Phonotactic Knowledge and the Acquisition of Alternations

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ABSTRACT

Phonological alternations often serve to modify forms so that they respect a phonotactic restriction that applies across the language. For example, the voicing alternation in the English plural produces word-final sequences that respect the general ban against a voiceless obstruent followed by a voiced one. Since Chomsky and Halle [1], it has been assumed that an adequate theory of phonology should capture the connection between phonotactics and alternations by deriving them using a shared mechanism. There is, however, no psycholinguistic evidence that speakers actually do use a single mechanism to encode phonotactics and alternations. In this study, we used an artificial language learning experiment to test whether an alternation that meets a phonotactic target is easier to learn than one that does not. The initial results suggest that phonotactic knowledge does aid in the acquisition of alternations.

1. INTRODUCTION

Alternations often enforce phonotactic well-formedness by eliminating structures that are generally absent from the language. This connection between alternations and static phonotactics was recognized by Chomsky and Halle [1]:

(1) ...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 (p. 382)

Subsequent research cast doubt on the viability of a purely rule-based approach to the duplication problem, and this became one of the early arguments for the introduction of constraints into phonological theory (see esp. [2, 3]). In Optimality Theory [4], the duplication problem is avoided by deriving phonotactics and alternations from a single set of constraints [5, 6].

While there is much agreement amongst phonologists that an adequate theory of phonology should deal with the duplication problem, it remains an open issue whether language learners/users do use a single mechanism to encode phonotactics and to generate alternations. There are alternations that serve no phonotactic aim, and there is evidence that learners do acquire productive knowledge of such alternations [7]. It is plausible that all alternations, even phonotactically motivated ones, are learned from raw observation of changes in the phonological structure of morphemes, without reference to any knowledge of related lexical regularities.

A single mechanism account, on the other hand, would seem to predict that phonotactic knowledge does aid in the acquisition of alternations. This is explicitly claimed to be the case in recent learnability work in Optimality Theory [5]. However, there appears to be no empirical evidence on this issue. This is not surprising, because it is unlikely that naturalistic language acquisition will ever afford the opportunity to compare two alternations that differ only in whether they are phonotactically motivated.

In this study, 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. The phonotactic motivation comes from the native language of the subjects, who were adult native speakers of English. We assume that second language acquisition involves creation of a new grammar, using the same resources as first language acquisition (though other cognitive strategies may be used as well). One major difference, however, is that the initial state of second language acquisition is the final state of first language acquisition. This is useful in the present context, because it allows us to make use of phonotactic properties of the subjects' native language in constructing the artificial languages.

English bans monosyllables whose rime consists only of a lax (short) vowel, possibly due to a minimal word constraint [8]. Thus, forms like those in (2a) are ill-formed, in contrast with those in (2b).

(2) a. *[blɪ], *[gɛ], *[flʌ]
b. [blɪt], [blij], [gej], [gɛk], [fluw], [flʌk]

There is some evidence that English speakers have productive knowledge of this restriction [9]. 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.

Since there are no alternations in English that repair sub-minimal words like those in (2a), we can address our research question by determining whether English speakers are able to learn such an alternation more readily than a comparable one that has no phonotactic purpose. The

alternation could augment sub-minimal words either by lengthening the vowel or adding an epenthetic consonant. We chose epenthesis, since vowel lengthening does occur elsewhere in English. The cross-linguistically most common epenthetic consonant is likely glottal stop, but because that would have been difficult to perceive, we chose the voiceless alveolar [t] instead, as used in languages like Axininca Campa [10, 11]

In both languages that we constructed, the plural is marked with a morpheme /–so/. In Language 1, epenthesis is used to avoid words that would be sub-minimal in English. It applies to avoid word-final lax vowels, as in the singulars in (3a-c), but not if the singular ends in a tense vowel (3d), or a consonant (3e):

(3) **Language 1**

	Root	Plural	Singular
a.	/blɪ/	[blɪso]	[blɪt]
b.	/gɛ/	[gɛso]	[gɛt]
c.	/flʌ/	[flʌso]	[flʌt]
d.	/blej/	[blejso]	[blej]
e.	/glɛk/	[glɛkso]	[glɛk]

In the other language, epenthesis applies in a similar fashion, but after back, rather than lax vowels (4a-c). It does not apply after front vowels (4d), or after consonants (4e):

(4) **Language 2**

	Root	Plural	Singular
a.	/fuw/	[fuwso]	[fuwt]
b.	/zow/	[zowso]	[zowt]
c.	/fɑ/	[fɑso]	[fɑt]
d.	/blej/	[blejso]	[blej]
e.	/gluwk/	[gluwkso]	[gluwk]

If alternations are learned simply by pattern recognition and rule formulation, without reference to other phonological knowledge, these two languages should be equally easy to learn. This is highlighted by the similarity between the following rules describing the alternations:

(5) **Language 1**: $\emptyset \rightarrow t \; / \; \underset{[-tense]}{V} \; \_\_\_ \; \#$

Language 2: $\emptyset \rightarrow t \; / \; \underset{[+back]}{V} \; \_\_\_ \; \#$

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

In terms of Optimality Theory, English-speaking learners of language 1 would only need to establish a ranking of faithfulness constraints that would choose epenthesis as a repair. The ranking of the relevant markedness constraint(s) (e.g. FOOT BINARITY; [4]) above faithfulness constraints would be given from a Markedness >> Faithfulness ranking bias [5, 12, 13]. Learners of language 2 would be faced with a more complex task. The exact nature of that task would depend on how "unnatural rules" are learned, since epenthesis following back vowels seems to be unattested cross-linguistically (see section 4 for further discussion). Under one account [14], they would have to construct a language-specific markedness constraint, and then fix its ranking with respect to the rest of the hierarchy, as well as establishing the ranking of faithfulness constraints.

