Articulatory Phonology (AP) and Tonal Alignment: further testing of a proposed AP model of tone-to-segment alignment in Mandarin Chinese

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Introduction: F0-to-segment Alignment

• Accumulating evidence for regular F0-to-segment alignment patterns in a range of languages (e.g. Swedish (Bruce, 1977), English (Ladd et al., 1999), Mexican Spanish (Prieto et al., 1995), Modern Greek (Arvaniti, 1998), and Mandarin Chinese (Xu, 1998; 2002))

• Various alignment patterns between F0 targets and acoustic segments across and within languages
  – lack of a unified account for alignment patterns

• An Articulatory Phonology account proposed for tone-to-segment alignment patterns of all four Mandarin tones (Gao, 2008)
Goal of Current Study

• Investigate tone-to-segment alignment pattern in Mandarin Chinese syllables with onset ([n])
  – within the Articulatory Phonology account proposed by Gao (2008)

• Examine whether the gestural account can capture tonal alignment patterns of syllables with coronal onsets
Articulatory Phonology
(Browman & Goldstein, 1986; 1992; 2000; etc.)

• Gestures are
  – contrastive units of action and units of information
  – dynamically controlled constriction actions of distinct vocal tract organs (e.g. lips, tongue tip, tongue body, velum, glottis)

• Gestures are dynamic events that are coupled (coordinated) in modes:
  – in-phase (synchronous), e.g. onset C - V
  – anti-phase (sequential), e.g. V - coda C
C-center Effect

(Browman & Goldstein, 1988; 2000)

- Gestural coupling graph of English CCV words (e.g. stay, spa)
**Tone Gestures** (Gao, 2008)

- **Tone Gesture** are
  - the smallest units that compose tones
  - dynamic events that are coupled in different modes

- **Gesture goal:** fundamental frequency location within a speaker’s pitch range

<table>
<thead>
<tr>
<th>Tone</th>
<th>‘high’</th>
<th>‘rising’</th>
<th>‘low’</th>
<th>‘falling’</th>
</tr>
</thead>
<tbody>
<tr>
<td>H</td>
<td>L</td>
<td>H</td>
<td>L</td>
<td>H L</td>
</tr>
<tr>
<td>Tone 1</td>
<td>Tone 2</td>
<td>Tone 3</td>
<td>Tone 4</td>
<td></td>
</tr>
</tbody>
</table>
Comparison of Speech Data and Simulated Output

Pitch contours of four Mandarin tones produced by a native speaker

Pitch contours output by Task Dynamic Model (Nam et al., 2005)
C-center Coupling Model for Mandarin Syllables with [m] onset (Gao, 2008)

______in-phase coupling  - - - - - anti-phase coupling

C
  ___________ T
  \   \     /     /
   \   \   /       /
    \   \ /         /
     \___\          /
       V            V

Tone 1, Tone 2 & Tone 3

C
  _________ T1(H)
  \   \     /
   \   \   /
    \   \ /
     \___\  /
       V   /

Tone 4

Tone 1, Tone 2 & Tone 3

Tone 4
Coordination Patterns of [ma(n)] (Gao, 2008)
## Method
### Carrier Sentences

<table>
<thead>
<tr>
<th>Tone</th>
<th>Carrier Sentence</th>
<th>Tonal Environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tone 1</td>
<td>shì ‘Lǐ Sì’ bù xiǎng xún mì _____ yí shì. ‘It is ‘LiSi’ who does not want to look for ___ ceremony.’</td>
<td>HL__H__LH</td>
</tr>
<tr>
<td>Tone 2</td>
<td>shì ‘Zhāng Sān’ bù xiǎng rù mí _____ yí shì ‘It is ‘ZhangSan’ who does not want to be fascinated (about) ___ ceremony.’</td>
<td>LH__LH__LH</td>
</tr>
<tr>
<td>Tone 3</td>
<td>shì ’Zhāng Sān’ bù xiǎng rù mí _____ yì yì ‘It is ‘ZhangSan’ who does not want to be fascinated (about) ___ meaning.’</td>
<td>LH__L__HL</td>
</tr>
<tr>
<td>Tone 4</td>
<td>shì ’Lǐ Sì’ bù xiǎng xún mì _____ yì yì ‘It is ‘LiSi’ who does not want to look for ___ meaning.’</td>
<td>HL__HL__HL</td>
</tr>
</tbody>
</table>
**Method**

