The coordination of tone gestures in Thai

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Overview

- Articulatory and acoustic study of Thai tone
- Examine the timing relationships between tone and segmental gestures

**Main findings:**
- Articulatory tone-bearing unit
- Mora-like groups of gestures
The mora as the Thai tone-bearing unit

- In addition to three level tones (low, mid, and high), Thai also contrasts two contour tones, Falling (HL) and Rising (LH)
- Standard analysis: Thai tone-bearing unit (TBU) is the mora (Morén and Zsiga, 2006)
  - Only syllables with two (*sonorant) moras can carry contour tones
  - Specifically, tones associate to the right edge of a mora

<table>
<thead>
<tr>
<th>Shape</th>
<th>Moras</th>
<th>Low</th>
<th>Mid</th>
<th>High</th>
<th>Fall</th>
<th>Rise</th>
</tr>
</thead>
<tbody>
<tr>
<td>CV</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CVO</td>
<td>2*</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>CVS</td>
<td>2</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>CVV</td>
<td>2</td>
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<tr>
<td>CVVO</td>
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</tr>
<tr>
<td>CVVS</td>
<td>2</td>
<td></td>
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</tbody>
</table>
Some flaws with the “right edge” analysis

- Acoustically, the “right edge” breaks down
  - The turning point changes based on the content of the mora
  - Acoustic landmarking is not as consistent as articulatory landmarking (Prieto and Torreira, 2007)
- Standard approach does not emphasize the relationship between representation and production
Articulatory Phonology: Tones as gestures

- Aims of Articulatory Phonology (AP):
  - Explicit predictions regarding articulatory timing
  - Demonstrate implementational reality of abstract representations

- Recently, tone has fruitfully been treated as a gesture

- Proposal: a TBU is a gesture with which a tone gesture coordinates
  - In Thai, these gestures correspond with the segments that are traditionally viewed as moraic
  - The mora corresponds to a bundle of gestures that are selected and activated together: “co-selection set”
In-phase coordination

- Two gestures activated in the same phase
- Onsets together, but may not end together
- CV syllables: co-selection set with C, V gestures in in-phase coordination
Coordinating gestures: VC syllables

Anti-phase coordination

- Two gestures activated 180° out of phase with each other
- Still activated at the same time: feedback not necessary to start the temporally second gesture
- VC syllables: co-selection set with V, C gestures in anti-phase coordination
Groups of gestures that are selected together and coordinated

- **Segment-like**: Lips closing, velum lowering, vocal folds vibrating ([m])

- **Syllable-like**: Coordination of segment-like co-selection sets to make \{CV\}, \{V-C\}, \{CV-C\} (etc.) syllables

- **Mora-like**: Consists of the gesture that constitutes the segment that is considered moraic, plus any non-moraic gestures that may be associated
  - A V and its onset consonant C—\{CV\}
  - A V and its non-moraic coda C—\{V-C\}
  - A V and its tone—\{VT\}
Recent work has found that lexical tone gestures behave like consonants (Gao, 2008)

- C-center effect

--- anti-phase

--- in-phase
How is $T2$ coordinated?

- Is $T2$ most like a coda?
- What is the relationship between $T2$ and the other members of its mora?

Figure: The schematic of complex codas from Marin and Pouplier 2010 (left) and the associated coupling diagram (right).
Current study: hypotheses and predictions

▶ Hypothesis:
  ▶ There is an “articulatory TBU”—i.e., there is some gesture that T gestures are robustly coordinated with.
    ▶ Possibility 1: T gestures are coordinated within their moraic co-selection set, but not with each other
    ▶ Possibility 2: There is an additional level of coordination between T gestures

▶ Schematic below illustrates the predictions of Possibility 1:
Current study: Methods

- **Articulatory**: Electromagnetic articulograph (EMA) with sensors on tongue, lips, jaw
- **Acoustic**: For F0
- **Target words**: Bimoraic words with falling tones

