

# Derived-environment effects and learning: An experimental study

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# Derived-environment effects

- Phonological alternations often reflect static phonotactic restrictions in the lexicon (e.g. Kenstowicz & Kissberth, 1977)
- But sometimes static phonotactic patterns mismatch with constraint that motivates alternations: non-derived environment blocking – (NDEB/DEE; e.g. Kiparsky, 1973, 1993)

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

(1) Suffixes agree with final vowel of stem in backness:

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

(2) But roots themselves can be disharmonic:

a.	takvim	'calendar'
b.	bobin	'spool'

# Learning derived-env. effects

- Constraint-based models: learning phonotactic knowledge **assists** learning of alternations (Prince and Tesar, 2004; Jarosz, 2006; Tesar and Prince, 2007; Hayes and Wilson, 2008)
- Predicts that phonotactic mismatch impedes alternation learning.
  - Derived-environment alternations should be more difficult to learn than across-the-board cases.
  - What is the relationship between phonotactic and alternation learning?

# Experiment 1

*Q: Are derived-environment alternations more difficult to learn?*

- Vowel harmony:
  - Alternation pattern is learnable in the lab: (e.g. Pycha et al. ,2003; Finley & Badecker, 2009)
  - Static phonotactic pattern is also learnable in the lab: (Skoruppa & Peperkamp, 2011)
  - Attested derived-environment pattern: Turkish
- Artificial Grammar Learning:
  - All languages had the same amount of evidence for alternations – 100% rate of alternations
  - Varied proportion of harmonic stems (i.e. amount of phonotactic evidence for alternation)

# Artificial languages

	Derived-Env.		Across-the-board
	'Non-harm.'	'Semi-harm.'	'Harmonic'
<u>Alternations:</u>			
No. of harmonizing stems	<b>32 (100%)</b>	<b>32 (100%)</b>	<b>32 (100%)</b>

<u>Stem phonotactics:</u>			
No. Harmonic stems	<b>16 (50%)</b>	<b>24 (75%)</b>	<b>32 (100%)</b>
No. non-harmonic stems	16 (50%)	8 (25%)	0 (0%)

- Harmonic: all stems were harmonic for backness/roundness
  - E.g. [ʌbunu]~[ʌbunumu], \***[ʌpume]~[ʌpumemi]** ([ʌpime]~[ʌpimemi])
- Non-harmonic and Semi-harmonic: some stems were non-harmonic
  - E.g. [ʌbunu]~[ʌbunumu], **[ʌpume]~[ʌpumemi]**

# Artificial languages

- Consonants: [p, b, t, d, k, g, m, n]
- Vowels: [i, e, o, u]
- Singular stems: 'CVCV (e.g. [!bunu])
- Plural suffix: [-mu]/[-mi]
  - In all languages, suffix alternated based on backness of the final vowel of the stem  
e.g. [!beme]~[!bememi], [!bunu]~[!bunumu]
  - Always an alternation at the morphological boundary
- Recorded a naïve phonetically trained female American English speaker
- Total of 32 singulars in each language

# Procedure overview

Tested online in Experigen (Becker & Levine, 2014)

1. Training Phase



2. Blick test – decide which word belongs to lg.

Stem  
phonotactics



3. Wug test – decide correct plural

Alternation

# I. Training phase

- Listeners were instructed that they were going to be learning words from a new language and that they didn't have to memorize any of the words
- Listeners heard singular and plural forms for a target word individually across different trials
  - Not presented side-by-side
  - No overt paradigmatic information
- Paired with images of objects (animals, everyday objects)
- 3 blocks of 64 training trials (32 singular, 32 plural)




