

# The role of predictability in shaping phonological patterns

Hall, Hume, Jaegar, & Wedel (2018)

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## 1 Introduction

- Speakers/listeners have expectations when using language.
- Word predictability can influence response times, reading times, and surprisal estimates (e.g., N400), among other things.
- Word predictability can also affect features of speech production and perception/comprehension.
- **Goals:**
  1. To review existing evidence that supports their claim that word predictability has an effect on speech production and comprehension.
  2. To show that these phonetic/phonological effects can lead to certain phonological patterns/sound change.
  3. To show that predictability-related sound changes are based on word-level predictability (and not sub-lexical predictability), called meaning bearing unit (MBU).

## 2 Predictability versus frequency

- Predictability ≠ frequency because predictability relies on context, but frequency does not.
- Example: [vækju\_] → 'vacuum'.
  - [ə] is more frequent than [m] but not in that context.
  - [m] is more predictable

## 3 Predictability in phonetics/phonology

- 'Natural' articulatory and perceptual biases shape sound patterns.
- Predictability is another bias that can shape sound patterns.
  - In production: faster speech rate, more central vowels (ə), less articulated segments, etc.
  - In comprehension: faster reading, easier recognition in noise, reduced surprisal responses, faster recognition with phonetic reduction.

### 3.1 Sound change

- This can bias sound change and phonological patterns over time, as well as the lexicon.
- Example: less predictable words have less phonetic reduction. Over time, this could result in other properties that facilitate comprehension of those words to become more salient.<sup>1</sup>
- If a given word is highly predictable and, consequently, has significant phonetic reduction, the reduction of these sounds may carry into other contexts in words that are less predictable, leading to a larger scale sound change.
- Biases towards certain phonetic variants of a sound do not need to be present in all contexts for sound change to occur; it needs to be present in 'enough words ... enough of the time'.
  - Note that these phonetic changes happen at the level of the MBU and spread throughout the lexicon to other MBUs.
- Many types of phonological phenomena show this susceptibility to be influenced by predictability.
  - allophony, epenthesis, assimilation, sound mergers, vowel harmony, etc.

### 3.2 Why at the level of MBUs? Part 1

- To retrieve words from the lexicon, listeners make hypotheses based on the acoustic information available. As the acoustic signal grows longer, the selection pool is more and more restricted until the word is selected.<sup>2,3</sup>
- Because of this, phonetic cues at the beginning of words are more informative than those at the end of words.
- The authors hypothesize that the end of MBUs should be more susceptible to phonetic reduction (production) and that, as a result, neutralization patterns will arise at the end of words more often than at the beginning of words.
- Wedel et al. (2018) tested this with a corpus of 50 languages and showed that this is the case for neutralization.<sup>4</sup>

## 4 Bayes' theorem to predict predictability effects

- It is important to try to integrate these 'in-the-moment' biases on production and perception based on predictability into a model that shows how these build up towards new lexical representations, that ultimately result in sound change.

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<sup>1</sup>Predictability likely differs in every context, so I'm not sure that it follows that phonetic cues should be enhanced based on word predictability. It seems like they are confusing predictability with frequency here, as words that are almost never predictable, and thus susceptible for phonetic enhancement, are probably low frequency.

<sup>2</sup>What about other models of lexical retrieval that aren't linear, like Neighborhood density model?

<sup>3</sup>It also seems that this model skips a step by going from acoustic signal to lexical retrieval. Is the lexicon composed of phonetic representations or phonemic representations? Is this model compatible with anything other than an exemplar model of the lexicon?

<sup>4</sup>They showed that this bias still exists even in the absence of coda neutralization. However, this is still questionable because codas may not be word-final and thus still valuable for identifying MBUs.

- Authors state that phonology is intermediary to the acoustic signal and MBUs, which is what predictability affects.
- This can be modeled with Bayes' Theorem, which shows the probability of intended message (M) in a specific context (ctxt) via the signal (S), relative to the sum of the probabilities of all other possible messages:

$$P(M|S, ctxt) = \frac{P(M|ctxt) * P(S|M, ctxt)}{\sum P(M_i|ctxt) * P(S|M_i, ctxt)} \quad (1)$$

- This represents the probability of accurate message transmission.
- As  $P(M|ctxt)$  measures the predictability of a message (MBU), the model states that the more contextually probable (predictable) the message is, the more likely it will be transmitted than less contextually probable (predictable) messages.
- Example: 'I find it hard to swallow \_\_\_\_.'
- 'pills' is more probable than 'bills'
- As  $P(S|M, ctxt)$  represents how likely the given signal is to be used for the intended message compared to other messages. 'Better' articulation will thus make the signal more distinctive and less likely to be used for other signals.
- Example: VOT of /p/ in 'pill' will be longer in contexts where 'bill' is also a competitor. This increases perceptual distinction between the two MBUs.
- We can increase the probability of transmitting an accurate message by increasing context or increasing signal specificity.
- Increasing (or decreasing) signal specificity is what contributes to phonological patterns/sound change.

