4pSC17: Influence of prosodic factors on segment articulations and acoustics in English

Pat Keating,
UCLA
Taehong Cho,
Hanyang University
Introduction

- Two kinds of prosodic effects:
  Boundary-marking vs. Prominence-marking
  - **Boundaries (edges):** beginnings and ends of prosodic domains, e.g. final lengthening, initial strengthening (Fougeron & Keating 1997)
  - **Prominences:** stresses and accents, e.g. stress lengthening, local hyperarticulation
- **Issue:** Cho (2002, in press) claims that edges and prominences are marked differently, are not the same strengthening/ hyperarticulation (Question A)
Two ways that prominence and edge effects could be different

1. **Opposite (conflicting) effects**
   Prominences and boundaries could be marked on the same phonetic dimensions, but in opposite ways, e.g. prominence marked by higher values but boundaries marked by lower values.

2. **Independent effects**
   Prominences and boundaries could be marked completely independently on different phonetic dimensions, e.g. prominence uses one dimension while boundaries use another.
How prominence and edge effects could be the same

3. **Converging effects:**

Prominences and boundaries could be marked on the **same** phonetic dimensions, with either

- **a.** Across-the-board effects of both prominences and boundaries separately, with no statistical interaction

- **b.** Interacting effects, e.g. a ceiling effect for total strengthening of any one syllable
Secondary issues

- Does the occurrence of initial strengthening depend in any way on the location of prominences? (Question B)
- Leaving aside edge effects and just considering two kinds of prominences, lexical stress vs. phrasal accent: When a word is accented, does the accent affect the whole word, or just the (stressed) syllable that hosts the accent? (Question C)
Outline of current study

Measure initial strengthening of C and V in CV along several phonetic dimensions while varying two prominence factors (Stress and Accent)

- Test Cho’s claim that initial-edge and prominence effects are different (Question A)
- Test for dependencies between initial strengthening and prominences (Question B)
- Test for dependencies between the prominences themselves (Question C)
Methods:
Prosodic factors tested

- Two boundary-related positions
  - Word-initial (=Utterance-medial)
  - Utterance-initial
- Two prominences
  - Lexical primary-stress (vs. secondary-stress)
  - Focal pitch accent (vs. no accent)
Methods:
Corpus

- 3-syllable words, but we look only at the initial CV syllables
- 4 factors, fully crossed
  - Consonant (n, t): \( \text{nɛbəben} \) vs. \( \text{tɛbəbet} \)
  - Stress: \( \text{ˈnɛbəˌben} \) vs. \( \text{ˌnɛbəˈben} \)
  - Accent (focused vs. unaccented)
  - Boundary in a 3-word sentence: \( \text{nɛbəben fed them} \) vs. \( \text{one deaf nɛbəben} \)
Example test utterances

- 'nɛbəbɛn fed them
- nɛbə'bɛn fed them
- tɛbə'bɛt fed them
- one deaf 'tɛbə'bɛt
- one deaf nɛbə'bɛn

(where ' = stress, underline = accent)
Methods:

- **Speakers**
  - four American English speakers
  - one male and three female phoneticians
  - the women were the 3 subjects in Fougeron & Keating (1997); one was the first author

- **Recordings**
  - total 15 repetitions of each sentence from 3 speakers, 10 or fewer from 1 speaker
  - items repeated if prosodic pattern not produced, e.g. if intermediate phrase boundary occurred mid-utterance
Methods:
Electropalatography (EPG)

- Speaker wears a false palate embedded with 96 contact electrodes
- When tongue touches electrodes, a circuit is completed and contact is registered
- Computer samples contact over entire palate every 10 msec
- A single frame of data shows how many electrodes contacted, and where
Pseudo-palate for EPG
Analysis: Regions of linguopalatal contact

- For consonants, analysis region of 45 electrodes in the front region of the palate
- For vowels, entire palate

Front Region (45 electrodes)

Molar

Back of Palate

Molar
Analysis: Linguopalatal contact measures

- C seal duration (as in our earlier studies)
- C peak contact (as in our earlier studies)
- C contact at acoustic release (perhaps more relevant perceptually than peak contact)
- Vowel contact at peak amplitude
- C-to-V maximum contact difference
Acoustic measures for: C and V

