What is in the neighborhood of a tonal syllable? Evidence from auditory lexical decision in Mandarin Chinese

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Introduction

• Words in a lexicon are not isolated islands. They are connected via various relations.

• Lexical neighbors can affect each other in lexical processing
  – Due to co-activation
  – Nature of such influence often depends on the task

• In this project, we focus on a particular type of lexical neighbor, i.e. phonological neighbor
Phonological neighborhood

• Similar sounding words form phonological neighborhoods
  – Often defined by the 1-phoneme difference rule (Luce & Pisoni, 1998)

Common measures:
• Neighborhood density (ND) = # of neighbors
• Neighborhood frequency (NFreq) = Avg. freq of neighbors
Effects of phonological neighbors on word processing

• Phonological neighbors
  – May compete with the target word
  – May also bring more activation to the target word
  – Opposite overall effects in perception and production
    • Inhibit spoken word perception (Luce & Pisoni, 1998, Vitevitch & Luce, 1999)
  – High-density words are harder to perceive but easier to produce.
Effects of phonological neighbors on phonetic variation

• High-density words tend to be
  – Phonetically reduced in spontaneously produced conversational speech (Gahl et al. 2012)
When we look across languages...

• Effects of phonological neighborhoods are not entirely consistent across languages
  – In French, high-density words are harder to perceive (Dufour & Frauenfelder, 2010; Ziegler et al. 2003), harder to produce (Sadat, et al. 2014) and hyperarticulated in conversational speech (Yao & Meunier, 2014)
  – In Spanish, high-density words are easier to perceive but harder to produce (Sadat, et al. 2014; Vitevitch & Rodríguez 2005, Vitevitch & Stamer 2006, 2009)
    • Phonologically related words also tend to be morphologically related. Higher percentage of onset-sharing neighbors.
    • Differences attributed to word structure, morphology and neighborhood structure
What about Mandarin Chinese?

• What would the Mandarin phonological neighborhood look like?
  – Tone
    • Previously proposed neighborhood models only consider segmental differences (e.g. the 1-phoneme difference rule) and mostly consist of short words (e.g. CVC)
  – Homophone
    • Previous models do not need to consider homophones due to the low number of homophones (i.e. words sharing the same phonological form) in European languages
Research questions

• Q1: Should tonal neighbors be included as well? How to modify the 1-phoneme difference rule?

• Q2: Do homophones have the same effects as neighbors? ND = num. of similar phonological forms or num. of lexical units associated with similar phonological forms?
Mandarin lexicon (cf. English)

- **Mandarin** (Zhou and Marslen-Wilson 1994, 2009)

- **English** (Luce and Pisoni, 1998)
Mandarin lexicon (cf. English)

- English (Luce and Pisoni, 1998)
Previous studies on Mandarin

• Neighborhood effects
  – Tonal and segmental cues are used concurrently but in different fashions in the recognition process of spoken monosyllabic words \cite{MalinsJoanisse2010, MalinsJoanisse2012}
  – ND defined with the 1-phoneme difference rule has an inhibitory effect in auditory naming \cite{Tsai2007, KirbyYu2007}
  – Neergaard and Huang (2016) tested the effects of ND and NFrq values under different neighbourhood models in auditory word naming, but the results are unclear due to issues in study design and statistical analysis.

• Homophone effects
  – Inhibitory effects of homophone density in auditory lexical decision \cite{Wang2012}
Current study

• Goals
  – To explore the phonological neighborhood effects and homophone effects in spoken Mandarin word recognition
  – To compare the effects of neighborhood metrics derived from different neighborhood models

• Experimental tasks
  – Auditory lexical decision
  – Auditory word naming
Stimuli

• Real monosyllables
  – N = 1258
  – ALL Mandarin syllables that can be associated with at least one morpheme (character).

• Pseudo (unattested) monosyllables
  – Accidental gaps
    • 353 “tonal” gaps (e.g. [tʰa 25])
    • 408 “segmental” gaps (e.g. [tʰiɑ 51])
Lexical measures

- Based on the Subtlex-CH corpus (Cai, Q., & Brysbaert, M. 2010, Neergaard et al. 2016)
  - Syllable frequency (Frq)
  - Neighborhood density and neighbor frequency (ND, NFrq)
    - ND = num. of unique phonological forms
    - 1-difference rule under different schemes (Neergaard et al. 2016)
  - Homophone density (HD)
    - Num. of morphemes with the same syllable (including tone)

<table>
<thead>
<tr>
<th></th>
<th>Including tone</th>
<th>Not including tone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit = segment</td>
<td>ND_SegT, NFrq_SegT</td>
<td>ND_Seg, NFrq_Seg</td>
</tr>
<tr>
<td>Unit = component (onset, rhyme)</td>
<td>ND_CompT, NFrq_CompT</td>
<td>ND_Comp, NFrq_Comp</td>
</tr>
</tbody>
</table>
Subjects

