Unconstrained Variables Oversimplify Phonotactic Learning

1. Introduction

When variables were first proposed for phonological representations, their primary purpose was explaining assimilation and dissimilation patterns (Halle 1962). Here I'll show that extending variables to explain other phenomena (as Halle did in his original proposal) makes pathological predictions regarding structural learning biases. However, a more restricted version of Halle's proposal (that resembles more recent theories of assimilation) avoids such unwanted predictions.

2. Variables in Phonology

If a phonological grammar lacks variables, then it has to represent patterns like voicing assimilation as two independent processes, as in (1).

(1) *Assimilation, without variables*

[-Syllabic] → [+Voice] /_[+Voice]

[-Syllabic] → [-Voice] /_[-Voice]

(2) *Assimilation, using variables*

[-Syllabic] → [αVoice] /_[αVoice]

In the analysis in (1), one rule voices consonants before voiced sounds and another rule devoices consonants before voiceless ones. Halle (1962) presents a way to explain assimilation using a single, unified rule. His solution used variables that could stand for either [+] or [-] feature values. This is shown in (2), where the symbol *α* is used to represent such a mechanism (for more recent discussion on this, see, for example, Berent 2013).

However, Halle (1962) did not just represent assimilation and dissimilation with variables. He also used them to simplify the representation of a complex pattern that had been observed in Slavic languages. In this pattern, the vowels /e/ and /o/ are both altered before nasals, however /e/ maps to [æ] while /o/ maps to [u]. These two mappings were explained by Halle (1962) with a single rule, as in (3):

(3) *Halle's Pre-nasal vowel rule for Slavic Languages (feature names changed for clarity)*

[-High, -Low, αFront] → [-αHigh, αLow] / _[+Nasal]

This use of variables simplified the representation of the Slavic pattern, since both the lowering of /e/ and the raising of /o/ could be captured in a single rule (see Wang 1967 for a similar approach to tonal processes). However, simplifying a pattern's representation is not always a desirable goal, since a number of studies have shown that patterns that are structurally simple are also easier to learn (see Moreton and Pater 2012 for a review). This means that patterns like the one in Slavic languages should be represented in a way that correctly predicts their learnability.

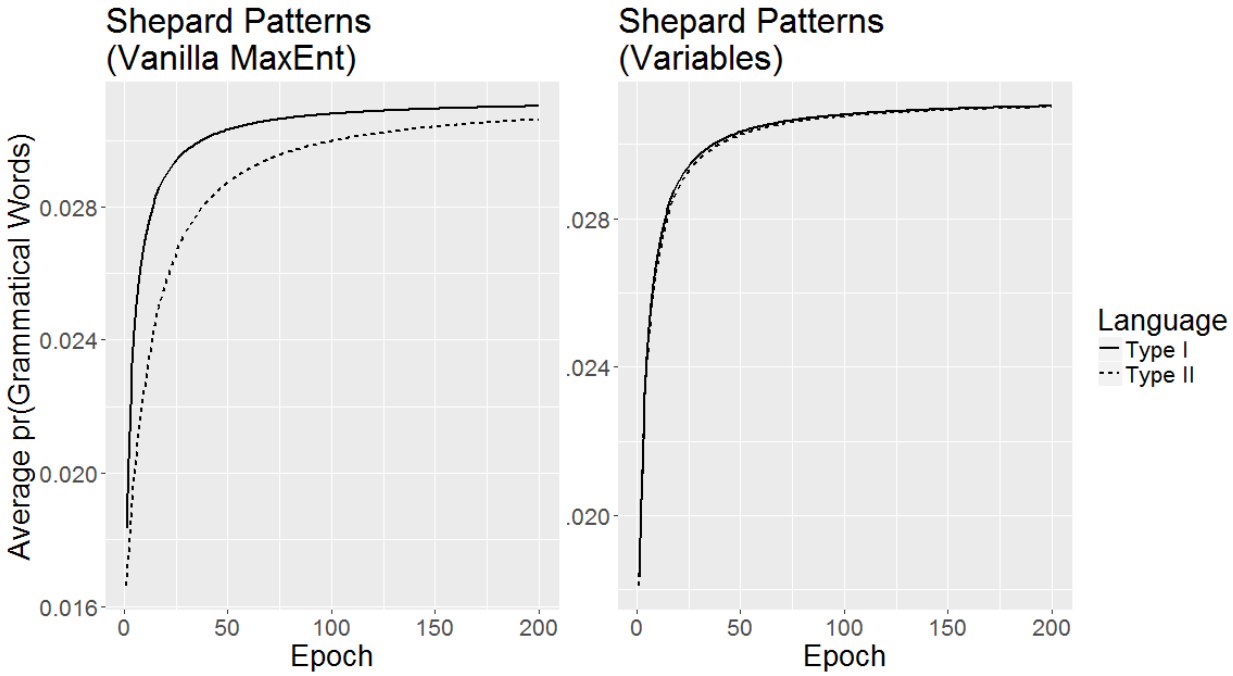
3. Variables and phonotactic learning biases

While (to my knowledge) the learnability of the Slavic pattern described above has not been studied, there are a set of relevant patterns whose learnability has been thoroughly established in the phonological literature: Type I and Type II phonotactic restrictions. Type I patterns can be described using a single, valued feature (such as segments all being [+Voice]). Type II patterns are more complex, and involve a logical biconditional (such as segments being *either* [+Voice, +Dorsal] *or* [-Voice, -Dorsal]). Shepard et al. (1961) originally explored and defined these two types of patterns in the domain of visual category learning. They found that Type I was significantly easier for humans to learn than Type II. These results have been replicated for phonotactic acquisition in a number of artificial language learning studies (see, e.g. Moreton et al. 2017) and mirror typological trends in phonological patterns (Moreton & Pertsova 2014).

Pater and Moreton (2014) showed that a MaxEnt phonotactic learner with a conjunctive constraint set can predict this Type I/Type II bias (see Moreton et al. 2017 for more on why this is the case). Since Type I phonotactic patterns are described with a single, simple constraint, they can be learned more quickly than the Type II patterns that require at least two constraints to describe. However, when constraints use the kinds of variables that Halle (1962) proposed, this difference in representational complexity between the two pattern types is eliminated. For example, if all of the segments in a language are either [+Voice, +Dorsal] or [-Voice, -Dorsal], this Type II pattern could be represented using the single constraint *[αVoice, -αDorsal].

4. Results

To confirm that the representational simplicity introduced by variables interferes with the Type I/Type II predictions made by a phonotactic learner with a conjunctive constraint set, I compared the predictions of such a learner (Pater & Moreton, 2014; Moreton et al., 2017) with and without constraints that made use of variables. The results shown below demonstrate that variables like the ones Halle (1962) used cause Type II patterns to be learned just as easily as Type I.



5. Discussion

Halle's (1962) original proposal regarding variables has been shown to make pathological predictions regarding phonotactic learning biases. However, a simple restriction on the use of variables can solve this problem—as long as they only occur on the same feature across different segments, variables no longer cause a mismatch between human learning biases and the biases predicted by a MaxEnt learner with a conjunctive constraint set. This is because such a restriction would limit variables to reducing the representational complexity of assimilatory and dissimilatory processes. Since these patterns *are* easier to learn than other Type II restrictions (Moreton 2012, Gallagher 2013), this creates a desired prediction, instead of a pathological one. This restricted version of variables resembles a number of more recent theories made to explain these kinds of phenomena, such as autosegmental spreading (Goldsmith 1976) and surface correspondence constraints (Rose & Walker 2004; Bennett 2013), providing further evidence for these formalisms.