**Collection of Kinematic Data**

- Use of EMMA (ElectroMagnetic Midsagittal Articulometer, Perkell et al., 1992)
- Articulatory data from 5 native speakers of Beijing Mandarin
- Articulatory data of [na], [nan] embedded in carrier sentences
- F0 information extracted from Praat (with manual correction)

*Illustration of receiver locations in EMMA experiment*
Method

Data Analysis
Working Hypothesis

- The C-center coupling model also applies to syllables with onset [n]

Gestural Score of [ma] (Tone 1) and [na] (Tone 1)
## Results

- Consistent patterns across five subjects

<table>
<thead>
<tr>
<th>Target Syllable</th>
<th>CV</th>
<th>TV</th>
<th>TC</th>
</tr>
</thead>
<tbody>
<tr>
<td>[m]</td>
<td>[n]</td>
<td>[m]</td>
<td>[n]</td>
</tr>
<tr>
<td>Tone 1</td>
<td>-42.8</td>
<td>32.2</td>
<td>-34.7</td>
</tr>
<tr>
<td>Tone 2</td>
<td>-44.7</td>
<td>44.5</td>
<td>-21.5</td>
</tr>
<tr>
<td>Tone 3</td>
<td>-44</td>
<td>56.9</td>
<td>-17</td>
</tr>
<tr>
<td>Tone 4</td>
<td>-46.2</td>
<td>13.7</td>
<td>-48.3</td>
</tr>
</tbody>
</table>
Alignment Patterns of [ma(n)] & [na(n)]
Gestural Score of [na] (Tone 1)
Evidence for C-center Account (1)

TC lags (ms)

\([\text{ma(n)}] \approx [\text{na(n)}]\)

Length of T gesture (ms)

\([\text{ma(n)}] \approx [\text{na(n)}]\)
Evidence for C-center Account (2)

C gesture length (ms)

$[\text{ma(n)}] \approx [\text{na(n)}]$

V gesture length (ms)

$[\text{ma(n)}] > [\text{na(n)}]$
Evidence for C-center Account (3)

C(onset) - V(target) Lag (ms)

[ma(n)] ≈ [na(n)]
Conclusion

- Mandarin tones represented as combinations of Tone gestures within the framework of Articulatory Phonology
  - For syllables with onset [n], observed alignment is complicated by measurement of V gestures and constraints on tongue movement
  - However, evidence from comparing [m] and [n] syllables confirms that T gestures are aligned to the C and V gestures in the same pattern in these two types of syllables
- [n] syllables provide additional evidence for the Articulatory Phonology account of Mandarin Chinese syllables
  - The C-center coupling model can also apply to syllables with coronal onset
- The gestural approach provides a unified account for tone-to-segment alignment patterns
Future Research

• Further comparisons of 1) Tone gesture-to-constriction gesture (C, V) alignment, and 2) f0-to-acoustic segment alignment
  – Which of 1) and 2) displays more consistent patterns and less variability?
  – Can the gestural approach provide a better account for the issue of f0-to-segment alignment?

• Extension of the notion of ‘Tone gesture’ to other languages. Can Tone gestures be used to account for
  – tonal systems in other tone languages, e.g. Thai?
  – pitch accents in pitch accent languages, e.g. Swedish?

• Studies of prosody-to-segment alignment from a gestural perspective
  – Are the proposed T-C-V coupling relations language dependent or universal?
  – Can the gestural approach lead us to a unified account of alignment pattern observed in different languages?
Selected References:


