Phonotactic Complexity across Dialects

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Outline

- Introduction
- Methodology
- Results
- Discussion
- Conclusion

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Compensation Hypothesis

- **Assumption**: all languages are equally complex
- **Compensation hypothesis**: “a simplification or complication in one area of an inventory will be counterbalanced by the opposite somewhere else” (Moran and Blasi 2014, Martinet 1955)

Phonotactic complexity

- **Phonotactics**: a set of language-specific constraints on what constitutes a licit or illicit sound sequence

(Chomsky and Halle 1965)

- **Phonotactic complexity**: the variety of structures allowed at different positions within a syllable or word
  - how unpredictably a language variety's phonemes behave at different positions

Phonotactic complexity and word length

- **Prior work**: negative correlation of -0.74 between phonotactic complexity and average word length across 106 languages (Pimentel et al. 2020)
- **Method**: estimated phonotactic complexity with Shannon entropy (bits per phoneme) from an LSTM-based phoneme-level language model

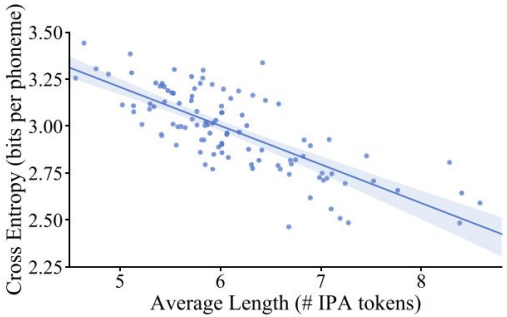

Figure 1: Bits per phoneme vs average word length using an LSTM language model.

Phonotactic complexity and word length

- Decrease in word length ↔ Increase in phonotactic complexity
- **Compensation Hypothesis**: increase/decrease occurs as compensatory mechanism

Limitations of Pimentel et al (2020)

- **Typological imbalance**: NorthEuraLex dataset (Dellert et al., 2020) favors Uralic and Indo-European languages
- **Solution**: examine correlation on a dialect level across dialect datasets
  - most variables (e.g. areal influences, phylogenetic biases) are relatively constant
- **Findings**: negative correlation holds strong even in dialect settings

Limitations of Pimentel et al (2020)

- **Syllable structure**: Pimentel et al (2020)'s phone-LSTM only considers the order of segments in a word
  - Does not model interaction between syllable structure and phonotactic constraints
- **Solution**: explicitly model syllable structure with multi-task learning
- **Findings**: syllable structure does not strengthen negative correlation

Social explanation of complexity distributions

- **Additional contribution**: we model the geographic distribution of phonotactic complexity
- **Findings**: areas of low phonotactic complexity concentrate around the capital regions

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Estimating phonotactic complexity

Pimentel et al. 2020:

- Phoneme-level language model: learns phonotactically valid sequences of phonemes
- Estimate Shannon entropy of the variety (bits per phoneme)
- Cross-entropy as upper bound on the true entropy to approximate phonotactic complexity

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Problem: distribution of phonemes also interacts with syllable structure

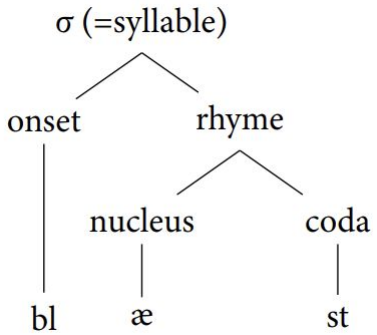
Syllable-aware phonotactic complexity

Solution: inject syllable knowledge into Pimentel's model with multi-task learning

Syllable constituency prediction task:

- Predict syllable constituents **c** given phonetic transcription of the word **x**