# I. Training phase



# II. Blick test: Stem phonotactics

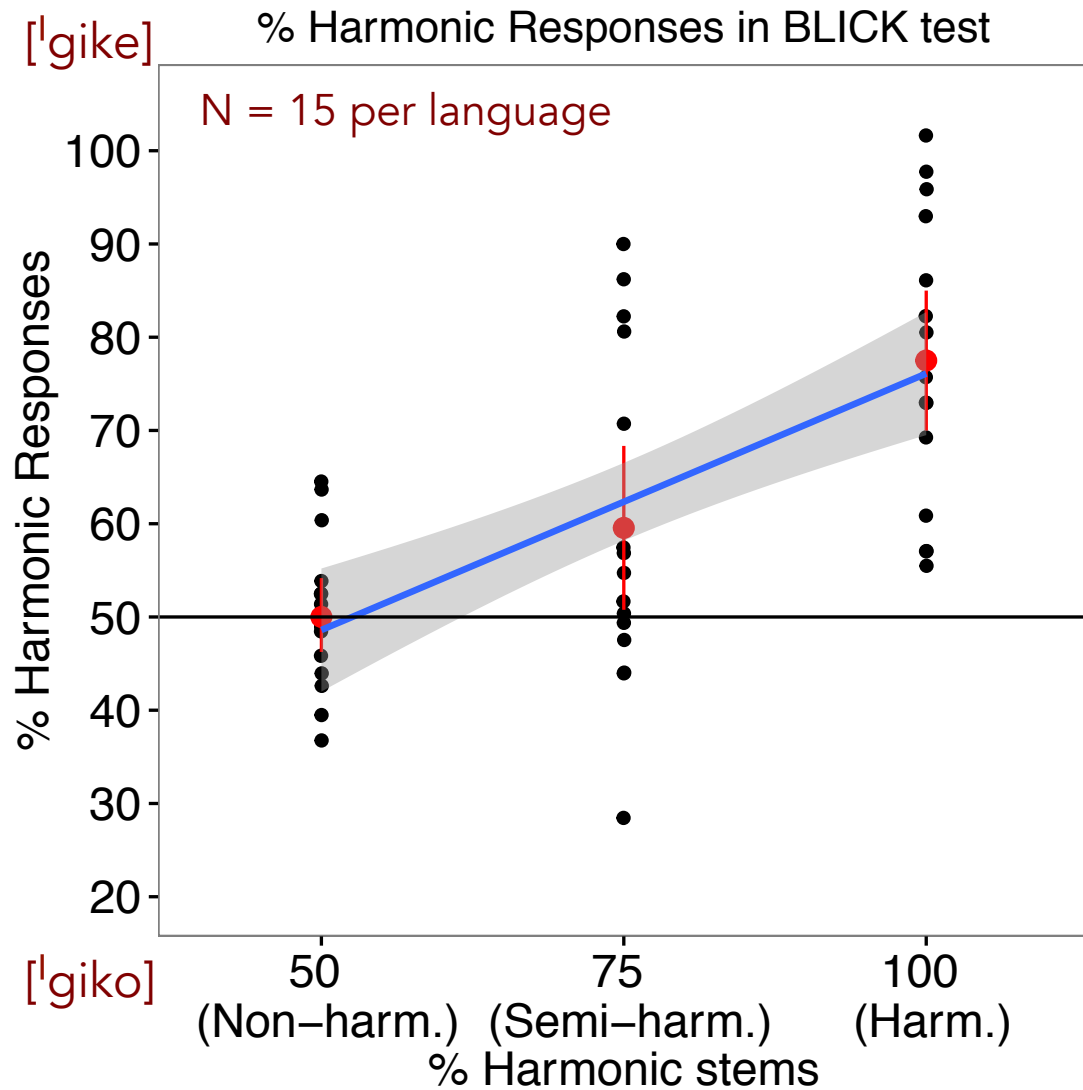
(Halle, 1978)

- 2-Alternative-Forced-Choice task (following Skoruppa & Peperkamp, 2011)
  - Heard two possible (singular) words: One harmonic & one non-harmonic stems
    - e.g. [gike] vs. [giko]
- 
- Did not see any images
  - Asked to decide which word belonged to the language they had just learnt
  - 16 test pairs (singulars) created in the same way as training items

