used **type** frequency (Pierrehumbert, 2003; Richtsmeier, 2011) –
  - Each entry gets frequency of 1.

Model parameters

- Only considered simple bigram constraints
- Limited the total number of constraints: 180
  - Although the algorithm can stop before this if it cannot find any more constraints that satisfy the specified level of accuracy.
  - Usually stopped around ~130.
- Observed/Expected values: 0.30 (following Hayes & Wilson, 2008)
- Other settings: Default

Results: Phonotactic learning

- Sanity check:

No.	Constraint	Weight	Description
1.	*[-consonantal,-syllabic][-syllabic]	7.667	No glides before another consonant
2.	*[-consonantal,-syllabic][+word_boundary]	7.418	No glides word-finally
3.	*[+aspirated][+consonantal]	7.2	No aspirated stops before a consonant
4.	*[-sonorant][+consonantal,+sonorant]	7.159	No obstruents before a sonorant
5.	*[+aspirated][+word_boundary]	7.12	No aspirated stops word-finally

- Crucially: Assigns a penalty score of 1.86 to Tl forms
  - Compare: constraints against [θ], [θɹ] or [tw] onsets in English (Hayes & Wilson, 2008: 399) - indicates that these sequences are rare and that constraint is violable.

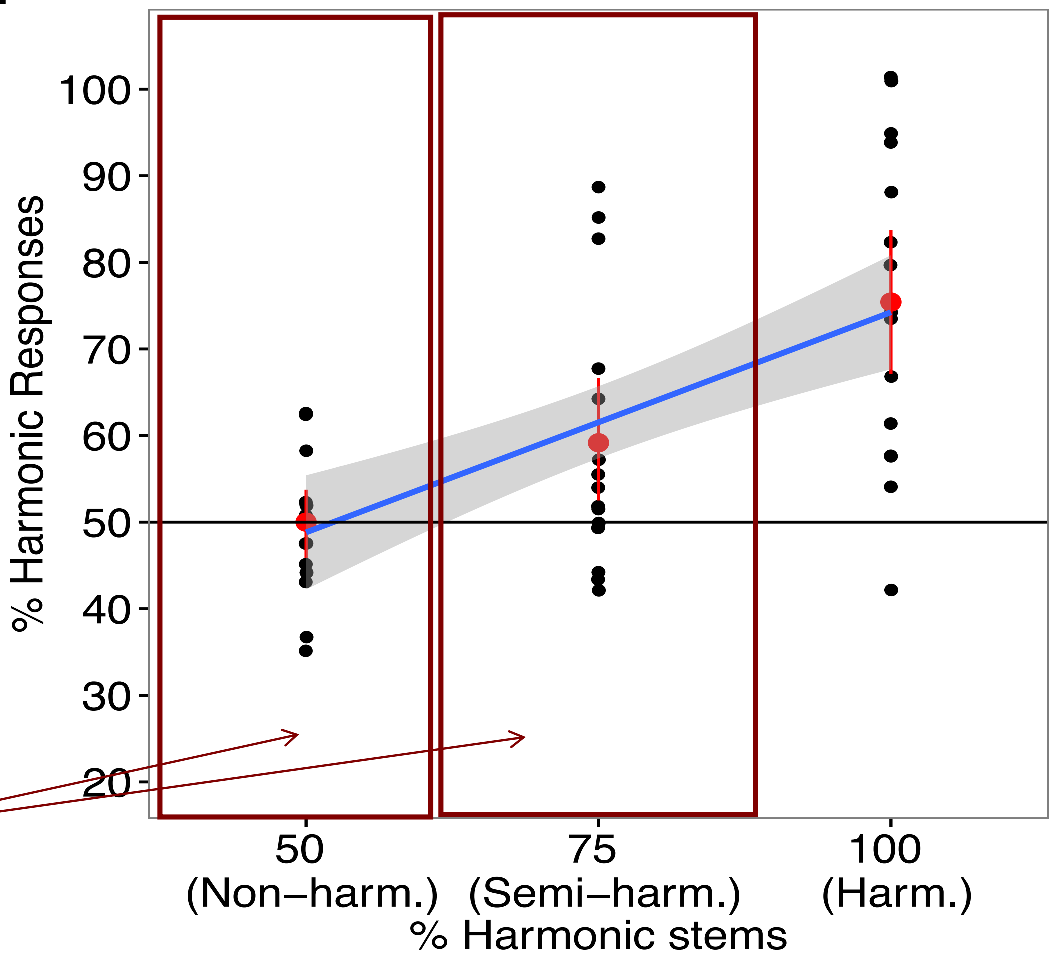
Gradient phonotactics in Korean

- Phonotactic Learner picks up on the under-representation
  - **Penalizes TI sequences that are involved in alternation**

- Empirical prediction: Korean speakers show gradient dispreference in a blick test – awaits testing!