$$p(\mathbf{c}|\mathbf{x}) = \prod_{i=1}^{|x|} p(c_i|\mathbf{x}_{\leq i})$$



Syllable-aware phonotactic complexity

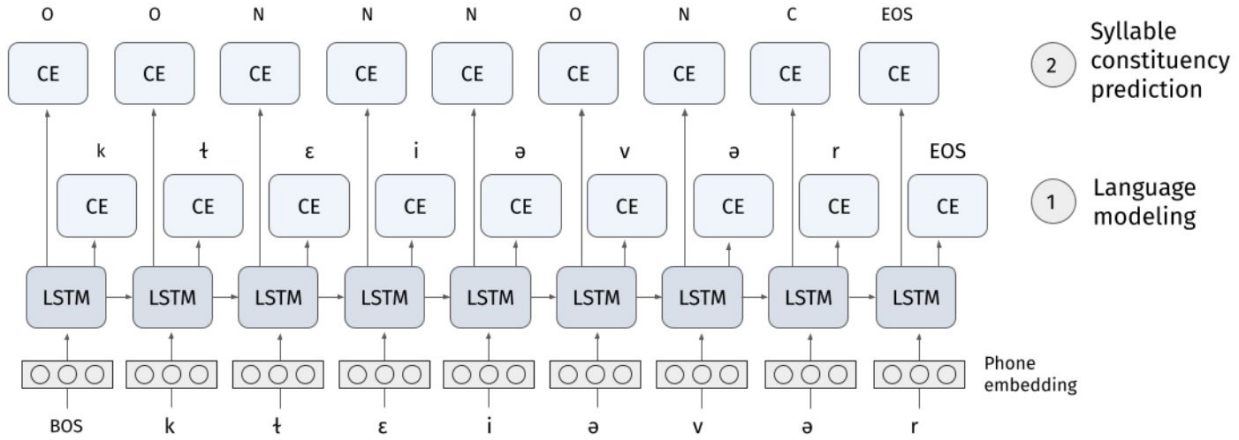


Figure 3: Diagram of our phonotactic language model with syllable constituency prediction as an auxiliary task, where O means onset; N, nucleus; C, coda; CE, cross-entropy loss. The example shown is the pronunciation of “klaver” in the Deurne NB dialect.

Task Weighting

We optimize the multi-task model by dynamically adjusting the task-specific loss contribution $\lambda_{a,b}$:

$$\mathcal{L}(\mathbf{x}, \mathbf{c}) = \lambda_a \mathcal{L}_{phon}(\mathbf{x}) + \lambda_b \mathcal{L}_{syl}(\mathbf{x}, \mathbf{c})$$

Weights are determined by uncertainty (Kendall et al 2018)

More uncertain task: higher loss variance

$$\tilde{L}_t = \frac{1}{2\sigma_t^2} L_t + \log \sigma_t$$

Log term avoids division by zero

Dialect Datasets

We use dialect datasets for Dutch and Min

- Chosen for typological diversity and data availability

Language	Source	# dialects (we use)	# words
Dutch	Taeldeman, Johan and Goeman, A (1996)	366	562
Min	Centre for the Protection of Language Resources of China (2023)	60	1200

Table 1: Statistics on the datasets in our experiments

Dutch Dialect Dataset

- Phonetic transcriptions of 1,876 lexical items across 613 dialect sites
- Collected between 1980 and 1995 in the Netherlands and Belgium
- Concept-aligned
- Analysis on data from only Netherlands
    - contains 424 sites
    - After removing Frisian: 366 Dutch sites

Min Dialect Dataset

- Phonetic transcriptions for 1,200 concepts across 1,289 Sino-Tibetan varieties in mainland China and Taiwan
- Focused on 60 Min dialects spoken in Fujian Province (where most Min dialects are concentrated)
- Concept-aligned

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Correlation results

Language	Syllable structure	Pearson *r*	Spearman ρ
Dutch	No	-0.678897	**-0.63107**
Dutch	Yes	**-0.684041**	-0.627137
Min	No	**-0.720228**	**-0.692592**
Min	Yes	-0.698437	-0.665027

