Quantifying the information carried in tonal contrasts in Phom

Phongshak Phom
English and Foreign Languages University
Hyderabad, TS, India

Charles Redmon
University of Kansas
Lawrence, KS, United States

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Background

- Phonemic contrasts are commonly treated as representing equivalent distinctions among abstract units in the *inventory* of a language, but at their conception contrasts were fundamentally *lexical* (Martinet, 1938)
- Within information theory, elements of the code are assumed to be utilized asymmetrically in conveying messages (Shannon, 1948; Hockett, 1967)
- Recent work has applied this perspective to cross-linguistic comparisons of contrast structures (Surendran & Niyogi, 2003; Oh et al., 2013, 2015), and to simulations of language change (Wedel et al., 2013)
- But the *role* of contrasts is rarely studied in under-documented languages
- Phom is one such case: a Tibeto-Burman language spoken in Nagaland with a ternary (high, mid, low) lexical tone contrast (Burling & Phom, 1999)
- Written Phom does not mark tones, making orthographic ambiguity one window on the unique information contributed by the tone system

Methods

- A 7,618-word corpus of written Phom based on selected chapters from *Manshah* (Phom, 2009) was developed for this study
- 521 tonal minimal pairs were identified in the 2,635-word corpus-derived lexicon (all data were processed in Python 3.5 and analyzed in R 3.2)
- The contrast size N_T – the number of different lexical items (excluding homophones) represented by a given orthographic word – was recorded for each *token* ($n = 2,222$) of the 521 minimal pair *types* in the corpus
- Values of N_T were then updated as the first author was given the context in which these words occurred in the corpus in the following stepwise procedure:
  - *Unigram* (no context) → *Bigram* (preceding word) → *Trigram* (preceding 2 words)
- Contrast size estimates defined a probability distribution from which effects of Word Length (syllable count, *mono–tri*) and Context (N-gram size) on tonal disambiguation could be measured

Results

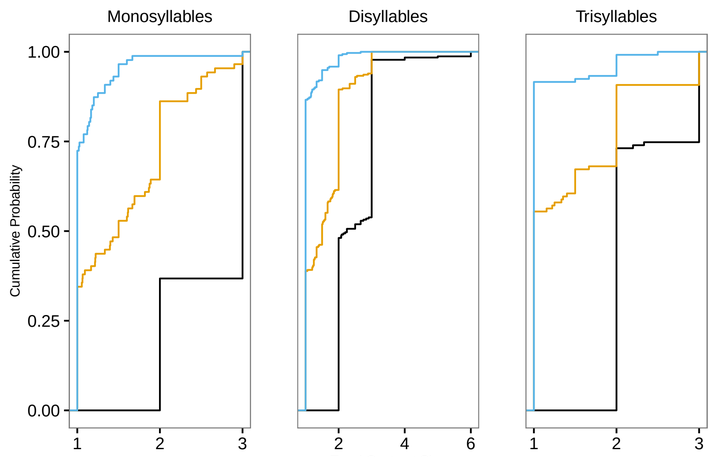

Figure 1:CDFs of contrast size in unigram (black), bigram (orange), and trigram (blue) contexts.

- Kolmogorov-Smirnov tests revealed a significant effect of Context on ambiguity: $trigram < bigram < unigram\,(p < 0.001)$
- Effects of Word Length were not consistent across contexts
  - Unigram: $tri < di < mono$ in N_T ($p_{m-d} = 0.019$; $p_{d-t} < 0.001$)
  - Bigram: $tri < di = mono$ ($p_{d-t} = 0.006$; $p_{m-t} = 0.012$)
  - Trigram: $tri < mono$ ($p_{m-t} = 0.025$)
- Information gain ($N_{T(n-1)} - N_{T(n)}$) with context was also studied as a stochastic process, with gain at the bigram significantly greater than gain at the trigram ($p < 0.001$)
  - This result was consistent across word lengths ($p < 0.001$)
  - Trisyllables showed smaller gains relative to di/monosyllables at both bigram ($p < 0.05$) and trigram ($p < 0.01$) contexts, though this result is primarily due to their lower overall starting values of N_T
- Context frequency in bigrams (i.e. frequency of the preceding word) was also shown to significantly modulate contrast size, with positive Kendall correlations between frequency and N_T found both overall ($\tau = 0.10$, $p < 0.001$) and within word lengths ($0.06 < \tau < 0.14$, ps < 0.01)
- The inverse of contrast size ($P_T = 1/N_T$) was introduced as a measure of disambiguation probability (conceived as a lower bound on lexical predictability) for the study of tone system entropy

