How attention to speech pitch is guided by its linguistic function

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The puzzle

• Speech stream contains
  – segmental information
    (cued by spectral changes)
  – suprasegmental, prosodic information
    (cued by duration, intensity, pitch)

• How are these two layers of information processed and integrated?
  – in production
  – in perception
  – in first language acquisition
Research question

• How do listeners process and attend to segments and pitch information?

• Is processing of pitch information influenced by language experience
  – listeners from tonal and non-tonal languages
Previous work on pitch processing

• Similarities between listeners from tonal & non-tonal languages
  – segments weighed more heavily than pitch (Cutler & Chen 1997, Ye & Connine 1999)
  – classification rate for non-speech f0-variation (Bent et al. 2006)
  – ...

• Differences regarding
  – processing of pitch level vs. contour tones (Gandour 1983)
  – lateralization of pitch processing (Wang, Jongman & Sereno 2001)
  – mismatch negativity in tone processing (Chandrasekaran et al. 1997)
  – perception of tones from another tone language (Francis et al. 2008)
  – ...
Do we need yet another study?

• Yes: Tacit assumption that lexical tones are *meaningless* (= non-linguistic) for listeners from an intonation language

• Is that really the case?

• No, pitch movements may be interpreted as
Research question *refined*

- How do listeners process and attend to segments and pitch information?

- Is processing of pitch information influenced by language experience
  - listeners from tonal and non-tonal languages

- Is processing of pitch information influenced by the role pitch plays in a given stimulus?
  - lexical information (lexical tone)
  - postlexical information (e.g., sentence type)
  - non-linguistic information
Current study

• When in conflict, do listeners rely more on segments or on pitch information?

• Is there a difference in reliance on these sources if pitch signals
  – potential lexical information
  – postlexical information
  – non-linguistic information

• ABX match-to-sample task (Dupoux et al. 1997)
  – congruent trials: X matches one of standards in segments and pitch (different token of same type)
  – incongruent trials: X matches one of the standards in pitch and the other one in segments
Experiment 1

• Processing of pitch rises that
  – are non-linguistic (Dutch listeners)
  – signal potential lexical information (Chinese listeners)
Experiment 1

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• Two listener groups
  – 8 native Dutch listeners (non-tonal dialects)
  – 8 native Mandarin Chinese listeners

• Two segmentally similar nonword pairs:
  – denu - zemu
  – mova - noba
Example of the Procedure

• **ABX task** – order of A and B counterbalanced
  
  – congruent condition (16 trials)
    
    e.g., mova-fall **denu-rise** mova-fall

  
  – incongruent condition (16 trials):
    
    e.g., mova-fall **denu-rise** **denu-fall**
Example of the Procedure

- **ABX task** – order of A and B counterbalanced
  - congruent condition (16 trials)
    e.g., mova-fall  denu-rise  mova-fall
  - incongruent condition (16 trials):
    e.g., mova-fall  denu-rise  denu-fall

1000ms  600ms  900ms

Analysis of response type (A or B) and reaction time
Rationale and Hypothesis

• **Responses:**
  – most responses along segmental dimension

• **Reaction times (RTs):**
  – RTs in congruent trials as baseline
  – increase in RT in incongruent trials suggests that pitch is attended to and competes with segmental information (interference)

• **Hypothesis:**
  – the more linguistically relevant pitch, the stronger the interference
Results: response type

- in congruent trials, no difference across languages

Condition

% classification segmental dimension

Dutch
Chinese

non-linguistic ↔ lexical
Results: response type

- In congruent trials, no difference across languages.
- In incongruent trials, Chinese listeners responded less along segmental dimension.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Dutch</th>
<th>Chinese</th>
</tr>
</thead>
<tbody>
<tr>
<td>Congruent</td>
<td>100</td>
<td>95</td>
</tr>
<tr>
<td>Incongruent</td>
<td>90</td>
<td>60</td>
</tr>
</tbody>
</table>
Results: reaction times
(only responses along segmental dimension)

- in congruent trials, no difference across languages
Results: reaction times
(only responses along segmental dimension)

- in congruent trials, no difference across languages
- in incongruent trials, Chinese listeners slowed down more than Dutch listeners
Interim Summary

- **Chinese listeners (pitch is potentially lexical)**
  - significant decrease in responses along segmental dimension in incongruent stimuli
  - increase in RTs in incongruent stimuli

- **Dutch listeners (pitch is non-linguistic)**
  - no difference in responses across conditions
  - increase in RTs in incongruent stimuli (but less than for Chinese listeners)
Follow-up question

• Is processing of postlexical pitch information (also linguistically meaningful) comparable to processing of potential lexical information?

• Replication of Experiment 1 with modified materials and another set of
  – 8 Dutch listeners
  – 8 Chinese listeners
Experiment 2

• Processing of pitch rises that signal
  – paralinguistic information (Dutch listeners)
  – potential lexical information (Chinese listeners)
Results: response type

- significant interaction: Chinese listeners show effect of trial type (congruent vs. incongruent), Dutch listeners not
Results: reaction times

- in congruent trials, again no difference across languages
Results: reaction times

- In congruent trials, again no difference across languages
- In incongruent trials, Chinese listeners slowed down more than Dutch listeners
Interim Summary

- **Chinese listeners (pitch is potentially lexical)**
  - significant decrease in responses along segmental dimension in incongruent trials
  - increase in RTs in incongruent trials

- **Dutch listeners (pitch is postlexical)**
  - no difference in responses across conditions
  - increase in RTs in incongruent trials
  - but less than for Chinese
  - more than for non-linguistic pitch rises (Experiment 1)
Conclusions

• Increase in RTs in incongruent trials is modulated by linguistic function of pitch in stimuli
  – non-linguistic < postlexical < lexical
Discussion

• Non-linguistic (unfamiliar) pitch movement also increases RTs and therefore
  – is attended to
  – is stored in short-term memory
  – interferes with processing
→ Dutch listeners not ‘tone-deaf’

• Chinese listeners even classify stimuli along pitch dimension

• Even though stimuli are nonwords
Discussion

• Ability to process and store pitch information in short-term memory is dependent on
  – linguistic experience
  – precise linguistic function of pitch in stimuli

• In conflict, segments outweigh pitch information
• Although meaningful, postlexical pitch information processed differently than potential lexical information

• Future work:
  – how does sensitivity to segments and pitch develop in L1?
  – can learners of tone language acquire native-like mechanisms?
  – how is paralinguistic information processed?
Thank you for your attention