Phonotactic Knowledge and the Acquisition of Alternations
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1. Background

- Alternations often serve to enforce phonotactic well-formedness by eliminating structures that are generally absent from the language:

  (1) Alternation                   Lexical Gap
  a. English /bæt + z/ → [bæts]    *tz# (word-final obstruents agree in voicing)
  b. Dutch /bɛd/ → [bet]           *d# (no word-final voiced obstruents)
  c. Lardil /yak/ → [yaka]         *#σ# (no monosyllabic words)

- This connection between alternations and static phonotactics was recognized by Chomsky and Halle (1968: 382):

  (2) ...regularities are observed within lexical items as well as across certain boundaries - the rule governing voicing of obstruent sequences in Russian, for example - and to avoid duplication of such rules in the grammar it is necessary to regard them not as redundancy rules but as phonological rules that also happen to apply internally to a lexical item

- The ‘duplication problem’ received considerable attention in subsequent research, and difficulties with the rule-based solution formed an early argument for the introduction of phonological constraints into generative theory (Kenstowicz and Kisseberth 1977, 1979)

- In Optimality Theory (Prince and Smolensky 1993), output constraints are used both to filter out ill-formed structures, and to induce alternations (see McCarthy 2002 for discussion)

- While there is much (unanimous?) agreement amongst phonologists that an adequate theory of phonology should deal with the duplication problem, it remains an open issue as to whether language learners/users employ a single mechanism to encode static phonotactics and to generate alternations

- The plausibility of treating alternations separately from phonotactics is enhanced by the fact that there are alternations like English velar softening (electri[k]~electri[s]ity) that serve no phonotactic ends (cf. rickety)

- Pierrehumbert (to appear) presents wug-test results showing that English speakers do have productive knowledge of velar softening

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Research question:

Are alternations that meet phonotactic targets easier to learn than alternations that don’t?

In recent OT learnability work, it has been claimed that learning static phonotactics is a useful first step toward learning alternations (Hayes to appear)

As far as we know, there is no empirical evidence bearing on this issue

2. Pilot Experiment

Naturalistic language acquisition will likely never afford the opportunity to compare two alternations that differ only in whether they are phonotactically motivated

Here we use artificial language learning to examine this variable, by comparing the learning of two languages: one with a phonotactically motivated alternation, and one with a non-phonotactically motivated alternation


2.1 The languages

English bans monosyllables whose rime consists only of a lax (short) vowel, possibly due to a minimal word constraint (McCarthy and Prince 1986/1996):

(4) a. *[bl], *[g], *[fl]
b. [blt], [blij], [g], [gk], [fluw], [flk]

Data from Moreton (1999) may be taken as evidence of English speakers’ knowledge of this restriction; listeners are more likely to identify a vowel that is ambiguous between [ij] and [I] as [ij] in the word-final context than in a context where both are permitted.

In English, this ban is a static generalization: it characterizes all words in the lexicon, but there are no alternations that repair sub-minimal words (cf. Lardil in (1))

Assuming that learners of a new language transfer their knowledge of their first language (i.e. final state of first language acquisition = initial state of second language acquisition), we use this gap as the basis for constructing the languages
• In both languages, the plural is marked with the morpheme /-so/
• In Language 1, epenthesis is used to avoid sub-minimal words:

(5) **Language 1**

<table>
<thead>
<tr>
<th>Root</th>
<th>Plural</th>
<th>Singular</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. /blṭ/</td>
<td>[blṭso]</td>
<td>[blṭt]</td>
</tr>
<tr>
<td>b. /gε/</td>
<td>[geso]</td>
<td>[get]</td>
</tr>
<tr>
<td>c. /fl√/</td>
<td>[fl√so]</td>
<td>[fl√t]</td>
</tr>
<tr>
<td>d. /blej/</td>
<td>[blejso]</td>
<td>[blejt]</td>
</tr>
<tr>
<td>e. /glek/</td>
<td>[glekso]</td>
<td>[glekt]</td>
</tr>
</tbody>
</table>

• In Language 2, epenthesis applies in a similar fashion, but after front, rather than lax vowels:

(6) **Language 2**

<table>
<thead>
<tr>
<th>Root</th>
<th>Plural</th>
<th>Singular</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. /brij/</td>
<td>[brijso]</td>
<td>[brijt]</td>
</tr>
<tr>
<td>b. /tej/</td>
<td>[tejso]</td>
<td>[tejt]</td>
</tr>
<tr>
<td>c. /wæ/</td>
<td>[wæso]</td>
<td>[wæt]</td>
</tr>
<tr>
<td>d. /zow/</td>
<td>[zowso]</td>
<td>[zow]</td>
</tr>
<tr>
<td>e. /nej/</td>
<td>[nejkso]</td>
<td>[nejk]</td>
</tr>
</tbody>
</table>

• If alternations are learned simply by pattern recognition and rule formulation, without reference to other phonological knowledge, these two languages should be equivalent:

(7) **Language 1:** \[ \emptyset \rightarrow t / \ V \quad \quad \# \]  
**Language 2:** \[ \emptyset \rightarrow t / \ V \text{-tense} \quad \# \]  

However, if English learners draw on their knowledge of the phonotactics of their native language, then learning language 1 should be easier than language 2.

• Learners of Language 1 would have an active constraint against the forms lacking epenthesis; they would have to learn the repair (fix the ranking of faithfulness constraints in OT terms)
• Learners of Language 2 would be faced with a more complex task, perhaps involving the creation of an “arbitrary” markedness constraint, as well as learning the repair

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1 For six of 14 subjects, epenthesis was triggered by back, rather than front vowels; the scores of these two groups does not differ significantly.
2.2 Methods

Materials

- Three sets of plural-singular pairs (nonce words in English) were created for each language
- There were twelve pairs for each set; the following are representative examples:

\[
\begin{array}{llll}
\text{Language 1} & \text{V-final roots (Alternating)} & \text{V-Final roots (Non-alternating)} & \text{C-Final roots} \\
\hline
\text{keso} & \text{kêt} & \text{blejso} & \text{blej} & \text{tretso} & \text{tret} \\
\text{glıso} & \text{glıt} & \text{lijso} & \text{lij} & \text{vejtso} & \text{vejt} \\
\text{y√so} & \text{y√t} & \text{pluwso} & \text{pluw} & \text{swijkso} & \text{swijk} \\
\end{array}
\]

\[
\begin{array}{llll}
\text{Language 2} & \text{V-final roots (Alternating)} & \text{V-Final roots (Non-alternating)} & \text{C-Final roots} \\
\hline
\text{lijso} & \text{lijt} & \text{vuwso} & \text{vuw} & \text{ruwkso} & \text{ruwk} \\
\text{blejso} & \text{blejt} & \text{trowso} & \text{trow} & \text{diytso} & \text{dijt} \\
\text{træso} & \text{træt} & \text{vaso} & \text{va} & \text{swijkso} & \text{swijk} \\
\end{array}
\]

- The words were spoken by a trained phonetician in carrier phrases, and edited out for presentation via computer over headphones
- Words were paired with picturable nouns (e.g. airplanes/airplane, trees/tree, balls/ball), which were displayed on the computer monitor

Testing and Training

- Subjects were native speakers of English, with no knowledge of a second language beyond high school level
- Recruited by advertisement/word of mouth, paid for participation
- Between-subjects design: each subject learned one of the languages

- The experiment consisted of training and testing phases interspersed with one another
- The subjects were seated in front of a computer screen, with headphones on

- In training, plural/singular pairs were presented by displaying the visual referents on the computer screen, while simultaneously playing the aural label over the headphones (first the plural, then the singular; subjects pressed a key to move on to the next pair)
- For the testing component, we followed Saffran et al. (1996) in using a forced choice task

(10) Example test trial

\[
\begin{array}{lll}
\text{audio:} & \text{X} & \text{A} & \text{B} \\
\text{visual:} & \text{apples} & \text{apple} & \text{apple} \\
\end{array}
\]

- Subjects had to choose between A and B as singular forms for X, choices always differed in the presence of the final consonant
- Subjects were only trained on half of the items, but tested on all of them
- The ‘novel’ test items allowed us to examine whether subjects had acquired the ‘rule’, rather than having simply memorized the items
The training and testing proceeded as follows

(11) a. Training, then testing (9 pairs)
    b. Training, then testing (9 pairs)
    c. Review of 18 from a. and b., then testing on all 36