• 78 native speakers of Mandarin, mostly born and raised in Mainland China
  – 49F, 29M
  – Mean age = 21.7 y.o., SD = 3.77
Experimental procedure

• Auditory lexical decision
  – Auditory stimuli ➔ Decide on lexicality (real vs. pseudo syllable) as fast and accurately as possible
  – Response time (RT) and accuracy recorded
  – 1258 real syllables divided into 6 blocks. One block per subject
  – 12 items shared across blocks, to evaluate cross-block consistency
Data overview

- Average RT and accuracy rates

<table>
<thead>
<tr>
<th>Condition/item type</th>
<th>RT (ms)</th>
<th>Accuracy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Auditory lexical decision</strong></td>
<td></td>
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</tr>
<tr>
<td>Real syllables</td>
<td>1023 (sd = 375)</td>
<td>83.6</td>
</tr>
<tr>
<td>Pseudo syllables (tonal gaps)</td>
<td>1137 (sd = 466)</td>
<td>84.5</td>
</tr>
<tr>
<td>Pseudo syllables (segmental gaps)</td>
<td>995 (sd = 376)</td>
<td>91.6</td>
</tr>
</tbody>
</table>

- Cf. Wang et al. (2012), Avg RT = (794ms, 836ms), SD around 70. In total, 60 stimuli, all associated with frequently used words
ND and syllable length

- A general trend for ND to decrease with syllable length
  - Focus on 3-phoneme (CXX) syllables for now

![Mean ND by syllable length](chart.png)
Statistical analysis

- (Generalized) Mixed-effects modeling
  - Outcome: log(RT), Accuracy (1 or 0)
  - Fixed effects
    - Neighborhood density, log(neighbor frequency)
    - Homophone density
    - log(Frq)
    - log(item duration), tone
  - Random effects
    - Subject, Item

- Different sets of neighborhood metrics tested in separate models; real syllables and pseudo syllables modelled separately
## Modeling results: Exp1

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Neighborhood density (ND) and neighbor frequency (NFrq) effects</th>
<th>Homophone density effects (HD)</th>
</tr>
</thead>
</table>
| Real syllables        | Best neighborhood predictors: \( \text{ND}_\text{SegT} (\beta = 0.002, t = 2.5) \)  
                          \( \text{NFrq}_\text{SegT} (\beta =-0.01, t = -3.0) \)  
                          Other sets of neighborhood measures show similar trends but with reduced significance | n.s. \((|t|<1)\)               |
| RT                   |                                                                                                                               |                               |
| Accuracy              | n.s.                                                                                                                          | \( \beta = 0.25, t =3, p =.003 \) |
| Pseudo syllables      | Best neighborhood predictors: \( \text{ND}_\text{SegT} (\beta = 0.011, t = 8.4) \)  
                          \( \text{NFrq}_\text{SegT} \) (n.s.)                                                                 | --                            |
| RT                   |                                                                                                                               |                               |
| Accuracy              | \( \text{ND}_\text{SegT} (\beta = -0.12, t = -4.4, p <.001) \)  
                          \( \text{NFrq}_\text{SegT} \) (n.s.)                                                                 | --                            |
General findings

- Auditory lexical decision
  - Higher ND → Longer RT  inhibit
  - Higher NFrq → Shorter RT  facilitate
  - Higher HD → Higher accuracy  facilitate
  - Neighborhood measures using the 1-phoneme/toneme rule are most sensitive
  - Patterns persisted in alternative models that separated ND and NFrq with residualization
Revisit the questions

• Q1: Should tonal neighbors be included as well? Does the 1-phoneme difference rule still apply?
  – Yes tonal neighbors should be included in the neighborhood.
  – It seems that the 1-phoneme/toneme rule would produce neighborhood measures sensitive to behavioral data from lexical decision.
Revisit the questions

• Q2: Do homophones have the same effects as neighbors? ND = num. of similar phonological forms or num. of lexical forms with similar phonological forms?
  – Homophone effects are not exactly the same as neighborhood effects.
  – Contra Wang et al. (2010), we found facilitatory effects of homophone density in auditory lexical decision.
  – In an alternative analysis, neighborhood density calculated as the number of lexical neighbors did not produce significant effects in any model.
Revisit the lexicon model

- **Mandarin** (Zhou and Marslen-Wilson 1994, 2009)

  - Our results suggest that neighborhood effects exist at the PF level, and provide evidence for the nature of the effects.
Future work

• Complete the analysis of word naming data
• Interaction of neighborhood density and neighbor frequency
  – Strong vs. weak neighbors (Chen & Mirman, 2012)
• Thanks!
• Questions and comments are extremely welcome.
Selected References


References (cont’d)