#### 4.1 The role of the lexicon

- The degree to which we enhance or reduce production relies on the lexicon.
- A given message will be more specific to the intended message when there are fewer phonological neighbors.
- Back to the /p-b/ example: /p/ had longer VOTs when /b/ words were possible responses than when non /b/ words were possible responses.
- Hyperarticulation is used to increase distinction from perceptually similar contextual competitors.
- Hyperarticulation of this sort can become lexicalized.
- /p/ words with /b/ minimal pairs tend to have longer VOTs than /p/ words without /b/ minimal pairs across the board, regardless of context.
- The same is true for vowel distinctness.

- These results suggest that enhancing phonetic cues can be a result of predictability effects of MBUs.
- This bias could explain some sound changes, like certain phoneme mergers, which are more likely when there are fewer minimal pairs.<sup>5</sup>
  - i.e., If you have 18 minimal pairs for ‘pill’ in a given context, your language is more likely to maintain /p/ as a unique phoneme than if you just have 2 minimal pairs in that context.

## 5 Why at the level of MBUs? Part 2

- One goal of this paper was to argue that predictability-related effects on phonology happen at the level of MBUs and not at any sublexical level.
- The Bayesian model above could define ‘message’ at any linguistic level, not just MBU (e.g., phonological features, phonemes, syllables, etc.).
- But we should continue to define ‘message’ at the level of MBUs when looking at predictability effects on phonology.

### 5.1 Why?

- Phonology (with some exceptions) tends to focus on patterns within phonological categories and *not* on the properties of words and their relationship with other words.
- This paper differs because it argues that the physical acoustic signal is determined not only by its phonological features, etc., but also by its context.
- Diachronic phonological change and patterns are sensitive to these physical properties of the signal that are dependent on the predictability of the MBU.

### 5.2 Supporting evidence

#### 5.2.1 German final-devoicing

- German has final-devoicing; English does not.
- The voicing contrast in final position distinguishes way more minimal pairs in English than in German.
- In English dialects with final-devoicing, other acoustic cues have been enhanced to maintain this contrast.
- **German has more predictability in this instance and thus was more susceptible to neutralization in this context.**

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<sup>5</sup>It is not immediately clear to me how any sort of predictability bias could result in assimilation, even though they mention this in the introduction.

### 5.2.2 English /t/ allophony

- /t/ has the following allophones: [t<sup>h</sup>, t, r, ʔ].
  - [t<sup>h</sup>] has strongest phonetic cues (enhanced variant).
    - \* We find [t<sup>h</sup>] in the onset of stressed syllables, where the aspiration cue is super salient. We do not find [t<sup>h</sup>] in reduced (unstressed) syllables.
    - \* **Initial stressed syllables are good targets for phonetic enhancement if MBU is the unit because it allows more disambiguation earlier in the syllable.**<sup>6</sup>
  - [ʔ] is found word finally.
    - \* **We expect reduction here, since material in this position provides the least amount of identifying information from the signal.**
  - [r] is found intervocalically preceding unstressed syllables. This is also an allophone of /d/.
    - \* **Neutralization of /t-d/ in this context is predicted if MBU is message unit because there are very few instances where contrast is needed here (latter-ladder).**
- These patterns would not fall out of an account where the message unit is sublexical.

## 6 Conclusions

- Speakers manipulate phonetic variation by enhancing or reducing phonetic cues based on the predictability of MBUs.
- Phonetic enhancement should be more likely when a given segment provides a lot of information for lexical selection.
- Phonetic reduction should be more likely when a given segment provides little information for lexical selection.
- Over time, these phonetic manipulations that result from MBU predictability, can lead to changes in lexical representations, and then later on, the development of phonological patterns. Articulatory and perceptual biases also contribute.
- Due to this MBU predictability bias, phonologies should favor patterns that enhance phonetic cues that contribute more to MBU transmission and should favor patterns that reduce phonetic cues when they contribute little to MBU transmission.

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<sup>6</sup>In an online experiment I did with /t/ allophony, listeners accepted the ‘enhanced’ variant [t<sup>h</sup>] in incorrect contexts much more than any other wrong allophone. I don’t think this goes against this paper’s argument, but it may show that the ‘enhanced’ variant does in fact contribute more information about the lexical entry.