Combining Indicators of Allophony

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Introduction

Allophonic rules and coarticulation are responsible for the great variety in phoneme realizations. Infants can not reliably infer abstract word representations without knowledge of their native allophonic grammar.

We explore the hypothesis that some properties of infant-directed speech, referred to as indicators, are correlated with allophony and phonemehood.

Framework

We build upon Peperkamp et al.'s (2006) framework: the task is to induce a two-class classifier deciding, for every possible pair of segments, whether or not they realize the same phoneme.

As a model of early language acquisition, this classifier is induced without supervision.

Experimental setup

In the absence of phonetic transcriptions of infant-directed speech, and as the number of allophones infants must learn is unknown (if assessable at all), we created a range of possible inputs, applying artificial allophonic grammars to the now-standard CHILDES 'Brent/Ratner' corpus of English (Boruta et al., 2011).

We quantify the amount of variation in a corpus by its allophonic complexity, i.e. the ratio of the number of phones to the number of phonemes in the language.

Simplifying assumptions

We assume infants are able to segment continuous speech into a sequence of discrete segments, and that they quantize each of these segments into one of a finite number of phonetic categories.

Distributional indicators

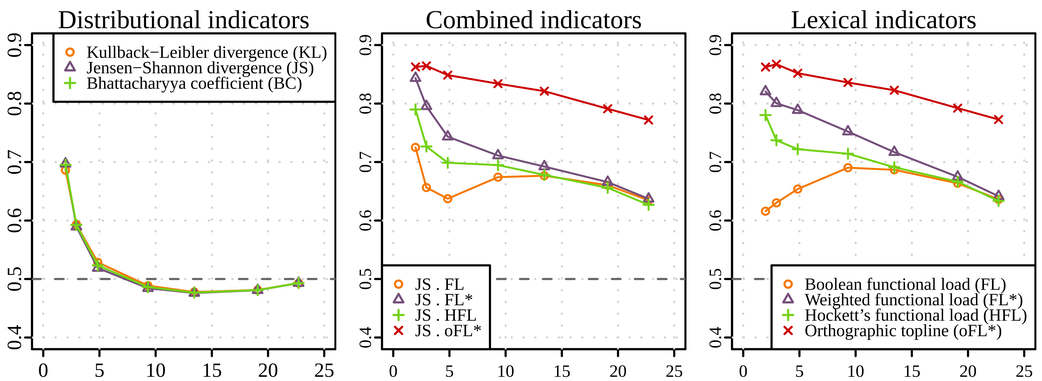
Complementary distribution is a ubiquitous criterion for the discovery of phonemes. If two phonetic segments occur in mutually exclusive contexts, the two may be realizations of the same phoneme.

Lexical indicators

Adjacent segments can condition the realization of a word's initial and final phonemes. If two words only differ by their initial or final segments, these segments may be realizations of the same phoneme. Lexical indicators use the output of Venkataraman's (2001) online word segmentation algorithm.

Combination schemes

As indicators were designed as necessary, but not sufficient, correlates of phonemehood, conjoining them so they are collectively sufficient is a natural extension. To approximate interactions between their values, we used a numerical combination scheme, merging indicators' values using multiplication as a numerical counterpart of conjunction. (Additional schemes in the paper!)



x-axis: average number of allophones per phoneme. y-axis: probability that a randomly-drawn allophonic pair outscores a randomly-drawn non-allophonic pair.

Evaluation

For a given allophonic complexity, we evaluate indicators across all possible discrimination thresholds, reporting the area under the ROC curve. Values lie in [0,1] and are equal to the probability that a randomly-drawn allophonic pair outscores a randomly-drawn non-allophonic pair. (Additional metrics in the paper!)

Discussion

For comparability with previous studies, we only considered combination schemes requiring no modification in the definition of the task. Unfortunately, none of the combinations we tested outperform individual indicators.

One explanation for distributional indicators' bad performance, yet to be tested experimentally, would be that they come into play later in the learning process, once part of allophony has been reduced using other indicators.

Where to go from here?

Acoustic indicators are needed! Segments have been nothing but symbols: the task is as hard for [a]∼[ã] as it is for [w]∼[k]. Yet, not only do allophones of a given phoneme tend to be acoustically similar, but acoustic differences may be more salient and/or available earlier to the infant.

Reformulating the problem as a clustering task, using the so-called 'parallel universes' approach to combine indicators, would allow the definition of an online model.

Boruta et al., 2011, Testing the robustness of online word segmentation: effects of linguistic diversity and phonetic variation. • Hockett, 1955, A manual of phonology. • Le Calvez, 2007, Approche computationnelle de l'acquisition précoce des phonèmes. • Martin et al., submitted, Learning phonemes with a pseudo-lexicon. • Peperkamp et al., 2006, The acquisition of allophonic rules: statistical learning with linguistic constraints. • Venkataraman, 2001, A statistical model for word discovery in transcribed speech.

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