# Blick test: Predictions

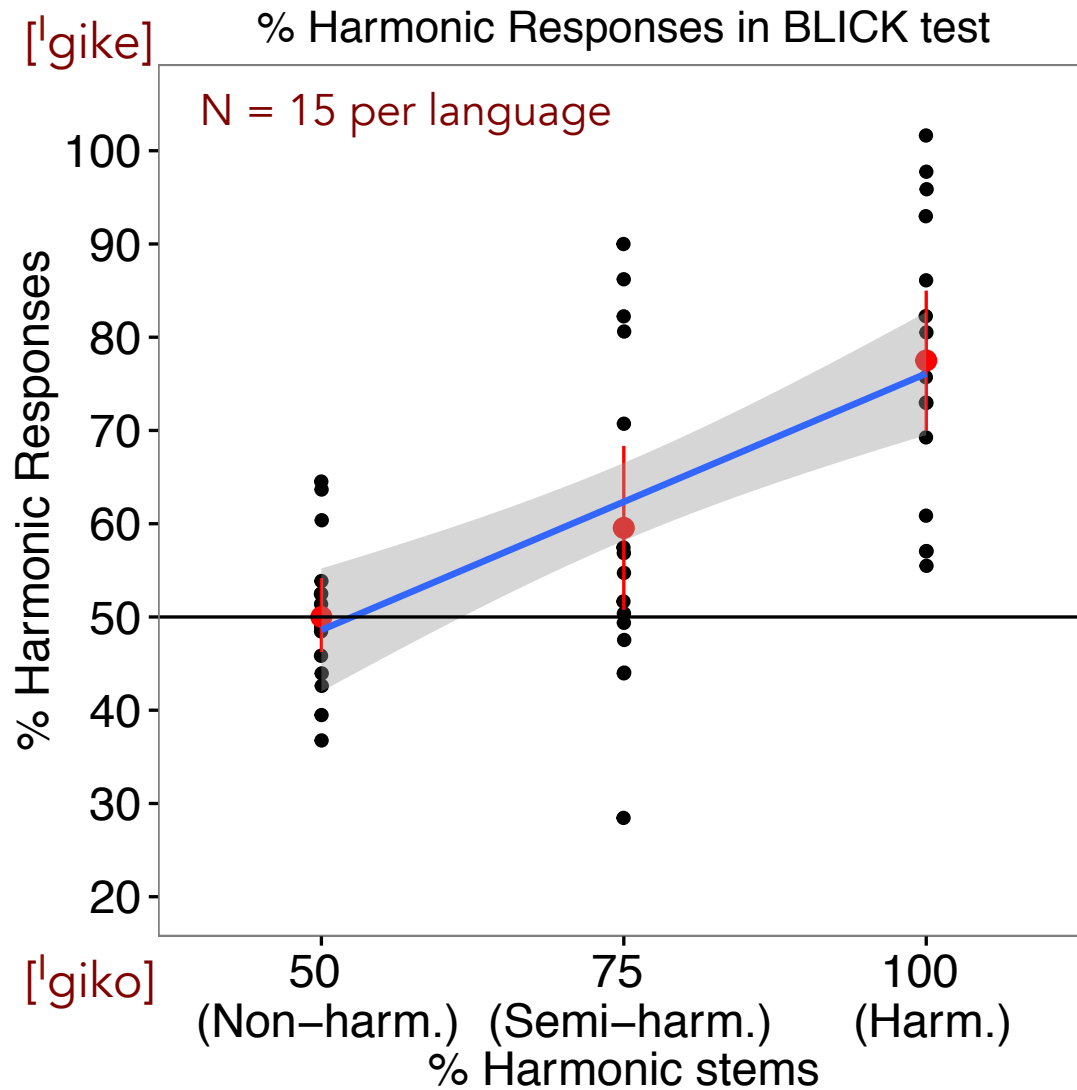
- Non-harmonic learners should not learn any phonotactic constraint – no strong preference in lexicon for harmonic words
  - Technically no correct response – both harmonic and non-harmonic forms are legal
- Harmonic learners only trained on harmonic stems – should prefer harmonic words (e.g. [ˈgike]) over non-harmonic ones like (e.g. [ˈgiko]).
- That is, the harmonic learners should infer some kind of phonotactic constraint.

# Results: Blick test - phonotactics



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

# Results: Blick test - phonotactics



➤ Rate of harmonic responses increases as % harmonic stems in lexicon increases

# III. Wug test: alternations

(Berko, 1958)

- Participants first heard a singular word (and saw singular image)
- Then they saw a plural image and heard two possibilities: [X-mu] or [X-mi]
- Asked to pick the correct word



[!kobo]



[!kobomi]



[!kobomu]

