Degrees of representational abstraction in phonology: an argument from learning

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Speech sounds may be conceptualized at multiple levels of abstraction (e.g., acoustic profiles, phoneme units, phonological features; see also Pierrehumbert 2003). However, it is standard practice in current phonological theory to assume that there is one single level of representation which is relevant to phonological grammar: the (classificatory) phonological feature (Kenstowicz & Kisseberth 1979). Even though it has been shown that the mind does make use of different levels of abstraction in processing linguistic sound (see, for instance, Nielsen 2011), it is commonly assumed that only the highest level of abstraction is used by the phonological system (Pierrehumbert 2003).

The alternative hypothesis is that phonological grammar appeals to various degrees of abstraction. For instance, phonological grammar could refer to classificatory features, and, in addition, to phonemes as atomic categories. Such a grammar seems highly uneconomical at first sight, since phoneme units may be defined as the intersection of features.

However, one important consequence of grammars which appeal to multiple degrees of abstraction is that they enable a non-derivational account of phonological opacity, as they contain multiple independent representations for the same sound event. Non-derivational accounts of phonological opacity have been pursued by many authors (a.o., Bye 2006, Boersma 2007, and Oostendorp 2008), but such accounts are often forced to stipulate levels of representation axiomatically[1]. If levels of abstraction have an independent motivation, then an approach with multiple levels of abstraction avoids this problem.

In this work, I will provide an argument for a multi-leveled view of representation in phonological grammar from the standpoint of phonological learning. Abstract categories like features always involve learning: either the categories themselves are learned, or the abstract categories are innate but need to be connected to a range of appropriate realizations (see Mielke 2004 for a convincing argument against phonological features having universal interpretations).

For the purposes of this work, I will assume that classificatory features are learned over phonemic representations (see Nielsen 2011 and others for arguments for the psychological reality of phonemic representations). If all features are induced based on information provided by the phonological grammar, then the most natural scenario is that the grammar starts out without reference to features, and, as features become available, new constraints containing these features may be added - including constraints which reformulate previously added phonemic constraints (for instance, *#[m], *#[n], *[ŋ] may be reformulated as *#[nasal]).

Crucially, it is not always more efficient to reformulate a generalization in terms of features: sometimes a generalization can already be fully stated in terms of phonemes. In the latter case, the featural reformulation is homonymous with an existing constraint and is unlikely to be added. This entails that generalizations will typically be present in the grammar at the lowest degree of abstraction at which they can be represented as a single constraint.

For instance, if a language has the phonotactic restrictions in (1), the former two restrictions are predicted to be represented as feature-based constraints (see (1ab)) since these patterns cannot

[1] With the exception of Boerma's (2007) approach.

be represented as a single phoneme-based constraint, whereas the latter restriction is predicted to be represented as a phoneme-based constraint (see (1c)), since this constraint captures the entire pattern. In this manner, a grammar whose constraints refer to more than one level of abstraction (namely, both phonemes and features) is predicted to emerge.

(1)

a) no word-initial nasals [m,n,ŋ]:	***#[nasal]**, not *#[m],*#[n],*#[ŋ]
b) no labials in between high vowels:	***[hi][lab][hi]**, not *[ubu], [ibu], [umi], .. etc.
c) no word-final [m]:	***[m]#**, not *[labial,nasal]#

These predictions were tested in a series of learning simulations performed in the Maximum Entropy framework for phonotactic learning (Hayes & Wilson 2008). Constraints, which banned n-grams of phonemes (and features, as soon as they were induced), were selected based on their information gain value (an estimate of how much closer the predictions of the current grammar can be brought to the observed data distribution). Features, which were clusters of phonemes, were found by applying a mixture of Gaussians model (Everitt 2011) to the information gain values of all potential constraints created by inserting every possible phoneme in the language into a certain phonological context. When a feature was induced, it became part of the inventory of the symbols that could be part of a constraint.

This learning model was applied to a toy language which had precisely the three phonotactic restrictions as presented in (1). This toy language models existing phonotactic problems in English (onset clusters with or without initial [s]; Fudge 1969) and Yoruba (lack of word-initial [u]; Pulleyblank 1989), as it has a one-phoneme generalization in which the single phoneme is the intersection of two phoneme classes referred to by generalizations in the language.

The result of these simulations was that 31 out of 32 runs generated final grammars which included both constraints referring to phonemes and constraints referring to features. Since the type of data offered to the learner occurs in natural language, these results strongly suggest that, given that some feature learning must occur, grammars which refer to different levels of phonological abstraction emerge naturally.

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