Tonal Timing in Articulatory Phonology: Evidence from Igbo Vowel Assimilation

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Background: Tone Timing

• Lots of *acoustic* work on tone timing:


• Tones associate to syllables, moras, segments or prosodic boundaries

• Goal of this talk: relate this work to Articulatory Phonology (Browman & Goldstein 1986 et seq., Goldstein et al. 2009)
  • For which these units do not exist as primitives
  • Within which very little work on tone has been done
Outline of the Talk

• Why is the tone-bearing unit (TBU) important?
• Prosody and gestural timing in AP
• Why Igbo? (Zsiga 1993, 1997)
• New data on tones and vowels
• Conclusions: tonal timing in AP
Why is the TBU important?

• Begin with a look at the phonological importance of the mora vs. the syllable in
  • Thai (Morén & Zsiga 2006, Zsiga & Nitisaroj 2007)
  • Serbian (Zsiga & Zec 2013, Zec & Zsiga 2019)

• Note: Both languages investigated from an AP perspective by Robin Karlin (Karlin 2014, 2018a, 2018b, Karlin & Tilsen 2015).
Thai tones in citation and in context

- Five ways to say /na:/ in Thai
  
  [na:] ‘rice field’
  [nà:] ‘custard apple’
  [ná:] ‘aunt’
  [nâ:] ‘face’
  [nǎ:] ‘thick’

- Syllable as TBU?

\[
\begin{array}{ccccccc}
\text{mid} & \text{high} & \text{low} & \text{falling} & \text{rising} \\
H & H & L & H L & L H \\
\sigma & \sigma & \sigma & \sigma & \sigma \\
\end{array}
\]
Thai tones in citation and in context

• Syllable as TBU?

Citation form:

Connected speech:
Thai tones in citation and in context

- The mora is the TBU
- Falling tones are simplified in non-phrase-final position
- But remain distinct from High tones

### a. Thai tones in phrase-final position (including citation forms)

<table>
<thead>
<tr>
<th></th>
<th>Mid</th>
<th>High</th>
<th>Low</th>
<th>Falling</th>
<th>Rising</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>H</td>
<td>L</td>
<td>H L</td>
<td>L H</td>
</tr>
<tr>
<td>μ μ</td>
<td>μ μ</td>
<td>μ μ</td>
<td>μ μ</td>
<td>μ μ</td>
<td>μ μ</td>
</tr>
</tbody>
</table>

### b. Thai tones in nonphrase-final position

<table>
<thead>
<tr>
<th></th>
<th>Mid</th>
<th>High</th>
<th>Low</th>
<th>Falling</th>
<th>Rising</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>H</td>
<td>L</td>
<td>H</td>
<td>L (H)</td>
</tr>
<tr>
<td>μ μ</td>
<td>μ μ</td>
<td>μ μ</td>
<td>μ μ</td>
<td>μ μ</td>
<td>μ μ</td>
</tr>
</tbody>
</table>
Serbian suprasegmentals

- Another example of syllable vs. mora timing
- Dialectal variation in Serbian (Neo-Štokavian) “rising” pitch accents:
  - Novi Sad
  - Belgrade
  - Valjevo
Serbian Suprasegmentals

- **Vowel length:** contrastive
  
  \[
  \begin{align*}
  \text{mami} & \quad \text{‘mother-dat-sg’} \\
  \text{ma:mi} & \quad \text{‘entices-3p-sg’} \\
  \text{selo} & \quad \text{‘village-nom-sg’} \\
  \text{se:lo} & \quad \text{‘get together-nom-sg’}
  \end{align*}
  \]

- **Stress:** realized by increased vowel duration preferentially leftmost, never final

- **Intonation:** boundary L% in statements

- **Tone:** traditionally characterized as a "pitch accent" system, with Rising and Falling melodies associated to stressed syllables
  
  (Lehiste & Ivić 1986, Smiljanić 2002)
3-way tone contrast on tri-syllables

“Falling” accent

“Rising” accent

Initial stress

Non-initial stress
Serbian suprasegmentals

- When the tone is associated to the word-final syllable, potential conflict with intonational boundary L%
  - ra'mena_H \(\text{shoulders}\)
  - 'jovan_H \(\text{proper name}\)
  - ju'veli:r_H \(\text{goldsmith}\)
  - 'vola:n_H \(\text{steering wheel}\)

