1. Introduction

- Many languages have a phonological voicing contrast in stops, but phonetic implementation of voicing varies cross-linguistically (Keating, 1984).
- True voicing languages (e.g., Spanish) exhibit phonetic voicing (vocal fold vibration during closure) for stops with the feature [voice].
- In English, phonologically voiced stops are often phonetically voiceless in utterance-initial position (Lisker & Abramson, 1964).
- Utterance-initial position: ‘active voicing’ gestures by speakers are needed, the context to test whether or not a language has stops with pre-voicing (Beckman et al., 2013).
- Initiating or maintaining phonation during stop closure involves several adjustments, including tongue root advancement to enlarge oral cavity volume (Westbury, 1983; for fricatives: Proctor et al. 2010).
- This mechanism may also facilitate short-lag voice onset time (Cho & Ladefoged, 1999).

This study explores the tongue root position of stops in languages with different laryngeal contrasts, comparing alveolar/dental stops in utterance-initial position.

Research Questions:
1) Are laryngeal contrasts reflected in tongue position in each language?
2) Can the same acoustic realization have different tongue positions depending on whether a language shows phonological contrasts or not?

2. Methodology

Ultrasound imaging

- Ultrasound technology has been widely used in many language studies recently; relatively non-invasive and portable (Stone, 1997; Davidson, 2012).
- Smoothing Spline ANOVA was used to compare the average contours between stops (Gu, 2002; Davidson, 2006).
- Polar coordinates were used in calculating smoothing spline comparisons including tongue root position (Mielke, 2015).
- Articulatory and acoustic data were collected simultaneously
- Participants: 
  - English: 17 speakers (9M/8F)
  - Hindi: 8 speakers (4M/4F)
  - Spanish: 3 speakers (3F)
  - Korean: 2 speakers (1M/1F)
- Followed by the low vowel /a/
- 10 repetitions

Stimuli

<table>
<thead>
<tr>
<th>Language</th>
<th>Stimuli</th>
</tr>
</thead>
<tbody>
<tr>
<td>English</td>
<td>t* tie shoes</td>
</tr>
<tr>
<td></td>
<td>d* die young</td>
</tr>
<tr>
<td>Hindi</td>
<td>t* tala bandākərē</td>
</tr>
<tr>
<td></td>
<td>d* daru maṭāpēi</td>
</tr>
<tr>
<td>Spanish</td>
<td>t* tapa de una botella</td>
</tr>
<tr>
<td></td>
<td>d* datos personales</td>
</tr>
<tr>
<td>Korean</td>
<td>t* tarīta (lax)</td>
</tr>
<tr>
<td></td>
<td>t* tarīta (tense)</td>
</tr>
<tr>
<td></td>
<td>t* tarīta (aspirated)</td>
</tr>
</tbody>
</table>

3. Results

- Spanish unaspirated voiceless stops are phonetically similar to English unaspirated stops.
- English: phonated and unaspirated stops are variant realizations of the same phoneme → same tongue root position
- Spanish: phonated voiced stops and unaspirated voiceless stops are different phonemes → different tongue root position
- The difference in tongue root position reflects the phonological laryngeal contrasts.
- Articulatory differences align with a more abstract two-way laryngeal distinction that is the same for Spanish and English.

- Artificial and acoustic data were collected simultaneously.
- Participants: 
  - English: 17 speakers (9M/8F), 
  - Hindi: 8 speakers (4M/4F), 
  - Spanish: 3 speakers (3F),
  - Korean: 2 speakers (1M/1F).
- Followed by the low vowel /a/.
- 10 repetitions.

4. Discussion

- Spanish unaspirated voiceless stops are phonetically similar to English unaspirated stops.
- English: phonated and unaspirated stops are variant realizations of the same phoneme → same tongue root position.
- Spanish: phonated voiced stops and unaspirated voiceless stops are different phonemes → different tongue root position.
- The difference in tongue root position reflects the phonological laryngeal contrasts.
- Articulatory differences align with a more abstract two-way laryngeal distinction that is the same for Spanish and English.

- Korean: tongue root advancement may facilitate short-lag VOT as well as phonation during closure.
- Hindi: it is language-specific as to whether advancement corresponds to phonation or short-lag VOT, but it may be more natural to employ it for the former. It cannot be used for both.
- Tongue root position is likely a gesture controlled by speakers and used differently in languages with various laryngeal contrasts (Kingston & Diehl, 1994).

5. Future Research

- Other environments: post-vocalic c, post-fricatives.
- More languages:
  - German (similar to English).
  - Thai (3-way laryngeal contrasts).
- Effects of manner (fricatives, affricates) and vowel contexts.
- The relation between VOT and tongue root position.
- ATR tongue root position.
- "More" languages: German (similar to English), Thai (3-way laryngeal contrasts).
- "More" environments: post-vocalic c, post-fricatives.

Summary

<table>
<thead>
<tr>
<th>Phonological contrasts</th>
<th>English</th>
<th>Hindi</th>
<th>Spanish</th>
<th>Korean</th>
</tr>
</thead>
<tbody>
<tr>
<td>d</td>
<td>t</td>
<td>d</td>
<td>t*</td>
<td>d*</td>
</tr>
<tr>
<td>Phonetic implementation</td>
<td>short-lag VOT (phonation)</td>
<td>long-lag VOT</td>
<td>phonation</td>
<td>short-lag VOT</td>
</tr>
<tr>
<td>Tongue root position</td>
<td>more ATR</td>
<td>more ATR</td>
<td>no difference</td>
<td>more ATR</td>
</tr>
</tbody>
</table>

References