
The psychological reality of phonological representations: The case of Mandarin fricatives

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Introduction

- Complementary distribution of Mandarin fricatives (Duanmu 2007)

<table>
<thead>
<tr>
<th>Palatal</th>
<th>ʨ, ʨʰ, ɕ before [i, y] or [j, ɥ]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dental</td>
<td>ts, tsʰ, s</td>
</tr>
<tr>
<td>Velar</td>
<td>k, kʰ, x before non-high-front vowels/glides</td>
</tr>
<tr>
<td>Retroflex</td>
<td>ʦ, ʦʰ, ʂ</td>
</tr>
</tbody>
</table>

Hypotheses on the representations of the palatals

- [ʨ, ʨʰ, ɕ] as /k, kʰ, x/ Chao (1943)
- [ʨ, ʨʰ, ɕ] as /ʦ, ʦʰ, s/ or /k, kʰ, x/ Cheng (1968)
- [ʨ, ʨʰ, ɕ] as /ʨ, ʨʰ, ɕ/ Cheng (1973)

Wan (2010) conducted four experiment to investigate the psychological status of palatals: [ʨ, ʨʰ, ɕ] → /ts, tsʰ, s/.

- Real word stimuli
- Direct comparisons among palatals, dentals, velars, and retroflexes
- One can argue that the results only reflect the perceptual similarity between dentals and palatals.

Goal

- The current study focuses on the palatal [ɕ] and the dental [s].
- To avoid direct comparisons:
  - Compare with a contrastive sound [f]
  - Compare with the same pair of sounds in another language (Korean in which [s] and [ɕ] are allophonic)

  e.g. [sal] ‘flesh’ [ɕi] ‘poem’

[nas-ɕe] ‘sickle-loc’ [nas-ɕi] ‘sickle-nom’

Variants of the same phoneme are processed differently than contrastive phonemes (Beckman & Pierrehumbert 2000; Sumner & Samuel 2005)
**Experiments**

- Discrimination on a continuum
  - Speakers discriminate better when sounds are categorically/phonemically different. (e.g., Werker & Lalonde 1988)
- Similarity rating
  - Speakers tend to rate allophones as more similar than phonemes (e.g., Boomershine et al. 2008; Johnson & Babel 2010)
- Semantic priming
  - Facilitation between variants of a category, but not between sounds belonging to different categories (e.g., Sumner & Samuel 2005)

**Methodology**

- 20 Mandarin participants
- Stimuli: two 8-step synthesized continua
  - [s] to [ɕ]: 1, 2, 3, 4, 5, 6, 7, 8 (6 pairs)
  - [f] to [s]: 1, 2, 3, 4, 5, 6, 7, 8 (6 pairs)
- ABX discrimination paradigm comparing two step apart sound pairs
  - E.g., [s-ɕ] 1-3-1
- Participants were asked to judge if the 1st sound or the 2nd sound is the same with the 3rd sound.

**Predictions**

- If [s] and [ɕ] are perceived not different from those with [f] → [ɕ] and [s] should be considered different categories.
- If Mandarin listeners’ perception of [s] and [ɕ] are similar to Korean listeners’ perception of the same sounds → [s] and [ɕ] should be considered variants of the same category.

**Expt I: Discrimination on a continuum**

- Speakers discriminate better when sounds are categorically/phonemically different in their native language (Best et al. 1988; Lasky et al. 1975; MacKain et al. 1984; Werker & Lalonde 1988)
- Werker & Lalonde 1988: [pʰa]-[ba] continuum
  - Hindi listeners: 2 perceptual boundaries reflecting the 3 way contrast of stops
  - English listeners: 1 perceptual boundaries reflecting the 2 way contrast of stops

**Predictions**

- Categorical boundary only for the [f-s] continuum but not for [s-ɕ] continuum → [s] and [ɕ] are perceived as variants of the same category.
- Categorical boundary for both continua → [s] and [ɕ], just like [s] and [f], are perceived as separate categories.