- Resolution depends on the dialect:
  - Novi Sad: Lexical tone wins
  - Belgrade: Retraction from short vowels only
  - Valjevo: Retraction from both long and short vowels
<table>
<thead>
<tr>
<th>Belgrade: TBU = mora</th>
<th>Valjevo: TBU = syllable</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>medial</strong></td>
<td><strong>final</strong></td>
</tr>
<tr>
<td>H</td>
<td>H L%</td>
</tr>
<tr>
<td>μ μ</td>
<td>μ μ</td>
</tr>
<tr>
<td>jovan</td>
<td>jovan</td>
</tr>
<tr>
<td>H</td>
<td>H L%</td>
</tr>
<tr>
<td>μ μ μ</td>
<td>μ μ μ</td>
</tr>
<tr>
<td>vola:n</td>
<td>vola:n</td>
</tr>
</tbody>
</table>
Interim Conclusion

• Why the detours to Asia and Europe when the talk is about Igbo?
• Distinguishing between mora and syllable as TBU is important.
• How can Articulatory Phonology address that distinction?
Timing: Articulatory Phonology

• The basic units are articulatory gestures, not features or segments

• Prosodic structure (syllables, phrases) are not primitives, but arise out of stable patterns of coordination.

• Can we find a gestural approach that is consistent with the acoustic findings? What are the stable patterns of coordination, and do they correspond with the prosodic structure that acoustic investigations have found?
Gestural score for “pan”
C-center timing:

Gestural scores for “span” and “plan” (Browman & Goldstein 1988)

- Coupled oscillators
- Simultaneity (solid line) and precedence (dotted line)
- Cross-linguistic patterns of syllable structure: linear precedence in codas, simultaneity in onsets
- C-center timing: competing couplings in onsets result in overlap

A. non-competing couplings in coda position

B. competing couplings in onset position
What about tone?

- Initial studies in Mandarin (Gao 2008, Yi 2017), find that the tone gesture acts as a second consonant in the onset, participating in a c-center relationship with other onset consonants.

- Also proposed for Valjevo Serbian (Karlin 2018b) and for at least some tones in Thai (Karlin 2014, Karlin & Tilsen 2015, Karlin 2018b)

- Tone gestures behave like consonants!

![C-center effect with tone and complex onset](image-url)

Karlin 2014:127
Igbo vowel assimilation as a test case

- Extend the typology to an African language
- Previous work documented changes in TB gestures for vowel sequences
- What happens with tone when the vowel gestures change?
Igbo Vowel Assimilation:

• Igbo is a Niger-Congo language spoken in southern Nigeria
• 8 vowels: i, ì, e, a, u, ʊ, o, ɔ
• 3 (surface) tones: H, M, L
• No complex onsets, no codas

In a sequence of two vowels at a word boundary, the first assimilates to the second: V1 # V2 → V2 # V2

édè àtó → édà àtó 3 cocoyams
ólı̀ úbì → ólù úbì farm house
Complete vs. Gradient

• Clark (1990: 18): Complete assimilation of vowel quality but no change in tone. “The tone of the assimilating vowel remains constant even though its entire set of place features is changed.”

• Emenanjo (1978): Complete assimilation only if tone is shared.

• Welmers (1973:41): Partial and gradient assimilation of both vowel quality and tone: “The quality of the first vowel merges very quickly into the quality of the second. Thus the second vowel is more prominent but the first remains identifiable.”

• Zsiga (1997): Variable reduction of V1, no change in tone.
Previous experiment: Zsiga 1993/1997

- 3 speakers of Igbo
- 6 repetitions of 28 noun phrases: ...CV1#V2C...
- Measure F1, F2, duration
- F1 and F2 show variable reduction/assimilation
- Greater assimilation was not correlated with shorter duration
In an [e#a] sequence, at onset and at 25 ms into the vowel, F2 varies between the value expected for [e] and the value expected for [a].
Zsiga 1997

• the V1 gesture is reduced in time
• the V2 gesture was extended,
• two tone gestures maintaining consistent timing in both unassimilated (left) and assimilated (right) sequences.

But F0 was not actually measured!
Current experiment: What about tone?

• Measure $F_0$, $F_2$, duration
• Is $F_0$ stable across segmental variation, as proposed by Clark (1990) and Zsiga (1997)? Prediction:
  • timing of $F_0$ stable at 50% of vowel duration
  • $F_0$ and $F_2$ change independently
• Or do formants and pitch vary together? Prediction:
  • timing of $F_0$ and $F_2$ will be correlated
• What does the result tell us about models of tonal timing?
Current experiment: What about tone?