- Having constraint against TI in place can then aid in learning the phonological alternation

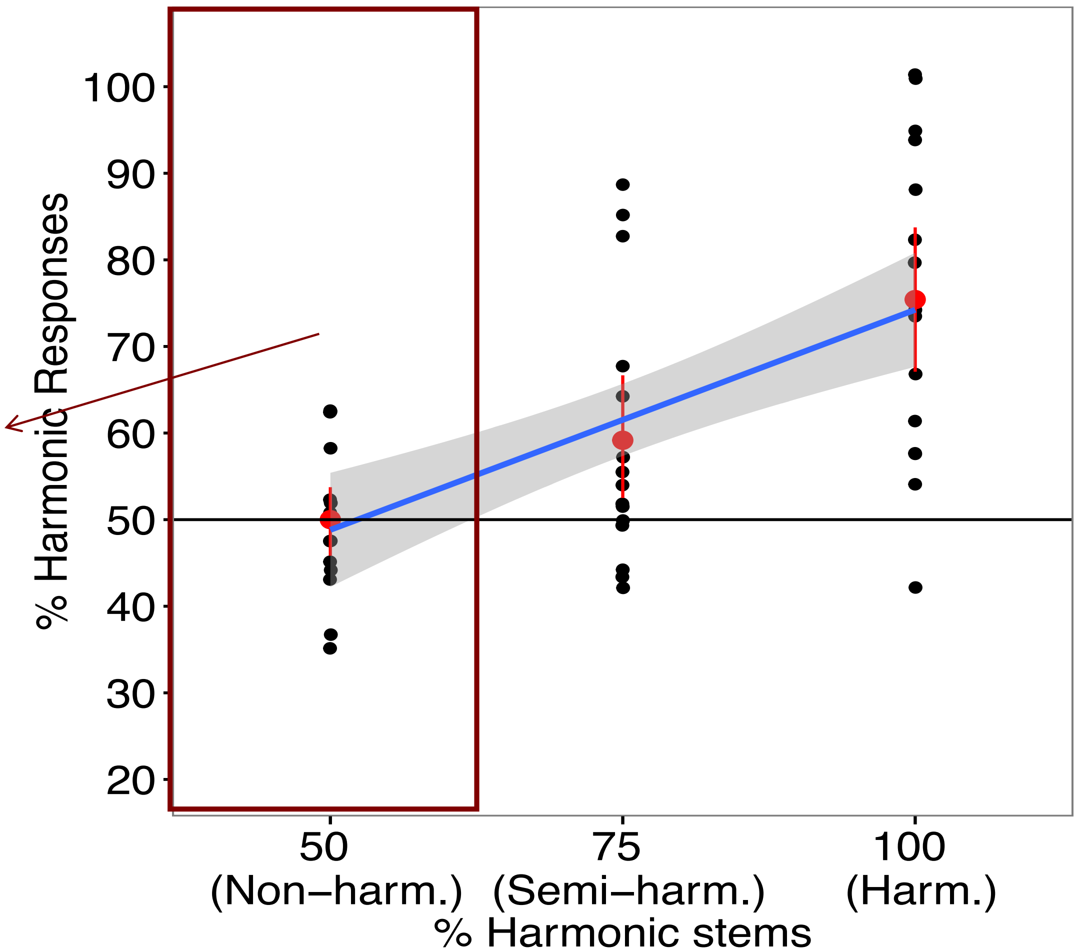
Gradient phonotactics in Korean



Korean Palatalization

Non-harmonic languages?

Turkish velar deletion



Another example: Turkish Velar Deletion

Suffix boundary velar deletion

(Lewis, 1967; Zimmer & Abbott, 1978; Sezer, 1981; Inkelas & Orgun, 1995; Inkelas, 2011)

$$/k, g/ \rightarrow \varnothing \;/\; V\_\_+V$$

a.	/bebek-In/	→	[bebein]	'baby-GEN'
b.	cf. /bebek/	→	[bebek]	'baby-NOM'

Deletion does not occur within stems (data from Inkelas, 2011)

a.	/hareket/	→	[hareket]	'motion'
b.	/sigorta/	→	[sigorta]	'insurance'
c.	/sokak-A/ 'street-DAT'	→	[sokaa]	'to the street'