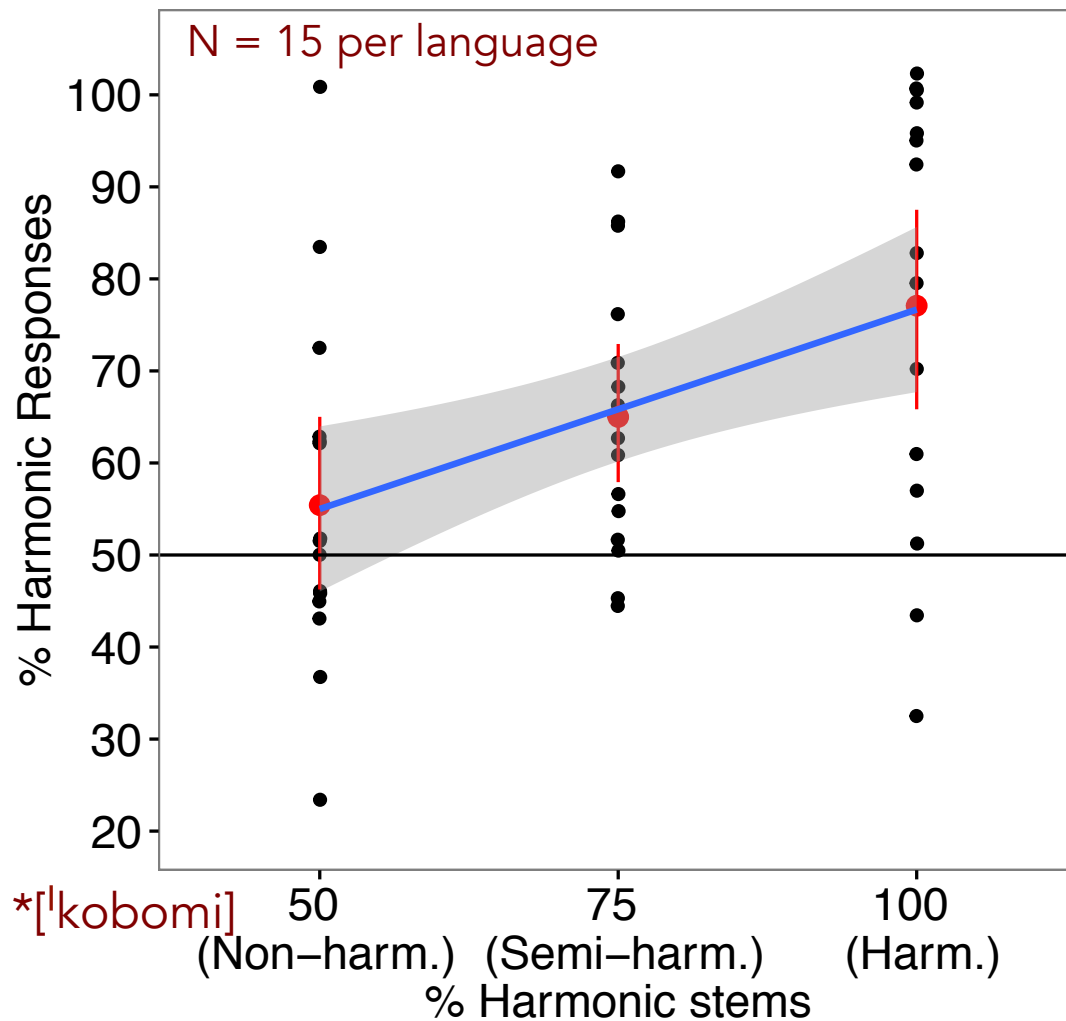
- 16 test words – all were harmonic singulars

# Wug test: Predictions

- Amount of evidence for alternations is the same in both languages
  - Correct response is harmonic plural (i.e. [!kobomu] (\*[!kobomi])
1. If phonotactic and alternation learning are completely separate:
    - Learners in ALL languages should learn alternation equally well
  2. If phonotactic facilitates alternation learning:
    - Strength of alternation learning might mirror phonotactic learning (blick test) – Harmonic learners the best, Non-harmonic learners the worst