**Results (Appendix A)**

- Accuracy

![Accuracy Graph](image-url)
Results

- There was a boundary present in both continua.
  - [f-s] continuum: around pairs 2 to 3
  - [s-ɕ] continuum: around pairs 2 to 4
- RT as a positive function of uncertainty (Pisoni & Tash 1974)
  - Shorter RTs when the comparisons of two sounds were across categorical boundary
  - Longer RTs when the comparisons of two sounds were within a category

Expt II: Similarity rating

- “Phonological relationship increases the perceived phonetic similarity of the sounds” (Johnson & Babel 2010)
- Similarity judgments of [ð], [d], and [r] by English and Spanish speakers (Boomershine et al. 2008)

Methodology

- Participants: 20 Mandarin, 20 Korean
- Stimuli: 12 VCV with [s], [ɕ], [f], and [h] in three vowel contexts (a_a, i_i, u_u), produced by a native Mandarin speaking trained phonetician.
- AX paradigm. E.g., asa-aha with 1000ms ISI
- Participants were asked to rate how similar the stimuli were on a scale of 1 to 5
**Predictions**

- Comparable similarity ratings of [s] and [ɕ] from Mandarin and Korean listeners → [s] and [ɕ] are variants of the same category.
- Mandarin listeners’ ratings of [s] and [ɕ] are more different from those of Korean listeners → [s] and [ɕ] are different categories.

**Results**

- Standardized z-score transformation: reduce variability
- The standardized scores were centered around zero, with scores above zero indicating ‘more different’ and scores below zero indicating ‘more similar.’

**Expt III: Semantic priming**

- Sumner & Samuel (2005): facilitation on lexical decision when hearing a target after a semantically related prime e.g., music → flute
- priming with canonical [t], coarticulated [ʔt’] and glottalized [ʔ]
- no priming with a contrastive phoneme *[flus]
**Method**

- The extent to which [s] primed [ɕ], or vice versa in Mandarin
- The results were compared with the priming effects when [s] and [ɕ] were changed into a contrastive sound [f].

**Stimuli:**

<table>
<thead>
<tr>
<th>Language</th>
<th>Condition</th>
<th>Prime</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mandarin</td>
<td>SAME</td>
<td>[ɕi-jan] ‘breed’</td>
<td>[tsɔŋ-wu] ‘animal’</td>
</tr>
<tr>
<td></td>
<td>[ɕi-jan] ‘banquet’</td>
<td>[tɕje-hun] ‘wedding’</td>
<td></td>
</tr>
<tr>
<td></td>
<td>cf. [ɕi-jin] ‘attract’</td>
<td>[sɿ-pow] ‘stone’</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SWAPPING</td>
<td>*[ɕi-jan]</td>
<td>[tsɔŋ-wu] ‘animal’</td>
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<td>*[fi-jan]</td>
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<td></td>
<td>cf. *[fi-jin]</td>
<td>[sɿ-pow] ‘stone’</td>
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**Participants:** 60 Mandarin

**Conditions:** Same, Swapping, Contrastive

**Norming pretest**

**Stimuli:**

- Between-subject design
- 72 primes
- 36 related targets
- 36 unrelated targets
- Fillers: 18 real words, 90 pseudowords

**Results**

- The mean RTs and the priming effects (the difference between Related and Unrelated) with standard deviations in parentheses

<table>
<thead>
<tr>
<th>Condition Relation</th>
<th>Same</th>
<th>Swapping</th>
<th>Contrastive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Related</td>
<td>1014.94 (110.34)</td>
<td>1019.19 (106.21)</td>
<td>1062.26 (135.16)</td>
</tr>
<tr>
<td>Unrelated</td>
<td>1137.34 (116.27)</td>
<td>1123.48 (107.22)</td>
<td>1133.46 (139.57)</td>
</tr>
<tr>
<td>Priming effect</td>
<td>122.4</td>
<td>104.29</td>
<td>71.2</td>
</tr>
</tbody>
</table>
Results—Mandarin

![Graph showing RT and priming effect](image)

Discussion

- There is no three-way difference in RT corresponding to same, allophonic, or contrastive sounds.
- The results do not seem to conform to the previous two experiments in which [s] and [ɕ] are shown to belong to separate categories.