• Revisit a subset of the data from Zsiga (1997)
• New sentences from a previously recorded (but not digitized) corpus
  • Same three participants
  • Reading a different set of phrases
  • Reading a set of sentences with direct and indirect objects
  • Plans for new data collection currently on hold
• Selected for:
  • Tone H#L or L#H: Change in F0
  • Vowel front#back or back#front: Change in F2
  • Adequate quality for both to be measured
  • No pauses between words
  • 138 tokens of 38 different phrases
Example phrases

• 1997 data, controlled for consonant and vowel environment, phrase structure, and for tone:

  ezí ātó  3 loans
  ézé ātó  3 teeth
  ósé ǧzó  another stream
  ózí ǧzó  another errand

• additional corpus data, more varied environments:

  ótù íhé  one thing
  óbòtji úkwú  a big day
  óbòrò égó  he carried some money
  ósòrò ézè  he followed a Chief
Measurements

• Utterances segmented and analyzed in Praat (Boersma & Weenink 2020)

• F0 target: end of T1 steady state, start of transition to T2
• F2 target: end of V1 steady state, start of transition to V2

• If there is no transition, just V2 or T2 steady state, target marked at vowel onset

• Measurements made in two separate passes

• Overall duration of the vowel sequence

• Distance from vowel onset to F0 and F2 targets was calculated
Results

• F0 and F2 vary together.
• Targets are later as overall duration increases, but tone timing is not keeping the duration constant.

S3 i#a: less assimilation
S1 e#a: more assimilation
Correlation between F0 and F2 (all data)

Correlation: F0 target with F2 target

\[ r = 0.637 \]

another one
this one
country house
Fixed phrases?
Correlation between F0 and F2 (zeros removed)

Correlation: F0 target with F2 target (zeroes removed)

r = .647
Correlation between F0 and F2 (1997 data only, controlling C, V, and tone sequence)

Correlation: F0 target with F2 target

\[ r = 0.859 \]
Correlation between F0 and duration (all data)

Correlation: F0 target with V#V duration

\[ r = 0.541 \]
Correlation between F0 and duration (1993 data only, controlling C, V, and tone sequence)

Correlation: F0 target with V#V duration

\[ r = .521 \]
Discussion

The model proposed by Zsiga 1993/1997

• accounts for the formant trajectories
• but is not consistent with the F0 variation
• and is not consistent with current models of articulatory timing as coupled oscillators
A new timing model

- Following Marin & Goldstein (2012) on Romanian vowel sequences
- If V1 and V2 are in an anti-phase coupling, no overlap and no assimilation
A new timing model

- Assimilation takes place if both V1 and V2 are timed *in-phase* to C1, but still *anti-phase* to each other. The result is overlap and blending during the first half of the vowel sequence.

- Variation in the degree of assimilation can be modelled as varying blending strengths: as V1 becomes weaker, V2 dominates.

- **Tones are timed only to vowels**
Conclusions

• What does this mean for general models of tone timing?
Conclusions

Tone timing in Igbo

• Tones and vowels are co-selected (Tilsen 2016)
• Contra findings for Mandarin and other languages, Igbo tones are not associated to the consonant

What is the prosodic unit targeted for reduction?

• Reduction affects vowel and tone equally
• Consonants and overall syllable duration are not reduced
• a mora-sized unit?
Tone timing in Articulatory Phonology

• C-center timing is diagnostic of syllable structure (Shaw et al. 2009)
• C-center effect = Syllable TBU
  • Mandarin (Gao 2008), Valjevo Serbian (Karlin 2018b)
  • Karlin (2018a) finds no clear c-center effect in Belgrade Serbian, consistent with the argument that the syllable is not the TBU in this dialect
• Lack of c-center effect, Vowel reduction effect = mora TBU
  • Igbo
• Anti-phase timing = boundary TBU (intonation)
• Thai? More research into complex tones is needed
  • Karlin 2014 examines Falling tones, suggests H is timed to onset, L to vowel, which is consistent with the tone simplification facts discussed earlier.
Tone timing in Articulatory Phonology

• So far n = 4
• Additional data collection on Igbo underway
• Additional data collection on Ikpana (Kwa; Ghana) underway (Baron, in progress)
• More diverse tone studies needed
• Definite direction for research in my next 25 years. 😊
Thank you!
References


Yip, M. (2002), *Tone*. CUP.