# Results: Wug test - alternations

[!kɔbomu] % Harmonic Responses in WUG test

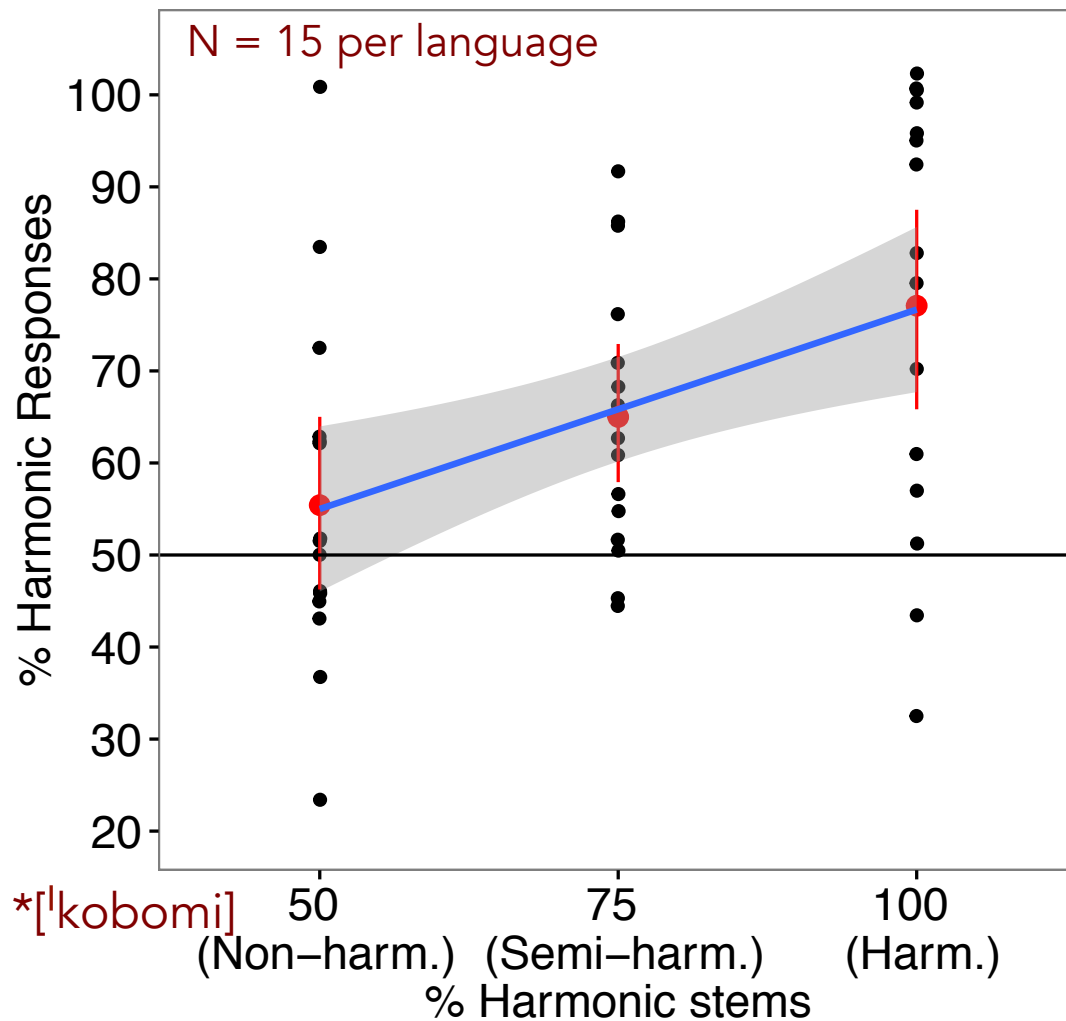


- Mixed-effects log. reg.:  
% Harmonic PLURALS selected
  - Linear Predictor =  
% Harmonic Stems (linear)
- Harmonic learners successfully learned alternation
- Non-harmonic learners did not learn the alternation