Modelling geographic distribution

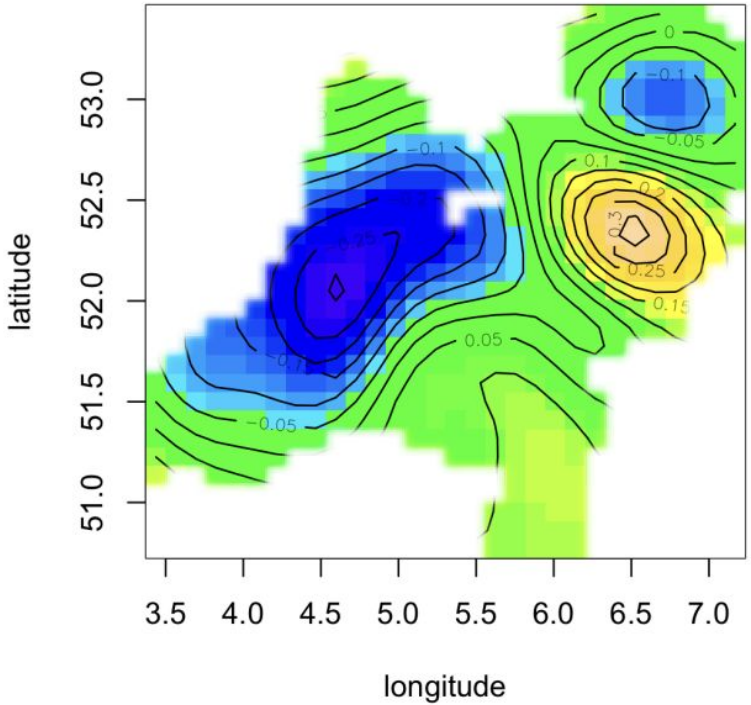
We model phonotactic complexity / average word length as function of their coordinates with generalized additive models (GAM):

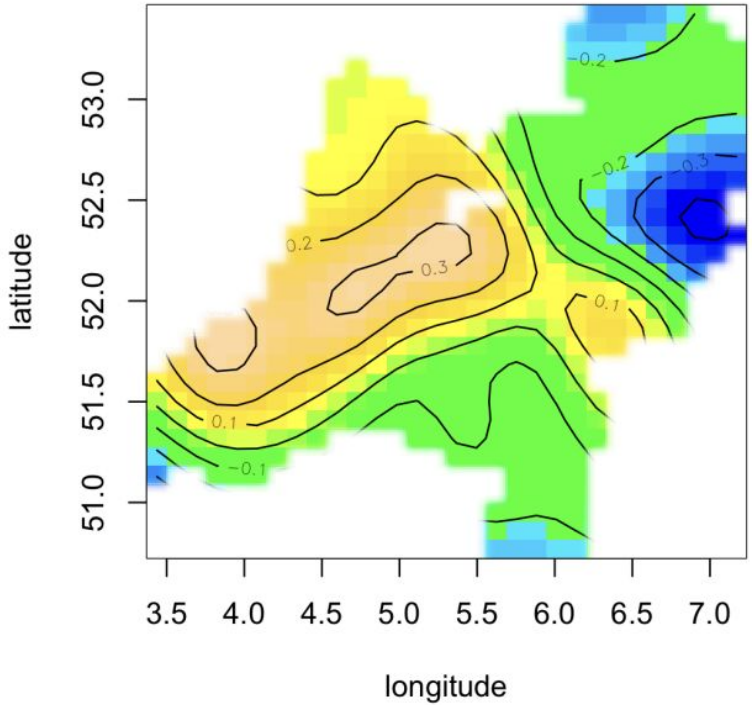
- Mean μ of a random variable Y is related to a weighted sum of linear predictors X with coefficients β (where Xβ is denoted η) through a link function g:

$$g(\mu(Y)) = \eta = X\beta$$

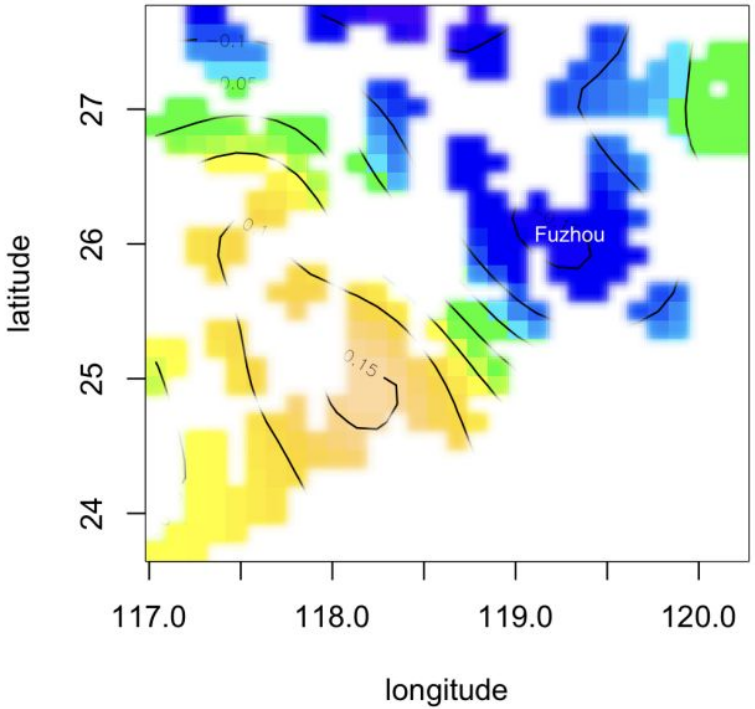
- Where η is composed of functions that are learned to fit to the predictors:

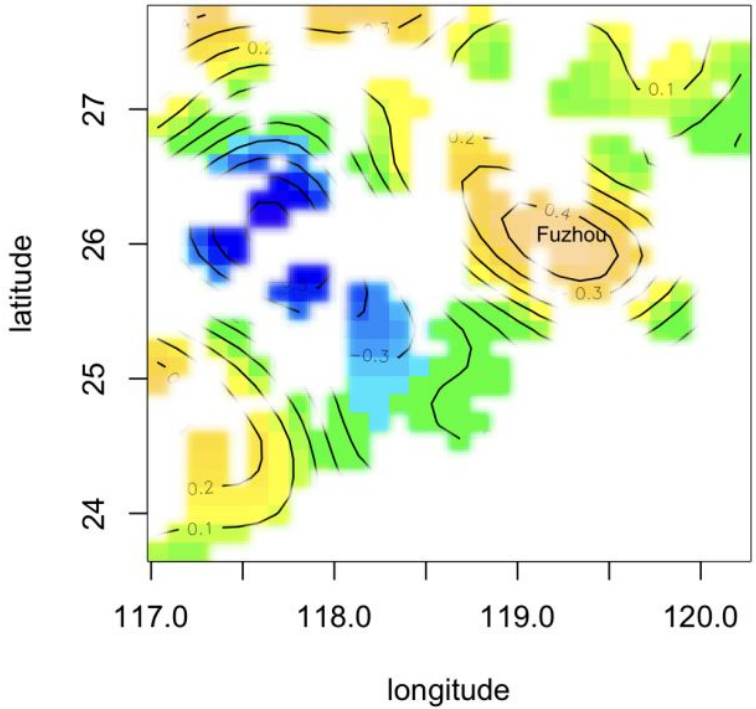
$$\eta = b_0 + f(x_1) + f(x_2) \ldots + f(x_p)$$





- Phonotactic complexity (left) is complementary to word length (right) for Dutch dialects
- Holland demonstrates low phonotactic complexity





- Phonotactic complexity (left) is complementary to word length (right) for Min dialects too
- Similar concentration of low phonotactic complexity around Fuzhou (capital)

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Our results corroborate the linguistic niche hypothesis

- Concentration of low complexity & high word length around Holland = evidence of linguistic niche hypothesis

- **linguistic niche hypothesis** (Lupyan and Dale, 2010; Dale and Lupyan, 2012): linguistic structure adapts to social constraints (Trudgill, 2001; McWhorter, 2007; Bentz and Winter, 2014)
  - Contact leads to grammatical simplification

Koineization

- **Koineization**: Mutual accommodation of dialects into a simplified form
  - Integration → avoidance of strong regional linguistic forms
  - learning constraints of adult speakers → bias towards simple forms
  - children in such multi-dialectal contexts simplify the wide range of dialectal input in their environment
  - Howell (2006), Kerswill and Williams (2000)

- Internal migration → contact between Dutch dialects → simpler phonotactics (Hendriks et al., 2018; Howell, 2006)

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Conclusion

- The tradeoff between phonotactic complexity and word length reported by Pimentel et al (2020) cross-linguistically occurs across closely-related dialect varieties as well.
- Incorporating syllabification into a phonotactic language model by virtue of multi-task learning does not strengthen the negative correlation in our data.
- Our results support the view that a decrease in phonotactic complexity in certain Dutch varieties occurred due to extensive language contact, which led to a compensatory increase in word length.

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Questions or Comments?

Open an issue at
https://github.com/cmu-llab/
phonotactic-complexity-across-dialects