For /n/:
- Nasal duration
- Nasal energy

For /t/:
- VOT
- RMS burst energy
- Center Of Gravity (COG) of burst spectrum

For /ε/:
- Duration
- Peak Amplitude
- F1 at peak amplitude
Statistical analysis

- Basic analysis was RM ANOVA, averaging repetitions within speakers, trend $p < .08$
- Posthocs based on repetitions, $p < .01$
- Error bars in graphs are standard error
### Overview of main effects:

<table>
<thead>
<tr>
<th>Position</th>
<th>vs.</th>
<th>Prominence</th>
</tr>
</thead>
<tbody>
<tr>
<td>More C contact</td>
<td></td>
<td>Same C contact</td>
</tr>
<tr>
<td>Same V contact</td>
<td></td>
<td>Less V contact</td>
</tr>
<tr>
<td>• Greater CV contact difference</td>
<td></td>
<td>• Greater CV contact difference</td>
</tr>
<tr>
<td>More V amplitude</td>
<td></td>
<td>More V amplitude</td>
</tr>
<tr>
<td>Same V F1</td>
<td></td>
<td>Greater V F1</td>
</tr>
<tr>
<td>Longer /t/ VOT</td>
<td></td>
<td>Same /t/ VOT</td>
</tr>
<tr>
<td>Same /n/, V duration</td>
<td></td>
<td>Longer /n/, V duration</td>
</tr>
<tr>
<td>Longer C contact (trend)</td>
<td></td>
<td>Longer C contact</td>
</tr>
<tr>
<td>Less /t/ energy, less /n/ energy (trend)</td>
<td></td>
<td>More /n/ and /t/ energy</td>
</tr>
</tbody>
</table>

effects: opposite independent converging
### Main effects and interactions: do entries line up in same rows?

<table>
<thead>
<tr>
<th>MEASURE</th>
<th>Main effects</th>
<th>Main effects</th>
<th>Main effects</th>
<th>Main effects</th>
<th>Interactions</th>
</tr>
</thead>
<tbody>
<tr>
<td>C peak contact</td>
<td>BOUNDARY</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C release contact</td>
<td>BOUNDARY</td>
<td></td>
<td></td>
<td></td>
<td>Bound x Str</td>
</tr>
<tr>
<td>C seal duration</td>
<td>BOUNDARY trend</td>
<td>STRESS</td>
<td></td>
<td></td>
<td>Bound x Str x Acc</td>
</tr>
<tr>
<td>/n/ nasal duration</td>
<td>STRESS</td>
<td>ACCENT</td>
<td></td>
<td></td>
<td>Bound x Acc x Speak</td>
</tr>
<tr>
<td>/n/ nasal energy</td>
<td></td>
<td>ACCENT</td>
<td></td>
<td></td>
<td>Bound x Str x Acc</td>
</tr>
<tr>
<td>/t/ VOT</td>
<td>BOUNDARY</td>
<td></td>
<td></td>
<td></td>
<td>Bound x Acc</td>
</tr>
<tr>
<td>/t/ burst energy</td>
<td>BOUNDARY</td>
<td></td>
<td></td>
<td></td>
<td>Bound x Acc</td>
</tr>
<tr>
<td>/t/ burst COG</td>
<td></td>
<td>STRESS</td>
<td>ACCENT</td>
<td></td>
<td>Bound x Str x Acc</td>
</tr>
<tr>
<td>V min contact</td>
<td>STRESS</td>
<td></td>
<td></td>
<td></td>
<td>Bound x Str x Acc x Cons</td>
</tr>
<tr>
<td>V peak F1</td>
<td>STRESS</td>
<td>ACCENT</td>
<td></td>
<td></td>
<td>Bound x Str x Cons trend</td>
</tr>
<tr>
<td>V duration</td>
<td></td>
<td>STRESS</td>
<td></td>
<td></td>
<td>Bound x Str</td>
</tr>
<tr>
<td>V energy</td>
<td>BOUNDARY</td>
<td>STRESS trend</td>
<td>ACCENT</td>
<td></td>
<td>Bound x Str</td>
</tr>
<tr>
<td>CV contact difference</td>
<td>BOUNDARY</td>
<td>STRESS</td>
<td></td>
<td></td>
<td>Bound x Str x Acc</td>
</tr>
</tbody>
</table>