2. METHODS

Three sets of plural-singular pairs (nonce words in English) were created for each language. Two sets were composed of vowel-final roots, which either induced alternations, or not. For each of the vowel categories (i.e. tense, lax, back, front) there were three vowels, with four instances of each. The other set consisted of consonant-final roots. There were twelve pairs for each set; the following are representative examples:

(6) **Language 1**

V-final roots (Alternating)		*V-Final roots (Non-alternating)*		*C-Final roots*	
[kɛso]	[kɛt]	[blejso]	[blej]	[trɛtso]	[trɛt]
[glɪso]	[glɪt]	[lijso]	[lij]	[vejtso]	[vejt]
[yʌso]	[yʌt]	[pluwso]	[pluw]	[vijkso]	[vijk]

(7) **Language 2**

V-final roots (Alternating)		*V-Final roots (Non-alternating)*		*C-Final roots*	
[vuwso]	[vuw]	[lijso]	[lij]	[ruwkso]	[ruwk]
[trowso]	[trowt]	[blejso]	[blej]	[dijso]	[dijt]
[vɑso]	[vɑt]	[træso]	[træ]	[vijkso]	[vijk]

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).

Subjects were native speakers of English, with no knowledge of a second language beyond high school level. They were recruited by advertisement and word of mouth, and paid for participation. A between-subjects design was used; 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.* [15] in using a forced choice task. An example test trial appears in (8)

(8) **Example test trial**

	X	A	B
audio:	[vuwso]	[vuwt]	[vuw]
visual:	*apples*	*apple*	*apple*

Subjects had to choose between A and B as singular forms for X. Choices always differed in the presence of the final consonant. For the example in (8), the correct answer for learners of Language 1 would be B, while for Language 2 it would be A.

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 generalization, rather than having simply memorized the correct singulars. Subjects were first trained and tested on 9 pairs, and then trained and tested on another 9. In training, each pair appeared three times, and in testing each pair appeared twice. The 18 pairs were then played once more for review, and then subjects were tested on all 36 pairs, again with each pair appearing twice. Items occurred in random order within each training and testing block.

3. RESULTS

To date, 6 subjects have been tested in each condition. The following table shows the results from the final test block for subjects in each of the language conditions, with the items that they had heard before, separated from the items that were novel in this test block. The results show the mean and standard deviation.

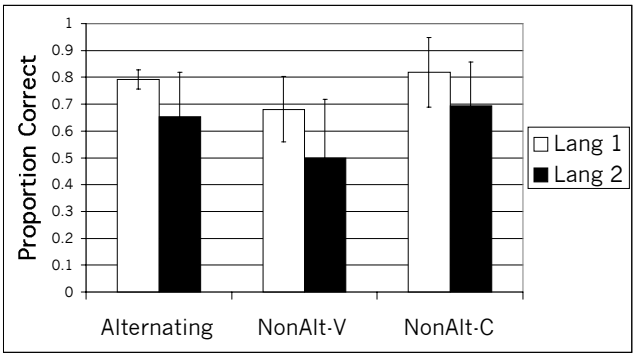
(14) **Results for final test block**

	Language 1	*Language 2*
Trained items	0.95 (0.03)	0.97 (0.03)
Novel items	0.76 (0.05)	0.62 (0.15)

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 ($t(6) = -2.18$, $p < 0.05$).

These results suggest that phonotactic knowledge does indeed play a role in the learning of alternations. There is a potential confound, however: phonotactic knowledge itself. In the Language 1 condition, subjects could respond correctly to the alternating on the basis of what is allowable in English. In choosing between [gɛ] and [gɛt] as the singular of [gɛso] the correct [gɛt] 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 decided based on what was well-formed in their native language.

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, since the latter involve a choice between forms that are equally legitimate in English. The following figure graphs the mean proportion correct for each of the two groups for the three root-types (see (6) and (7) for examples of each). Error bars indicate 95% confidence intervals.



(15) **Performance on different root types**

As this graph indicates, 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 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

4. CONCLUSIONS

Though the results are preliminary, they suggest that phonotactic knowledge does aid in the acquisition of alternations. This is consistent with a theory of phonology that captures static generalizations and alternations with the same constraints or rules. One might still posit separate systems for phonotactic knowledge and alternations, but in order to do so, it would seem to be necessary to specify how knowledge is transferred between the systems in the course of acquisition

There is, however, another explanation for these results. Subjects may have had trouble with Language 2 because it contained an "impossible rule": to the best of our knowledge, no language closes off open back-voweled syllables with an epenthetic consonant. This alternative explanation rests on the premise that speakers can distinguish between possible and impossible rules ([16], [17]). Whichever of these explanations is correct, however, it seems that learners do not learn alternations by simply observing the changes to the phonological shape of morphemes. Rather, they are aided in this task by other aspects of phonological knowledge.

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