Discussion

- Illegal sequences in Swapping and Contrastive conditions
- Ganong (1980): a tendency for listeners to make phonetic categorizations that make words
- Illegal sequences, phonetic similarity, and context help to map into possible legal sequences.
- Follow-up: adding a 4th condition with less phonetic similarity ([t]), half legal, half illegal: 20 Mandarin participants

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<td>[tcje-hun] 'wedding'</td>
</tr>
<tr>
<td>t</td>
<td>(illegal)</td>
<td>*[ti-jan]</td>
</tr>
<tr>
<td></td>
<td>(legal)</td>
<td>[ti-jan]</td>
</tr>
</tbody>
</table>

Results (Appendix D)

![Graph showing RT and priming effect](image)
Results—Mandarin

![Graph showing RT against Phoneme]

Discussion

- We found priming even for [t], but significantly less than the other three conditions
- No significant facilitation for legal sequences
- Priming due to illegal sequences, and phonetic similarity

Conclusion

- The psychological reality of the phonological representations of two Mandarin fricatives [s] and [ɕ]
- The categorical perception on a [s-ɕ] continuum, and the phonemic-like judgment on the similarity rating task \( \rightarrow [s] \) and [ɕ] are more phonemic than allophonic.
- Semantic priming tapped into different levels of processing.

Conclusion

- Sounds in complementary distribution, like [s] and [ɕ] in Mandarin, need not map onto the same underlying representation.
- The results support a framework in which there is a close match between underlying and surface representation except where allomorphic alternation requires two surface forms to derive from a single UR (e.g., Lexicon Optimization Principle or the Identity Map Hypothesis in Optimality Theory)
- Other requirements for defining phonological relationships e.g., morphological alternation, phonetic similarity
- Gradient phonological relationships (Hall 2009)
Acknowledgment

THANK YOU

- This work was supported by
  - NSF grant BCS 0746027 to Ellen Broselow, Marie Huffman, and Nancy Squires.
  - Chiang Ching-Kuo Foundation Dissertation Fellowship
- Special thanks to Dr. Yuwen Lai from National Chiao Tung University for making the subject-recruiting and experiment-running possible in Taiwan.

Appendix A

- A repeated measure analysis on [f]-[s] continuum:
  - Main effect of PAIR (F(5, 95) = 22.149, p < .001)
  - Pairwise comparisons: pairs 2&3 were not significantly different (p > .859), but pairs 1&2, and pairs 3&4 were significantly different (both p < .001).

- A repeated measure analysis on [s]-[c] continuum:
  - Main effect of PAIR (F(5, 95) = 9.620, p < .001)
  - Pairwise comparisons among pairs 2, 3, and 4 were shown not significant (all p > .05). Pairs 1&2, and 4&5 were significantly different (both p < .05).

Appendix B

- A repeated measure analysis (LANGUAGE: Mandarin, Korean; PAIR: [f-s, f-c, f-h, s-c, s-h, c-h]) was performed.
  - Main effect of PAIR (F(5, 38) = 73.545, p < .001), and significant PAIR by LANGUAGE interaction (F(5, 190) = 15.077, p < .001)
  - Simple effect of LANGUAGE in [s]-[c] pair was significant (F(1, 38) = 36.692, p < .001)

Appendix C

- Main effects of Relation (F(1, 57) = 171.660, p < .001; F(1, 210) = 47.836, p < .001)
  - The factor Condition yielded a significant effect in an analysis on priming (F(2, 127) = 4.356, p < .05).
  - Pairwise comparisons: the priming effects in the Same & Contrastive conditions were statistically different (p < .05); the other two pairwise comparisons (Same & Swapping, Swapping & Contrastive) were not (both p > .2).

Appendix D

- Simple effect of Relation in t condition (F(1, 39) = 9.211, p < .005)
  - Pairwise comparisons: the priming effects in the t & other conditions were all statistically different (all p < .05)
  - Simple effect of Relation in t (illegal) condition was significant (F(1, 19) = 9.173, p < .01)
  - Simple effect of Relation in t (legal) condition was not significant (F(1, 19) = 2.597, p = .124)