Tl;dr: Turkish velar deletion

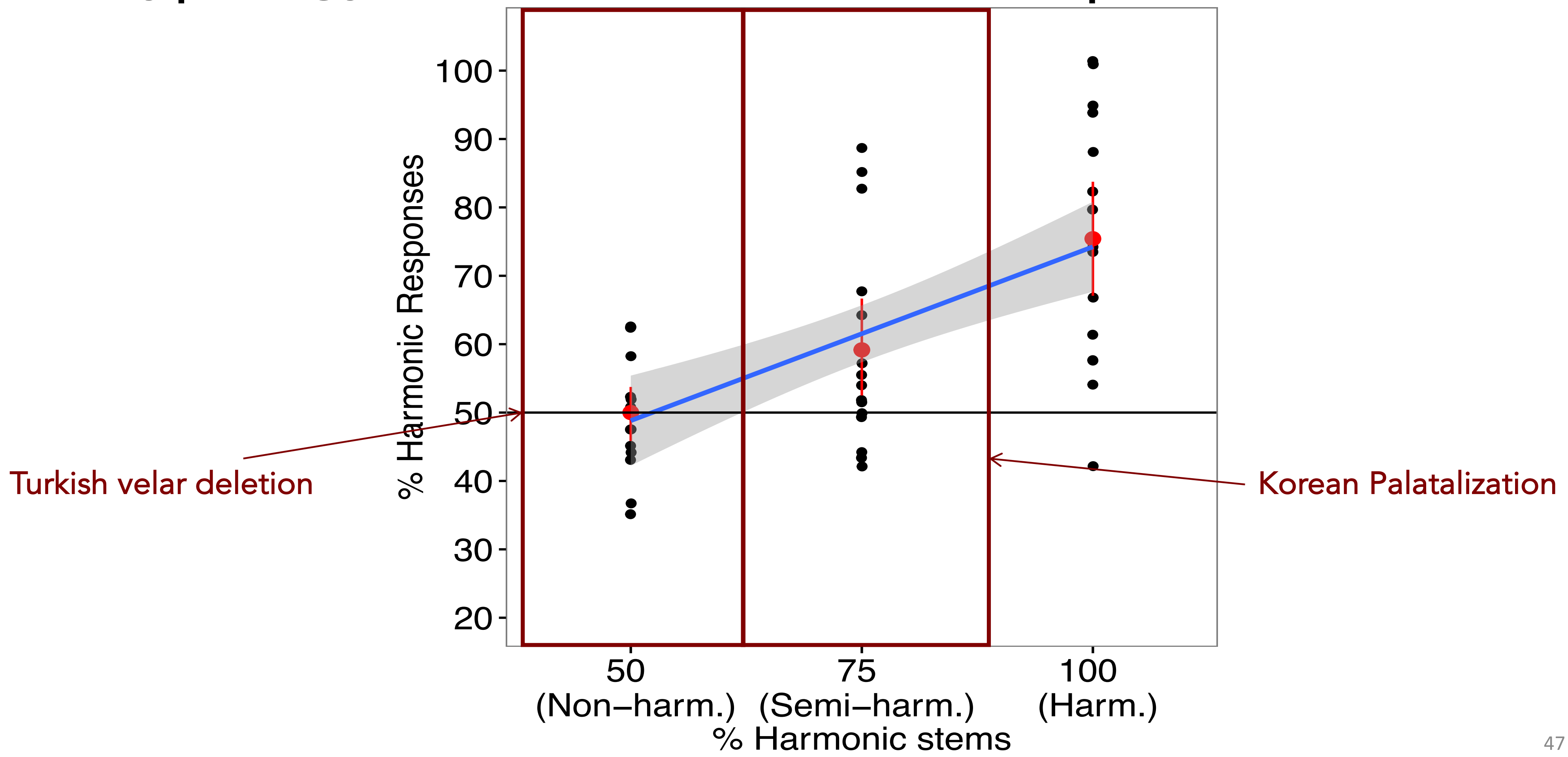
- Intervocalic velars are **not under-represented in the lexicon**
- Phonotactic learner **does not learn a markedness constraint** (e.g. *VKV) penalizing intervocalic velars

Turkish velar deletion: morphologically-conditioned

- Confined to polysyllabic nouns (Sezer, 1981; Inkelas, 2011):
  - Even here, alternation is variable (Becker et al., 2011)
  - Potentially different alternation rates dep. on suffix/root (Chong, 2019)
- Deletion does not occur:
  - With monosyllabic nouns
  - Verbs
  - When /k/ is suffix-initial

- Empirical prediction: Turkish speakers will show more constrained productivity for velar deletion beyond polysyllabic nouns (cf. Becker et al., 2011)

Typology of derived-environment patterns



Whither Derived-Environment Effects?

- Previous analyses of Korean palatalization and Turkish velar deletion miss the quantitative patterns in the lexicon

- Derived-environment patterns are **not a unified phenomenon**

	Phonotactic generalization	Alternation
Korean	Weak	Yes (Jun & Lee, 2007)
Turkish	No	Yes but morphologically-conditioned

Taking stock

1) How learnable alternations involved in DEEs relative to ‘across-the-board patterns? (Chong, under revision)

  - What happens to learning when phonotactics mismatch alternations?