System Entropy

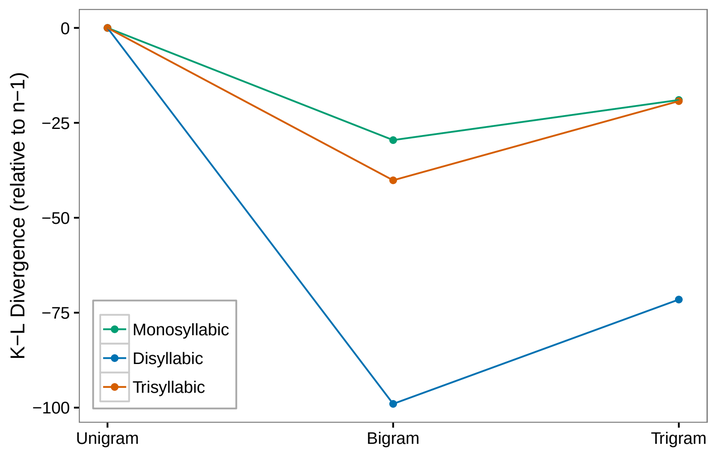

Figure 2:Relative entropy (the Kullback-Leibler divergence, $P_{T(n-1)}||P_{T(n)}$) by word length.

- Across word lengths, the Shannon entropy of P_T decreased nonlinearly from 266 to 126 to 22 bits with increasing context (unigram–trigram)
- Trisyllables showed the greatest asymmetry in information gain with context, with the ratio of relative entropy from bigram to trigram in the following relation: $di\,(1.38) < mono\,(1.58) < tri\,(2.11)$

Lexical Tone Distribution (monosyllables)

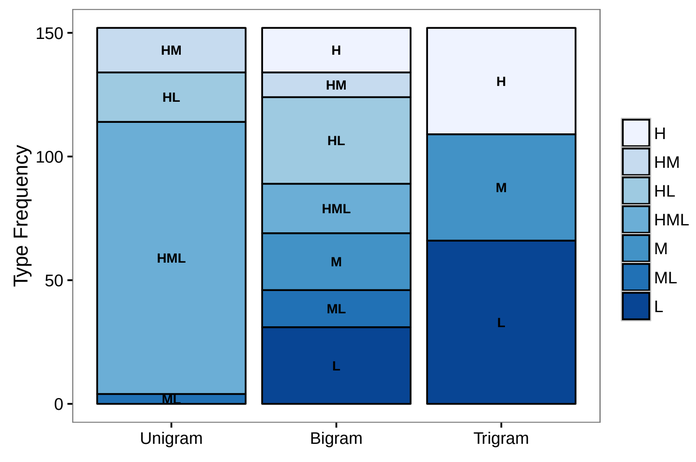

Figure 3:Distribution of potential tonal variants of monosyllables among unique paths (i.e. distinct contrasts: HM, HL, HML, ML) from ambiguous unigram to disambiguated bi/tri-gram.

- Binary contrasts involving the mid tone (HM, ML) were the least common, suggesting H and L might be more prominent under ambiguity
- Among disambiguated items, however, the three tones comprising the contrast were relatively evenly distributed: H – 30%; M – 30%; L – 40%

Morphology (disyllables)

- Disyllabic words formed via compounding exhibit asymmetries in the tonal variant of each constituent
- For example, the mid-tone variant of the second constituent in *yemshing* is more productive than the low ('stuffed up') or high ('to press') variants

yēm-shíng	*yém-shīng*	*yèm-shīng*
search-press	dry-place	animal-place
'to search for'	'a place to dry'	'a place for animals'

- For *vangdhum*, the first constituent is fixed, meaning the ambiguity is completely driven by the tone on the second constituent, *dhum*

váng-dhùm	*váng-dhúm*
rain-shade	rain-visit
'shade, shelter'	'rain visitation'

Conclusions

- The lexical role of the tone system in Phom, being more precisely quantified relative to effects of context (among others), may now serve as a reference for analyses of other tone systems in the region
- Future work should include syntactic and semantic constraints on N_T

References

References will be made available upon request.

Contact

E Phongshak Phom: phongshak@gmail.com
Charles Redmon: redmon@ku.edu
W http://redmonc.github.io