The discrimination of tonal contrasts by monolingual and bilingual adults

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Abstract

In previous TAL [1], we have demonstrated non-tone-learning monolingual and bilingual infants' tone perception in the first year of life. This talk presents a follow-up study on the tone discrimination patterns in the adulthood, specifically in Chinese (tone-language), Dutch (non-tone-language), and Dutch simultaneous bilingual adults (non-tone-languages). Interestingly, adults from all language conditions perform similarly in AX and AXB discrimination tasks for two tonal contrasts. A slight advantage can be observed in the sequence of Chinese adults > Dutch simultaneous bilingual adults > Dutch adults when perceiving a contracted (more difficult) tonal contrast in an upward order. The influence of bilingualism on tone perception as well as acoustic salience is discussed linking our previous finding that bilingual infants present earlier sensitivity rebound in discriminating tonal contrast [2].

Index Terms: tone, adult, speech perception, bilingualism, acoustic salience

1. Introduction

Learning two languages instead of one has profound influence on human speech perception and cognitive development [3]. Bilingualism affects language development and cognition from infancy [4, 5] to adulthood [6]. This paper focuses on the perception of tonal contrasts by tone-language monolingual, non-tone-language monolingual and bilingual adult listeners.

Tracing back to the first year after birth, non-tone-learning monolingual and bilingual infants were argued to differ in their developmental patterns when perceiving tonal contrasts [2, 7]. While non-tone-learning infants displayed unanimous sensitivity decrease to tonal contrast when tuning to the native phonological inventory by the second half of the first year after birth [8-11], bilingual infants seemed to present a faster sensitivity rebound to tonal contrasts than their monolingual peers [2, 7]. Specifically, none-tone-learning monolingual and bilingual infants showed initial sensitivity to tonal contrast at 5-6 months, and their sensitivity decreased at 8-9 months. Bilingual infants displayed sensitivity rebound at 11-12 months, whereas monolingual infants did not show such trace until later at 17-18 months. The acoustic salience of the tonal contrast influences infants' tone perception. The findings above only surfaced when infants discriminated a contracted T1-T4 tonal contrast (Mandarin Chinese), whereas their discrimination of the T1-T4 contrast remained intact.

As for adult listeners, previous studies largely focus on the comparisons between tone-language and non-tone-language adults' perceptual patterns. Several studies showed that non-tone-language listeners perceived tones as non-linguistic information [12, 13], and processed prosodic variation at the sentence level (e.g. as intonation) [14-18], whereas tonal categories functioned to distinguish between segmentally identical words in tone-language listeners [19]. Moreover, tones were perceived in the left hemisphere just as other speech segments for tone-language listeners and in the right hemisphere for non-tone-language listeners [20-25]. Similar to infant data, contrast acoustic difficulty influenced listeners' perception [18].

As for the comparison between monolingual and bilingual adults, it has been found that noise affected late bilingual listeners' word recognition in a noise condition [26]. Moreover, simultaneous bilingual adult listeners did not seem to have shared phonological categories for similar phones in their two L1s when discriminating coronal contrasts, unlike early bilingual listeners which seemed to merge the two categories [27].

While the influence of bilingualism was often studied in infant population, not much has been investigated in the perceptual difference between monolingual and simultaneous bilingual adult listeners, let alone the field of tone perception. Unlike consonants and vowels which often introduce L1 transfer in non-tone-language environment. Evidence from categorical perception studies suggests that tones are perceived psycho-acoustically by non-tone-language listeners whereas linguistically by tone-language listeners [15-17]. Moreover, given the perceptual differences found between non-tone-learning monolingual and bilingual infants, it is interesting to see if similar fashion can be shown between non-tone-language monolingual and bilingual adult listeners. In the current study, we test two contrasts that differ in the degree of salience among listeners from various language backgrounds.

