Electrophysiological Evidence for Early Categorical Processing of Tones

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Outline

- Introduction
- Materials and methods
- Results
- Discussion
- Conclusion
Categorical perception (CP):

- People divide the various speech sounds into certain linguistic categories.

The major signature of CP:

- Tone perception of Mandarin: **categorical perception**
Introduction

- **Event-related potentials (ERPs) components:**
  - Mismatch negativity (MMN)
  - Auditory N1 wave

In present study:
- Adaptation paradigm
- Active discrimination task

Expect:
- Different responses
- Lateralization
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Materials and methods

- Participants:
  - 12 participants (6 males and 6 females)
  - Right-handed
  - From the northern part of China
  - High self-evaluation score of Mandarin
  - Normal hearing
Materials and methods

Stimuli:

- Speech: syllable [i]
- Nonspeech: triangle waves

<table>
<thead>
<tr>
<th>Stimulus number</th>
<th>Onset Frequency</th>
<th>Offset Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>150 Hz</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>145 Hz</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>140 Hz</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>135 Hz</td>
<td></td>
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<tr>
<td>7</td>
<td>130 Hz</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>125 Hz</td>
<td></td>
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<tr>
<td>5</td>
<td>120 Hz</td>
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<tr>
<td>4</td>
<td>115 Hz</td>
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<tr>
<td>3</td>
<td>110 Hz</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>105 Hz</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>100 Hz</td>
<td></td>
</tr>
</tbody>
</table>

Stimuli:

- Within-category change:
  - 1-4, 4-1;
  - 8-11, 11-8
- Across-category change:
  - 4-7, 7-4;
  - 5-8, 8-5
- No-change:
  - 1-1; 5-5;
  - 7-7; 11-11

Materials and methods

- Data analysis:
  - Behavioral responses: accuracies and RTs.
  - EEG recordings: referenced offline against average-mastoid reference.

- N1:
  - F1, F2, F2
  - FC1, FC2, FC2
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Results

艟 Behavioral accuracy

ichte mean RT

Two-way (context × category) repeated measures ANOVAs:

- category: p < .001 ***
-  p < .001
Results

- N1 latency

- Three-way (context × category × position) repeated measures ANOVAs:
  - context: p < .005**
  - context × position: p = .05*
    - Marginal means: 117.8 ms, 125.0 ms

- The detection of speech stimuli was faster than that of nonspeech stimuli.
Results

N1 amplitude

- Three-way (context × category × position) repeated measures ANOVAs:
  - context: $p < .05$ * (speech: $-1.93 \ \mu V$; nonspeech: $-2.83 \ \mu V$)
  - category: $p < .05$ *
  - context × position: $p < .05$ *
  - context × category × position: $p < .05$ *
Results

Two-way (category × position) repeated measures ANOVAs

category × position:

category: p<.05*
position: p<.05*

N1 wave

(a) Speech

(b) Nonspeech

No-change
Within-category change
Across-category change
Results

› One-way *(category)* repeated measures ANOVAs were limited to speech context.

\[\begin{array}{c}
\text{Left} \\
\text{Right}
\end{array}\]

\[\begin{array}{c}
\text{category: } p = .06
\end{array}\]

\[\begin{array}{c}
\text{category: } p < .005^{**}
\end{array}\]
Introduction
Materials and methods
Results
Conclusion
In present study:

- **speech context** < **nonspeech context**

- **speech context** < **nonspeech context**

**Van Wassenhove et al. (2005):**

- Better predictor
Discussion

- CP effect exists:
  - Greater CP effects were found in speech than in nonspeech. (Xi et al., 2010; Zheng et al., 2011)

- Left hemisphere is more responsive to linguistic/phonological functions. (Gandour et al., 2004)

- p < .05
Henkin et al. (2010): the N1 amplitude of congruent stimuli was greater than that of incongruent stimuli.

In present study:

- Speech "congruent" vs. incongruent

![Graph showing N1 amplitude over time for different types of stimuli]
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The results of N1 latency showed that the detection of speech sounds was quicker than that of nonspeech sounds.

N1 amplitude elicited a CP effect only in speech context, indicating a speech-specific processing underlying speech perception.

The left hemisphere is more responsive to linguistic/phonological functions.
Acknowledgements

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Thank you!
References

Backup: distribution map

- **N1:**
  - F1, F2, F2
  - FC1, FCz, FC2
  - a) 90 – 150 ms

- **N2:**
  - F1, F2, F2
  - c) 240 – 300 ms

- **P2:**
  - P1, Pz, P2
  - POz
  - b) 150 – 210 ms

- **P300:**
  - P1, Pz, P2
  - PO3, POz, PO4
  - d) 300 – 500 ms
Backup: N1 lateralization

- Three-way (context $\times$ category $\times$ position) repeated measures ANOVAs:
  - Context **
  - Category *
  - Within category V.S across category *

- Two-way (category $\times$ position) repeated measures ANOVAs:
  - For speech: position $p=0.052$
Intensity levels of speech and nonspeech stimuli were 65 dB and 75 dB, respectively, so that participants would perceive the two types of stimuli as having comparable loudness.

All stimuli were presented binaurally at a sound pressure level that was comfortable for each subject.
This experiment consisted of four testing blocks, two for each context condition. In each testing block, 16 stimulus groups (four for within-category changes, four for across-category changes, four for no changes, and four for fillers) were repeated 15 times in a pseudo-random order.
Participants were instructed to press a mouse button at the end of the fourth stimulus to indicate whether they had perceived a change in the last stimulus. The hands used to respond "same" and "different" were changed in the middle of each experiment and counterbalanced across participants.