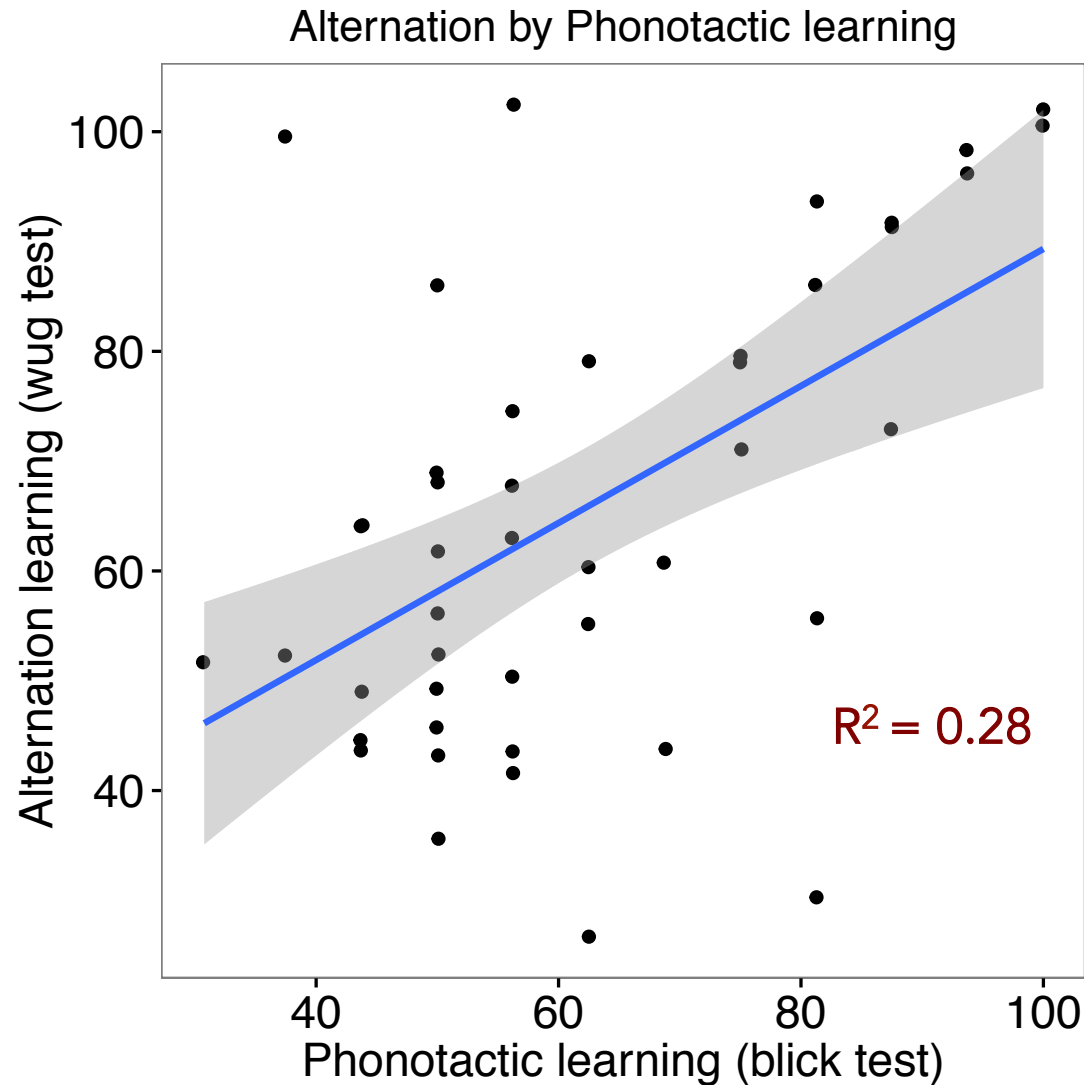
# Results: Wug test - alternations

[!kɔbomu] % Harmonic Responses in WUG test



- Same amount of evidence for alternations across all languages
- But, strength of alternation learning (pref. for harmonic plurals) dep. on % harmonic stems in the lexicon

# Relationship between phonotactics and alternations



- Significant **positive** correlation ( $r(43)=0.53$ ,  $p < 0.001$ ) between % of choosing harmonic responses in blick and wug tests
- Alternation learning is correlated with learning of phonotactic constraint

# Interim discussion

- Is a derived-environment alternation more difficult to learn?
  - Yes
- Harmonic language learners (Across-the-board):
  - Successfully inferred the phonotactic constraint AND
  - Learned the alternation the most successfully
- Non-harmonic learners (Derived-environment):
  - Did not learn the phonotactic constraint
  - Did not learn the alternation, despite evidence in training data

# Interim discussion

- All three languages had the same amount of evidence for the alternation
  - Exceptionless pattern – suffixes always alternated to agree with final vowel
- Only difference: % of harmonic bisyllabic stems
- If phonotactics and alternations are completely distinct:
  - Expected to find successful alternation learning regardless!
- Results are consistent with the conjecture that phonotactic mismatches impede alternation learning
  - Matching phonotactics facilitates alternation learning

# Interim discussion

- Phonotactic learning is gradient: Phonotactic learning (blick test) consistent with the lexical statistics in the input
  - Not surprising: speakers are sensitive to the lexical statistics – show gradient well-formedness (e.g. Frisch et al, 2004; Coetzee & Pater, 2008, a.o.)
- Gradient phonotactic learning → gradient alternation learning

