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:

<table>
<thead>
<tr>
<th>Nom.sg</th>
<th>Nom.pl</th>
<th>Gloss</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. ip</td>
<td>ip-ler</td>
<td>‘rope’</td>
</tr>
<tr>
<td>b. sap</td>
<td>sap-lar</td>
<td>‘stalk’</td>
</tr>
</tbody>
</table>

(2) But roots themselves can be disharmonic:

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>a. takvim</td>
<td>‘calendar’</td>
</tr>
<tr>
<td>b. bobin</td>
<td>‘spool’</td>
</tr>
</tbody>
</table>
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

<table>
<thead>
<tr>
<th>Derived-Env.</th>
<th>Across-the-board</th>
</tr>
</thead>
<tbody>
<tr>
<td>‘Non-harm.’</td>
<td>‘Semi-harm.’</td>
</tr>
<tr>
<td>Alternations:</td>
<td></td>
</tr>
<tr>
<td>No. of harmonizing stems</td>
<td>32 (100%)</td>
</tr>
</tbody>
</table>

#### Stem phonotactics:

| No. Harmonic stems    | 16 (50%) | 24 (75%) | 32 (100%) |
| No. non-harmonic stems | 16 (50%) | 8 (25%)  | 0 (0%)    |

- **Harmonic**: all stems were harmonic for backness/roundness
  - E.g. [ˈbunu]~[ˈbunumu], *[ˈpume]~*[ˈpumemi] ([ˈpime]~[ˈpimemi])

- **Non-harmonic and Semi-harmonic**: some stems were non-harmonic
  - E.g. [ˈbunu]~[ˈbunumu], [ˈpume]~[ˈpumemi]
Artificial languages

• Consonants: \([p, b, t, d, k, g, m, n]\)
• Vowels: \([i, e, o, u]\)

• Singular stems: ‘CVCV (e.g. [ˈbunu])
• Plural suffix: [-mu]/[-mi]
  • In all languages, suffix alternated based on backness of the final vowel of the stem
e.g. [ˈbeme]~[ˈbememɪ], [ˈbunu]~[ˈbunumu]
  ➢ Always an alternation at the morphological boundary

➢ Recorded a naïve phonetically trained female American English speaker
➢ Total of 32 singulators in each language
Procedure overview
Tested online in Experigen (Becker & Levine, 2014)

1. Training Phase

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

3. Wug test – decide correct plural

Stem phonotactics
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. [ˈgike] vs. [ˈgiko]

• 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. [ˈɡike]) over non-harmonic ones like (e.g. [ˈɡiko]).

• 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

G-Graph: % Harmonic Responses in BLICK test

N = 15 per language

[gike]
[giko]

(Non-harm.) 75 (Semi-harm.) 100 (Harm.)

% Harmonic stems
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

  [ˈkobo]  [ˈkobomi]  [ˈkobomu]

• 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. [ˈkobomu] (*[ˈkobomi])

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

- 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

N = 15 per language

% Harmonic Responses in WUG test

% Harmonic Responses

% Harmonic Stems

Non-harm. (50)

Semi-harm. (75)

Harm. (100)

[ˈkobomu] [ˈkobomi]
Results: Wug test - alternations

- 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

N = 15 per language

[gike]  [giko]
Results: Wug test (alternations)

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

N = 15 per language

% Harmonic Responses in WUG test

% Harmonic Responses

Language

50 (Non-harm.) 100 (Harm.)

[kobomu] *[kobomi]
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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References

References