- DEE patterns are more difficult to learn

2) How ‘productive’ are these patterns:

  - Phonotactic well-formedness of stem-internal sequences (Chong, 2019)

- Assumption does not always hold

Derived-environment effects: revisited

- Crucially, none really conform to classical notion of DEEs: 'perfect' mismatch between phonotactics and alternations (nor are they a single unified pattern)

- How do we account for the surface mismatch in phonotactics and alternation?
  - Use of Indexed Constraints (following Pater 2007)
  - Korean palatalization – **lexical exceptionality** (Chong, 2019)
    - **Exceptional non-undergoing** – indexed faithfulness
  - Turkish velar deletion – **morphologically-conditioned phonology** (Inkelas, 2011; Chong, 2019; see also Becker et al., 2011)
    - **Exceptional triggering** – indexed markedness

Problematic for the notion of MDEEs?

- How are these different from morphologically-conditioned phonology more generally? i.e. is there some special status as is often assumed? Are they just a 'spurious category'? (Bermúdez-Otero, 2018)
- Any analysis needs to account for these more nuanced patterns (cf. Rasin, 2016)

	Phonotactic generalization	Alternation
Korean	Weak	Yes (Jun & Lee, 2007)
Turkish	No	Yes but morphologically-conditioned
Finnish	No (Chong, 2017)	Yes but morphologically-conditioned (Anttila, 2006)
Turkish Vowel Harmony	Yes-ish (van Kampen et al., 2008; Hohenberger et al., 2016; Chong, under revision)	Yes (productively learnt by toddlers; Aksu-Koç & Slobin, 1985)

Implications for learning

- Upshot: DEE patterns are more difficult to learn.
- Predicted under a model in which phonotactic learning and alternation learning are inter-linked
  - Previously a prediction/assumption that lacked empirical support from learning expts. and L1 acq. (cf. Pater & Tessier, 2006; Pizzo, 2015; Chong, 2016)

Implications for learning

- Looking more at cases with mismatches between phonotactics and alternations likely fruitful avenue for elaborating on this

- Asymmetries in directionality?
  - Stem phonotactics but no active alternation amply attested (straightforwardly learnable; Gallagher et al. 2019)
    - Conservatism: also enforced through initial anti-alternation bias (Output-Output Faith)

  - Active alternation but no support from phonotactics
    - Overcome initial anti-alternation bias
    - Possibly posit (more complex; Martin 2011) structure-sensitive constraints

Implications for grammar

- Mechanisms for phonotactics and alternations cannot be completely independent

- Need a model that encodes a (learning) bias to maintain similar generalizations across both domains?
(see also Martin, 2011, Breiss & Hayes 2019; cf. Bermúdez-Otero, 2015)
  - Although adult learners don't extend a phonotactic gen. spontaneously to an unseen novel alternation (Chong, 2017, under revision)

Gradient phonotactics but categorical alternations?

- How exactly does gradient phonotactics influence categorical alternations?
  - Korean – although phonotactics are gradient, alternation is presumably categorical (complicated by lexical strata)

- What exactly happens in learning? (Moore-Cantwell & Pater 2017)

- What exactly is the relationship between frequency and productivity – likely not linear! (e.g. Coetzee, 2009; Moore-Cantwell & Pater, 2017)

Further questions

- How do morphology and phonology interact in infancy?
  - Trajectory/relationship in infant acquisition still unclear
  - Currently planning artificial grammar experiments – 8-10 month-olds

- How are domains (broadly conceived) for phonological generalizations learned from the input?
  - Morph. domains, Lexical strata etc.

Some final words

- Important to examine DEEs (and other such patterns) in more detail from multiple perspectives (learning, closer examination of the details of the pattern)

- More needs to be examined regarding the relationship between different types of phonological knowledge

Acknowledgements

- Discussion and feedback from Megha Sundara, Kie Zuraw, Bruce Hayes, Robert Daland, Sharon Peperkamp, Karen Jesney, Stephanie Shih, Sharon Inkelas, Ricardo Bermúdez-Otero as well as audiences at the UCLA Phonology Seminar group, UC Berkeley Phorum, USC Phonlunch, U. of Melbourne Phonetics Lab, U. of Manchester, U. Hawai'i, NYU, QMUL, AMP 2016 and LSA, 2016, 2017

- Audrey Kim for helping with initial piloting of experiment
- Eleanor Glewwe for recording stimuli
- Michael Becker (UMass) and Daniel Szeredi (NYU) for assistance with Experigen
- This research is funded by a UCLA Dissertation Year Fellowship.

Thank you!

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