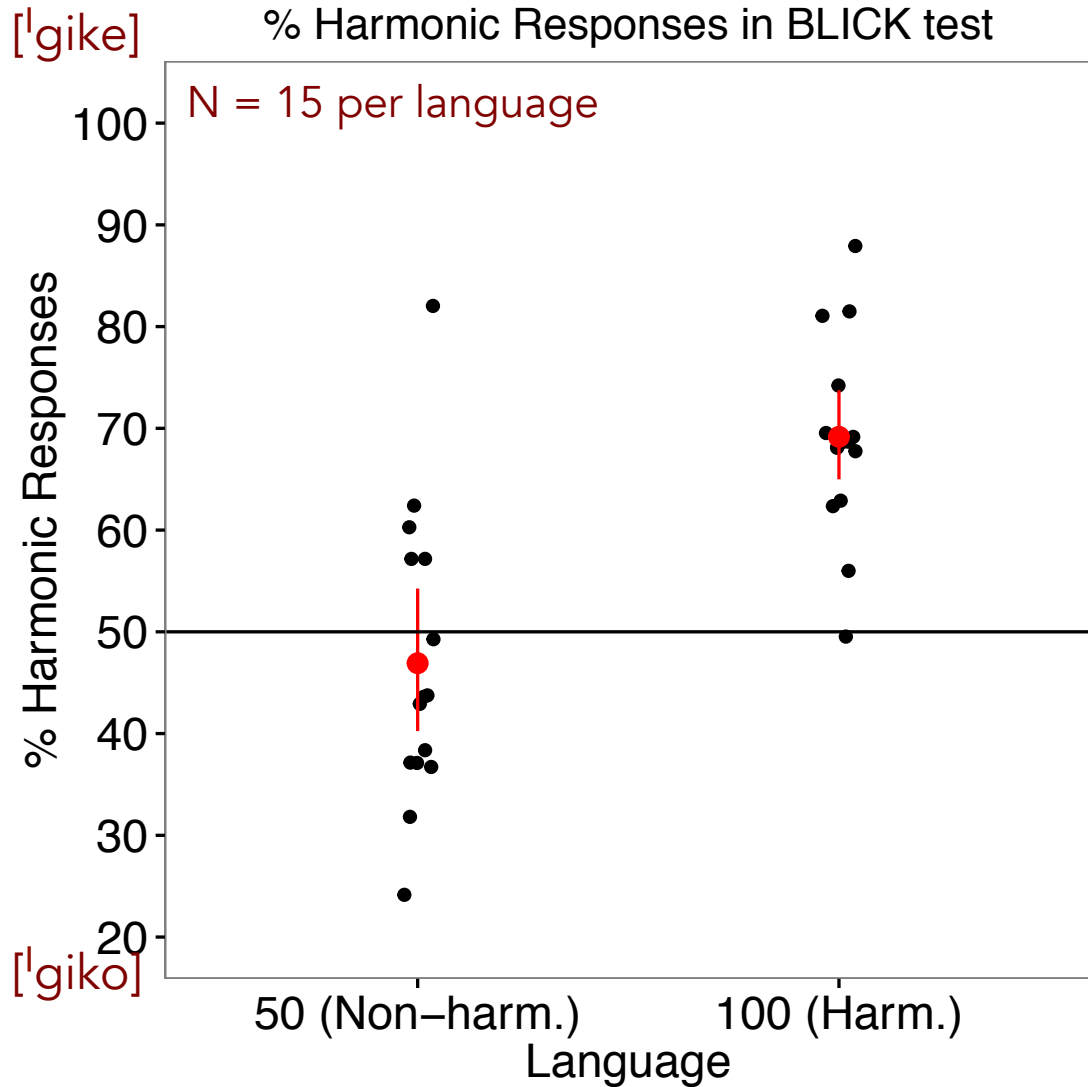
*Q: Do learners spontaneously expect alternations to reflect static phonotactic generalizations?*

- Strongest case for link between two types of generalization

# Experiment 2

- Training on only CVCV singulars with images:  
No plurals – Poverty of stimulus design
- Same Test Phases as in Expt. 1: Blick test followed by Wug test
- Do learners extend phonotactic generalization to unseen alternations?
- Only two languages: Harmonic (100% Harmonic) vs. Non-harmonic (50% Harmonic stems)
- To get the same amount of learning data as in Expt. 1, stems were repeated 6 times (for a total of  $32 * 6 = 192$  trials, as in Expt. 1)