• Each pair appeared 4 times in the training sessions (13 a,b.), and once in the review (13c.)²
• In testing, each pair appeared twice, with the correct answer once in ‘A’ and once in ‘B’

2.3 Results

• To date, we have tested 14 in Language 1, and 15 in Language 2
• Outliers were removed - 3 from Language 1, 1 from Language 2³
• Results from the final test block (mean and standard deviation):

(12) Performance on all trained and novel items in final test block

<table>
<thead>
<tr>
<th></th>
<th>Language 1</th>
<th>Language 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(n=11)</td>
<td>(n=14)</td>
</tr>
<tr>
<td>Trained items</td>
<td>0.94 (0.05)</td>
<td>0.96 (0.06)</td>
</tr>
<tr>
<td>Novel items</td>
<td>0.74 (0.06)</td>
<td>0.66 (0.14)</td>
</tr>
</tbody>
</table>

• Both groups did well on the trained items; this may simply indicate that they were able to memorize the correct singular form

On the novel items, the subjects learning the phonotactically motivated alternation of Language 1 did better than those in Language 2.
A single tailed t-test assuming unequal variance finds the between groups difference on the novel items to be significant (t(18) = 2.24, p < 0.02)

• These results suggest that phonotactic knowledge (or naturalness) does indeed play a role in the learning of alternations
• There is a potential confound, however: phonotactic knowledge itself!

The Possible English Confound
• In the Language 1 condition, subjects could respond correctly to the alternating on the basis of what is allowable in English.
• In choosing between [gə] and [gət] as the singular of [gəso] the correct [gət] is also the one that is well-formed in English.
• Thus, one might speculate that the two groups did equally well in learning the alternation, but that learners of Language 1 responded correctly more often because they sometimes based their decision on what was well-formed in their native language.

² The first 6 subjects in each condition heard each word only 3 times in training. The slight increase in training for the last subjects did not improve the scores significantly.
³ The decision to remove outliers resulted in slightly decreased statistical significance; a t-test with all subjects included has p < 0.01
Predictions of the confound

- Under this alternative explanation, the learners of Language 1 should only outperform Language 2 on the alternating roots, and not on the non-alternating ones.
- In both languages, the two choices for non-alternating singulars are both well-formed in English – see the A and B columns below:

(13)  *Sample trials for non-alternating root types*

<table>
<thead>
<tr>
<th></th>
<th>X</th>
<th>A</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>NonAlt-V</td>
<td>[vuwso]</td>
<td>[vwu]</td>
<td>[vuwt]</td>
</tr>
<tr>
<td>NonAlt-C</td>
<td>[swijkso]</td>
<td>[swijk]</td>
<td>[swij]</td>
</tr>
</tbody>
</table>

- The following figure graphs the mean proportion correct for each of the two language groups for the three different root types (alternating, non-alternating vowel-final and non-alternating consonant-final). Error bars indicate 95% confidence intervals.

(14)  *Performance on different root types in final test block*

- Subjects learning Language 1 did in fact do better on all root types.
- Poor performance on the non-alternating roots indicates that the learners were incapable of correctly determining the nature and scope of the alternation.
- It seems that this was more of a problem for learners of Language 2 than Language 1, though this conclusion is still tentative, given that the between group differences within root types do not reach significance.
- While it thus appears that we will be able to rule out this alternative explanation, it would be desirable to completely avoid this potential confound in future research.
3 Conclusions and directions for further research

| These results suggest that the learning of alternations is not done by raw observation of changes to morphemes, but is instead mediated by other phonological knowledge |

• Our current hypothesis is that knowledge of native language phonotactics is the source of the difference between Language 1 and Language 2
• This supports the position that phonotactics and alternations stem from a common source
• One might still treat phonotactics and alternations separately, but it would then be necessary to specify how knowledge of phonotactics is transferred to learning of alternations

• However, there are two other possible types of phonological knowledge that could be playing a role; in future research we aim to test the relative contributions of these and phonotactics:

(15) i. Relative salience of contrasts
Language 1 could be easier because the tense/lax contrast is more salient than back/front

ii. ‘Naturalness’ of alternations
Language 2 might be harder because the alternation is unnatural (see Schane et al. 1974, Nowak et al. 2003, Wilson 2003); no language closes off open front-voweled syllables with an epenthetic consonant

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