The research questions are: 1) How do non-tone-language monolingual, non-tone-language simultaneous bilingual, and tone-language monolingual listeners perceive tones? 2) How does the acoustic salience of the tonal contrast influence monolingual and bilingual adults' perception?
2. Experiments

2.1. Exp.1 – AX discrimination task

2.1.1. Stimuli

Four connectical tones exist in Mandarin Chinese (Fig.1): high-level (T1), middle-rising (T2), low-dipping (T3) and high-falling (T4). The first contrast, a high-level tone (T1) versus high-falling tone (T4) in Mandarin Chinese, was selected to create the stimuli. The tone-bearing syllable was /ta/. Both /ta1/ ‘build’ and /ta4/ ‘big’ are words in Mandarin. The productions of a Mandarin female speaker were recorded using the computer program Audacity [28] via a microphone (active speaker Genelec 1029A) in a sound-proof booth of Utrecht University phonetics lab. For each sound, four natural T1-T4 pairs were recorded to create within-speaker variation. The four natural Mandarin T1-T4 pairs created above were further manipulated via PRAAT [29]. The pitch distance between T1 and T4 was contracted to two F0 values occurring at 3/8 and 3/4 of the pitch distance of the original contrast, respectively, by introducing four interpolation points along the pitch contours (at 0%, 33%, 67% and 100%, see Fig.4). The new contrast shares precisely the same acoustic properties with the T1-T4 contrast used in Experiment 1 except for featuring a narrower distance between the pitch contours, thus shrinking the perceptual distance between the two tokens. In other words, the acoustic salience of this phonetic contrast is weakened by a pure manipulation of F0. Once again, four pairs of the contracted contrast were generated to account for within speaker variation (Figure 1).

Figure 1: T1-T4 [A] and contracted T1-T4 [B] contrasts

2.1.2. Participants

A total number of 100 normally developing adults (mean age: 25 years) participated in the study. Data from 90 adults were incorporated into the analysis eventually, with a drop-out rate of 10%. The exclusion criteria were: equipment failure (6); fail to understand the test (1); previous exposure to a tone-language in the non-tone-language conditions (3). These participants were from 3 language conditions: monolingual Dutch, monolingual Chinese and bilingual Dutch adult listeners. The other L1s in bilingual adults varied. All bilingual participants are simultaneous bilinguals. That is, they hear more than one language from the beginning of life. No monolingual or bilingual adults have exposure to any pitch accent or tone languages. Each language condition consisted of 30 listeners.

2.1.3. Procedure

Participants heard one pair of stimuli (A & X) per trial, and were required to respond as accurately and quickly as possible by clicking one of the two buttons on the screen, labeled “same” and “different”, upon hearing each pair. After each click, the next trial was presented. Participants’ responses to steps 1-8 and 3-6 were recorded 8 times for each participant along with filler trials. The total experiment was 5 minutes for each task.

2.1.4. Results

A One-way ANOVA was conducted with language condition (3-level) as the fixed factor. The dependent variables included mean correct discrimination response proportion with both separated and integrated stimuli presenting order, and with the two contrasts separated. The reason of looking into responses with separated orders was that some order effects were found in our previous studies [30]. For the T1-T4 contrast, a ceiling effect was observed, with no significant difference across participants (Figure 2).

For the contracted T1-T4 contrast, the only significance appeared when the pitch contours were presented in an upward order, F (2, 83) = 3.262, p = .043 (Figure 3). Post hoc analysis showed that under this order, monolingual Chinese participants discriminated the contrast significantly better than monolingual Dutch participants (p = .040, Bonferroni). One-sample t-tests showed that only monolingual Chinese participants discriminated the contrast above chance, and that bilingual Dutch listeners’ performance fell in between monolingual Chinese and Dutch listeners (Table 1).

Table 1: The discrimination of the contracted T1-T4 contrast

<table>
<thead>
<tr>
<th>Language</th>
<th>t (df)</th>
<th>sig</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Lower</td>
</tr>
<tr>
<td>Chinese</td>
<td>3.471 (29)</td>
<td>.002</td>
<td>.065</td>
</tr>
<tr>
<td>Bilingual</td>
<td>1.473 (25)</td>
<td>.153</td>
<td>-.034</td>
</tr>
<tr>
<td>Dutch</td>
<td>-.559 (29)</td>
<td>.465</td>
<td>-.155</td>
</tr>
</tbody>
</table>

Figure 2: The mean proportion of T1-T4 correct responses in various conditions (Error bar: 1 SE)

For the contracted T1-T4 contrast, the only significance appeared when the pitch contours were presented in an upward order, F (2, 83) = 3.262, p = .043 (Figure 3). Post hoc analysis showed that under this order, monolingual Chinese participants discriminated the contrast significantly better than monolingual Dutch participants (p = .040, Bonferroni). One-sample t-tests showed that only monolingual Chinese participants discriminated the contrast above chance, and that bilingual Dutch listeners’ performance fell in between monolingual Chinese and Dutch listeners (Table 1).
2.2. Exp.2 – AXB discrimination task