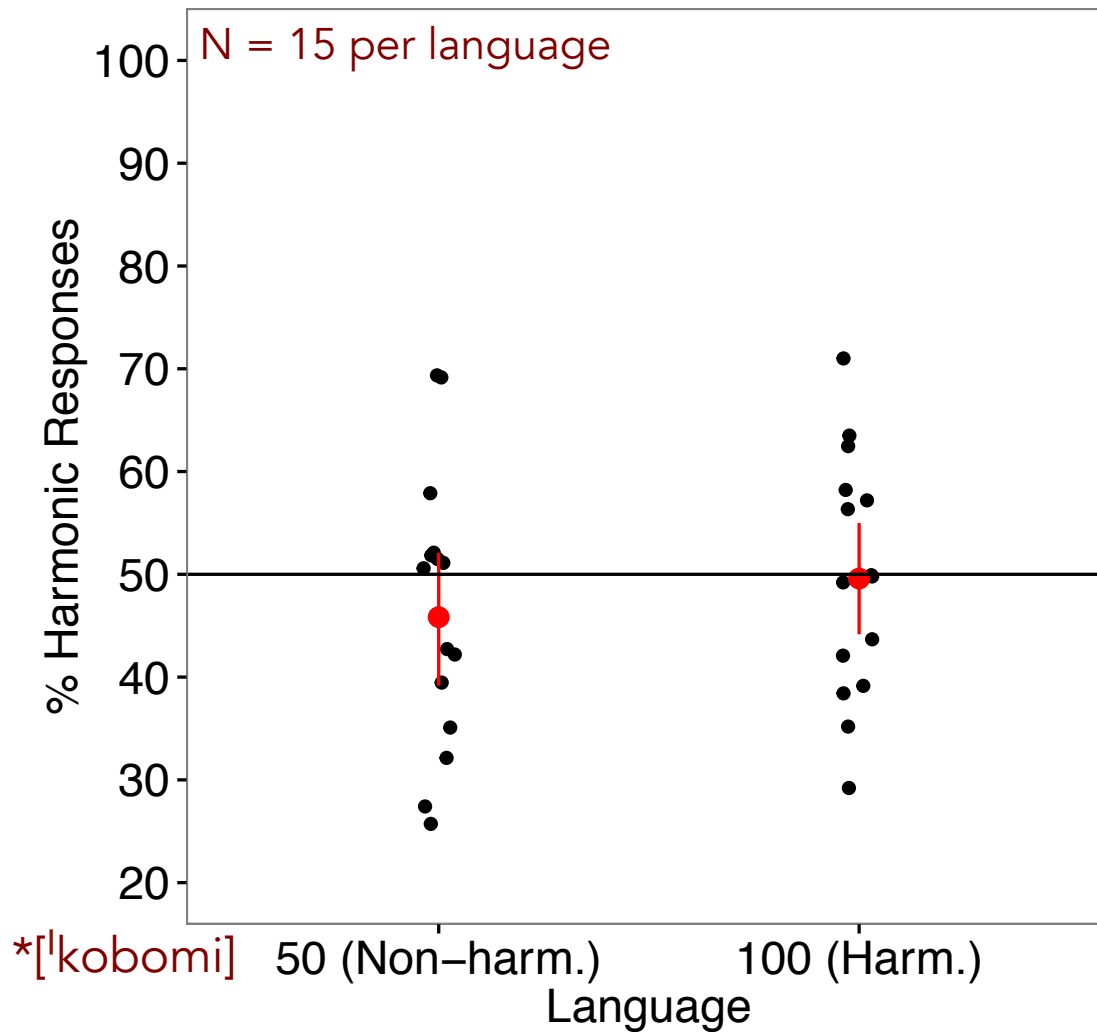
# Results: Blick test (phonotactics)



- Harmonic learners successfully inferred stem phonotactic constraint
- Harmonic learners chose harmonic words significantly more than Non-harmonic learners

# Results: Wug test (alternations)

[!kobomu] % Harmonic Responses in WUG test



- No differences in rate of choosing harmonic plural
- Learners in the Harmonic language did not extend phonotactic generalization to alternations



# Why lack of generalization?

- Learners are conservative in extending generalization
- Only heard bisyllabic CVCV singulars in training (no trisyllables)
- In the wug test, learners have to generalize to:
  1. Trisyllabic forms (plurals are all trisyllabic)
  2. Plural forms (new morphological environment)

Current follow-up - training on trisyllabic stems as well:

- If learners generalize to plurals:
  - Learners do expect alternations to reflect phonotactics, but
  - Need to have experience with relevant word types (syll. no.)
- But if they still fail to generalize to plurals:
  - Learners need explicit evidence for the alternation to learn it
  - But matching phonotactics still helps (Expt. 1)

# Phonotactics and alternations

- At first glance, learners are conservative in extending phonotactic generalization to unseen alternations (Expt. 2)
  - Unclear what exactly limits generalization
- A 'pure' derived-environment effect language (Non-harmonic) is more difficult to learn than an across-the-board one (Harmonic)
  - Mismatch phonotactics impedes alternation learning
- Alternations are easier to learn if supported by phonotactics
  - c.f. Pater & Tessier, 2005; Pizzo, 2015; Chong, 2016

# Phonotactics and alternations

- The degree to which an alternation is learned dep. on the strength of the phonotactic constraint in the lexicon
    - Gradient learning of phonotactics → gradient learning of alternation
  - In real derived-environment patterns: gradient phonotactics might facilitate in learning of alternation
    - Korean palatalization (Chong, *submitted*):
    - /t/ → [c] / \_+i, but [ti] sequences while attested in the lexicon, are significantly under-represented
    - Sufficient evidence for a gradient phonotactic constraint (\*ti) → might facilitate learning of alternation
- Overall, results support the basic conjecture that phonotactic learning facilitates alternation learning

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