<table>
<thead>
<tr>
<th></th>
<th>Monophthongs</th>
<th>Diphthongs</th>
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</thead>
<tbody>
<tr>
<td>No coda</td>
<td>mā</td>
<td>mâa</td>
</tr>
<tr>
<td>Coda: n</td>
<td>mân</td>
<td>màn</td>
</tr>
<tr>
<td>Coda: t</td>
<td>màt</td>
<td>màt</td>
</tr>
<tr>
<td>Moraic coda: n</td>
<td>màn</td>
<td>màn</td>
</tr>
</tbody>
</table>

- Two carrier sentences
- Three speeds
- Four participants
Figure guide: Trajectories

Gestural ONSETS

Lip Aperture
Tongue Body (y)
Tongue Tip (y)
Figure guide: Gestural scores

Active period of a gesture

Gestural ONSET

-50 0 50 100 150 200 250 (ms)

m
V1
T1
V2

C
/mən/, /mʊə/: $T_2$ anti-phase coupled to $\mu_2$
/mân/, /mûat/: $T2$ anti-phase coupled to coda
Variance patterns support moraic co-selection hypothesis

<table>
<thead>
<tr>
<th></th>
<th>mûan</th>
<th></th>
<th>mûa</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>St. Dev.</td>
<td></td>
<td>St. Dev.</td>
</tr>
<tr>
<td></td>
<td>V1 - m</td>
<td>V2 - n</td>
<td>T1 - V1</td>
</tr>
<tr>
<td></td>
<td>15.5 ms</td>
<td>19.3 ms</td>
<td>22.9 ms</td>
</tr>
<tr>
<td></td>
<td>17.7 ms</td>
<td>25.5 ms</td>
<td>28.4 ms</td>
</tr>
<tr>
<td></td>
<td>14.3 ms</td>
<td>15.0 ms</td>
<td>22.5 ms</td>
</tr>
<tr>
<td></td>
<td>33.2 ms</td>
<td>42.1 ms</td>
<td>42.6 ms</td>
</tr>
</tbody>
</table>

- **Same μ**: Light blue
- **Different μ**: Red
- **Moraic**: Yellow

- T1 - V2: 25.5 ms
- T1 - m: 22.5 ms
- T1 - V1: 23.0 ms
- T2 - V1: 25.9 ms
- T2 - V2: 28.6 ms
- T2 - m: 30.0 ms
- T2 - V1: 32.0 ms
- T2 - n: 31.2 ms
- V2 - V1: 32.4 ms
- V2 - m: 35.3 ms
- T1 - n: 42.1 ms
- n - m: 42.6 ms
Conclusions

- Support for Gao’s (2008) findings that T gestures are like C gestures
  - C-center effect in $\mu_1$
  - Complex coda-like organization in $\mu_2$

- T gestures show very consistent patterns of coordination with segmental gestures
  - Across target word;
  - Across speed conditions;
  - Across surrounding tone environments

- Data suggest that there is a co-selection set that resembles a mora
Diphthongs: $T1-T2$ coordination?

- Order of onsets is the same for all diphthong target words
- $T1-T2$ time lag is the same for all diphthong target words
- $V1-V2$ time lag is shorter when there is a non-moraic coda!
Discussion: $T1-T2$ coordination?

![Diagram](image)

**Figure**: A schematic of word organization including $T1-T2$ in direct anti-phase coordination, but with no coordination between $T2$ and the other second mora members.

![Diagram](image)

**Figure**: A schematic of word organization including $T1-T2$ in direct anti-phase coordination, along with each $T$ coordinated within its own mora.
Discussion: $T1-T2$ coordination

- Is it the $T1-T2$ contour that is “driving” the timing of the word?

- Not enough evidence yet, esp. with inconsistent monophthong data

- Thoughts from intonation: extended duration of words with extra pitch accents

- **Future research**: altered feedback of pitch contours (on-line, long-term effects?)
Thank you!


Discussion: Representation

- Is the whole word stored “pre-coordinated”?  
- Perhaps the tones are stored as their own unit, and lexical items are tagged for segmental and tonal content?  
- Possible evidence from Serbian:  
  - Intonational contours shift tone if there is crowding  
  - Suggests that perhaps tone and segmental content are stored separately (in Serbian)  
  - Thai intonation seems to be more of a “global” contour (i.e., %L lowers an entire tone contour)  
- Acquisition: tones acquired as a unit, or originally separate (i.e., a T1 and T2 that happen to be in one word)