2.2.1. Stimuli
The same stimuli as in Exp.1 were adopted.

2.2.2. Participants
The same participants as in Exp.1 were tested.

2.2.3. Procedure
Participants heard a triplet of stimuli (A, X, & B) per trial, and were required to respond to whether the second stimulus (X) sounded the same as the first (A) or the third stimulus (B) as accurately and quickly as possible by clicking one of the two buttons on the screen, labeled “first” and “third”, upon hearing each triplet. After each click, the next trial was presented. The AXB trials had four possible combinations (AAB, ABB, BAA and BBA). Similar to the AX discrimination task, responses in which the difference between A & B was two steps apart were recorded, adding up to 96 trials for each participant. Besides, 48 filler trials were used to prevent experiment-induced bias.

2.2.4. Results
A similar multivariate ANOVA as in Exp.1 was conducted. No significant difference was observed. Listeners from all groups behaved similarly when discriminating the two tonal contrasts in the AXB task (Figures 4 & 5), and the success rates were high.

3. Discussion
In general, listeners across language conditions score high in discriminating tonal contrasts except for one situation. For the T1-T4 contrast, ceiling performance can be observed in both AX and AXB discrimination tasks. For the contracted T1-T4 contrast, high performance can be seen in the AXB but not AX discrimination task. This suggests that contrast acoustic salience plays a significant role in online tone processing to both tone-language and non-tone-language listeners. In general, the current findings are compatible with previous experiments on native as well as non-native tone-language listeners’ tonal contrast discrimination ability [15-17]. In brief, non-tone-language listeners are not “deaf” to lexical tones, and perceive them in a psycho-acoustic fashion. Interestingly, tone-language listeners show similar performance as non-tone-language listeners in all but one situation (contracted T1-T4, upward order). Note that this does not necessarily mean that their perception of tones is acoustically based. Linking with identification task results in our previous study [31], Chinese listeners perceive tonal contrasts more categorically than their Dutch peers.

In the AX discrimination task, the performance seems to be on a chance level for non-tone-language listeners when discriminating the contracted T1-T4 contrast. This may indicate that the acoustic difference is small for them. The better performance by tone-language participants is not as high as that in the AXB task. Given the overall higher performance in the AXB task, it is likely that the task difficulty itself plays a role.

The significant effect is found when listeners discriminate the contracted T1-T4 tonal contrast presented in an upward order in the AX discrimination task. Monolingual Chinese listeners outperform monolingual Dutch adults, with bilingual Dutch adults fall in between the other two groups. Given that bilingual Dutch participants do not show significant difference with either group. We do not have conclusive evidence but a slight trace showing that the bilingual Dutch listeners may perform better than the monolingual Dutch participants when discriminating a difficult non-native tonal contrast. Moreover, it should be noted that order seems to play a role in discrimination. While the contracted T1-T4 stimuli presented downwards may be too difficult for all participants, it is less difficult, though still quite hard, for listeners and hence the effect surface. This indicates that future studies should carefully consider the degree of salience of the stimuli in test.

Linking the current finding with the sensitivity rebound advantage found in non-tone-learning bilingual over
monolingual infants, two possibilities remain. First, with the increased exposure in non-tone language environment just as monolinguals, bilingual listeners, though showing initial sensitivity to non-native tonal contrasts, may no longer present any specific acoustic advantage when hearing tones. This subsequently implies that the potential bilingual acoustic sensitivity advantage and their sensitivity towards novel languages found in the first year of life may decrease with the consistent exposure to the native languages. Indeed, by the age of 18 months, both monolingual and bilingual infants reach a similar level of discrimination of tonal contrasts [7]. A second possibility would be that bilingual adult participants may still be more sensitive to non-native tonal contrasts, than their monolingual peers, but such sensitivity is not shown in the current experiment due to the age of participants (mean age: 25 years) in the current study. This is the age when the acoustic sensitivity remains high for all listeners. To disentangle these two speculations, future studies may focus on testing different tonal contrasts or the same tonal contrasts on older adult listeners.

4. Conclusion

In sum, monolingual Chinese, Dutch and simultaneous bilingual Dutch listeners perform similarly in the AX and AxB discrimination tasks when perceiving a salient and a less salient tonal contrasts. A slight advantage is observed for Chinese over monolingual Dutch listeners, with bilingual Dutch listeners fall in between the two groups. Listeners’ discrimination performance is contrast dependent and is likely to be task and order dependent. This indicates that contrast salience influences adults’ tone perception regardless of their language backgrounds.

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6. References