Effects: opposite independent converging mixed
Boundary and prominence effects are different

1. When they affect the same dimension in opposite ways *(conflicting)*
2. When they affect different dimensions *(independent)*
Re #1: Boundary and prominences can conflict

- /t/ burst energy
  - Is lower in initial position than in medial
  - Is higher when accented

- /n/ nasal energy
  - Is sometimes lower in initial position than in medial
  - Is higher when accented, primary-stressed
/t/ burst energy conflict: Boundary vs. Accent

![Graph showing burst energy comparison between boundary and accent for initial and medial positions, and accented and unaccented conditions.](image-url)
Re #2: Boundary and prominences can be independent

- **C peak contact**: affected only by Boundary
- **V duration**: affected only by Stress
- **/t/ burst COG**: affected only by Stress and Accent

(main effects, no interactions)
C contact measures with boundary, stress, accent

- Peak Contact
  - Initial: F = 10.06 *
  - Medial: F = 13.98 *

- Release Contact
  - Initial: F = 3.11 n.s.
  - Medial: F = 3.49 n.s.

- Peak Contact
  - Primary: F = 3.87 n.s.
  - Secondary: F = 6.17 n.s.

- Release Contact
  - Accented: F = 3.11 n.s.
  - Unaccented: F = 3.49 n.s.
Effects can also converge on the same dimensions

- **C seal duration**: Lengthening of consonants occurs in all strong positions, especially primary-stressed but also to some extent initial or accented
C seal duration with boundary, stress, accent

F=6.87

F=15.85*

F=8.17*

seal duration (ms)

seal duration (ms)

seal duration (ms)

initial  medial  prim  sec  acc  unacc
Some effects that look converging, but probably aren’t

- **C-V contact difference**: larger both when initial and when primary-stressed, but this is because effects on C and V contact are largely independent.

- **V energy**: greater especially when initial, but to some extent also when accented/stressed;

BUT initial V, unlike accented/stressed V, is *not* more open; could its greater energy come from the voice source (as in Epstein 2002)?
Some mixed effects

• /n/ nasal duration
• V contact
• V F1

All combine opposite and converging patterns, either across speakers or across conditions
Discussion, Question A
Boundaries vs. Prominence: Independent effects

- **Initial strengthening** is more about having a more constricted initial consonant with more aspiration
- **Prominence** is more about having a more open, longer, louder vowel
Boundaries vs. Prominence: Opposite effects

- **Initial strengthening** decreases C energy measures
- **Prominence** increases C energy measures
Question B: Location of initial strengthening tied to prominences?

- If initial strengthening is part of a larger system of making some parts of an utterance more prominent, we might expect it to occur preferentially with already-prominent parts of an utterance: stressed syllables and/or accented words.
Only one clear effect like this

- Initial strengthening of C release contact occurs only when *primary-stressed*
- Not a converging or ceiling effect

- ALSO /t/ VOT shows initial strengthening only when *unaccented* – not a ceiling effect - unexpected!
Stress-dependent C release contact

- **n.s.**
- **Um**
- **Ui**

release contact (%)

prim.  second.
Question C: Is the domain of accent the stressed syllable, or the word?

- Most measures, especially V measures, showed accent limited to primary-stress syllables.
- Some /t/ measures (seal duration, COG, VOT) show a whole-word accent effect on the initial syllable of words with final stress (i.e., the initial /t/ in tɛbə'bɛt reflects an accent on the word).
Accent across stress levels

- Prim. U-initial
- Second. U-initial
- Prim. U-medial
- Second. U-medial

**Bar Chart**
- **Y-axis**: Seal duration (ms)
- **X-axis**: Prim. vs. Second. U-initial vs. U-medial
- **Legend**:
  - Gray: accented
  - White: unaccented

- Prim. U-initial: tr.
- Second. U-initial: *
- Prim. U-medial: **
- Second. U-medial: n.s.
Conclusions

- **Question A**: Boundaries and prominences were articulated differently on several phonetic dimensions, with boundary effects seen more in consonants and prominence effects more in vowels.
Conclusions

- **Question B**: Initial strengthening not much tied to the prominence system
- **Question C**: Accent generally limited to primary-stressed syllables, but some phonetic dimensions reflect accent through the word
Selected references