The Effect of Language Attrition and Tone Sandhi on Taiwanese Tonal Processing

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Abstract

This study investigates the effect of language attrition and tone sandhi on speech processing of Taiwanese tones. The mid level tone was previously found to be the most confusing category, and is largely confused with low-falling tone. This study argues that the tonal errors are caused by the effect of language attrition and tone sandhi. Three perception and one production tasks were conducted on 15 fluent speakers and 30 attriters. The results show that attriters significantly make more errors than fluent speakers. In the production task, both groups tend to mispronounce mid level tone as low-falling tone, but in the perception tasks, they tend to misperceive the mid level tone as high level tone. The strong tendency is argued to be determined by the effect of tone sandhi and phonetic similarity. The findings support the effect of language attrition, and suggest that both phonetic and phonological factors exert an influence on Taiwanese tonal processing.

Index Terms: language attrition, mid level tone, perception-production asymmetry, phonetic similarity, tone sandhi

1. Introduction

This study argues that the effect of language attrition leads to tonal confusion in Taiwanese speech processing, including both speech perception and production, and the tonal confusion, especially the change from mid level tone to low-falling tone, is largely determined by tone sandhi and phonetic similarity. Language attrition, as Paradis [1] suggests, is a specific case of language change triggered by the decrease of use frequency, and recently this has become a serious issue to many minority languages, such as Hakka and aboriginal languages, in Taiwan. The Mandarin-dominant speaking environment and the strong demand for English learning may even be making Taiwanese (Taiwan's second most spoken language, after Mandarin) an endangered language. Hsiao [2] finds that Taiwanese speakers used to speak their mother tongue at home, especially in the rural areas, but the younger generation no longer does so nowadays. The dramatic decrease of speaking opportunities leads to young speakers' nonnative accents and inadequate use of tone sandhi. For example, Chiung [3] finds that young speakers cannot make the tonal contrast between high checked and low checked tones, and Luo [4] finds that young speakers confuse mid level tone with low-falling tone. Both Chiung [3] and Luo [4] argue that the tonal confusion is induced by language contact with Mandarin and excessive Mandarin exposure, but they do not demonstrate how the effect of language contact leads to the tonal confusion. Some others, such as Chen [5] and Liu and Wang [6], find that the tonal confusion results from the effect of the complex tone sandhi system, as illustrated in Figure 1 and Table 1, and regard the confusion as refelcting speech errors. For example, mid level tone (Tone-33) becomes low-

falling tone (Tone-21) in non-final position (the basic sandhi domain), and keeps its citation form (Tone-33) elsewhere (the non-sandhi domain). Liu and Wang [6] suggest that all allophonic details, including non-sandhi and sandhi forms, are stored in the internal lexicon, and that the multiple (underlying) representations of each category take more time and cognitive efforts to be retrieved correspondingly to the category's surface form. Their conclusion is drawn from the production data only. Our study adopts both production and perception methods to re-examine the effect of tone sandhi and to investigate the effect of language attrition on Taiwanese tonal processing. We argue that the effect of language attrition is the more important determinant of tonal confusion, and the confusion matrix is determined by the effect of both tone sandhi and phonetic similarity.

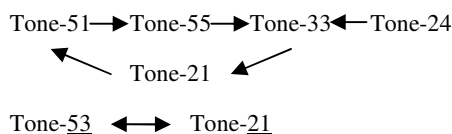Figure 1. *Taiwanese Tone Sandhi Rules* [7] (5= the highest pitch, 1= the lowest; underlines: checked tones)

Tone-51 → Tone-55 → Tone-33 ← Tone-24

Tone-21

Tone-<u>53</u> ⟷ Tone-<u>21</u>

Table 1. Tonal Inventory of Taiwanese [7] (H= high, L= low; 5= the highest pitch, 1= the lowest)

Contour	Ht.	Ex.	Gloss	Abb.
level	H	膚 hu55	skin	T1
rising	L	扶 hu24	to support	T2
falling	L	赴 hu21	to catch	T3
	H	撫 hu51	to console	T4
level	L	傅 hu33	master	T5
checked	H	佛 <u>hut53</u>	Buddha	T6
	L	忽 <u>hut21</u>	sudden	T7

2. Research Questions

The study examines the following three research questions: first, whether the effect of language attrition results in tonal confusion to a significant extent; second, whether the mid level tone is the most confusing category in Taiwanese and why; third, whether the mid level tone is more likely to be confused with low-falling tone and why.

2.1. The Effect of Language Attrition

The effect of language attrition is predicted to result in significantly more tonal errors in perception and production tasks, based on Paradis [1] and Yeh [8]. Yeh [8] suggests that the decrease of use frequency lowers the occurrence probability of lexical representations in dominated languages, and the lower occurrence probability increases the mismatch between acoustic signals and their corresponding lexical representations. The more phonetically similar the categories

and representations are, the more likely the mismatch will occur. The mismatch then leads to tonal errors and confusion. Therefore, Mandarin-dominant attriters are predicted to make more tonal errors than fluent Taiwanese speakers in the perception and production tasks.

2.2. The Mid Level Tone

The mid level tone is predicted to be more confusing than any other tone in the perception and production tasks, based on previous findings [4,8] and the tone sandhi approach [5,6]. According to Chen [5] and Liu and Wang [6], the mid level tone has the most complex allophonic details, since it not only has a low-falling allophone, but also can be an allophone of high level tone and low rising tone, as illustrated in Figure 1. The multiple representations of mid level tone increase the chance of mismatch, so more errors are predicted. The same prediction can also be made based on previous studies [4,8] assuming the effect of phonetic similarity. The mid level tone is the least distinctive in Taiwanese tonal space, since it is phonetically similar to high level tone in pitch contour and is similar to low-falling tone and rising tone in pitch height. The indistinctiveness of mid level tone is then predicted to result in more perception and production errors.

2.3. Confusion Matrix of the Mid Level Tone

The mid level tone is predicted to be confused with low-falling, high level, and rising tones based on the tone sandhi approach [5,6]. The mid level tone is allophonic to these tones, so the mismatch between mid level tone and these categories is more likely to occur. Assuming the effect of phonetic similarity, as Yeh [8] proposes, leads to the same prediction. The mid level tone is phonetically similar to high level tone in pitch contour and similar to low-falling and rising tones in pitch height, so the tonal confusion of these categories is highly possible.

3. Methodology

The three factors: recent Taiwanese and Mandarin exposure, tone types, and task types, are set up as experiment variables to answer the three research questions above.

3.1. Participants

45 participants are classified into two groups, young attriters and older fluent speakers, in terms of their language background, such as recent Taiwanese exposure. 30 young attriters (18 males, 12 females; mean age: 28.2 years old; Northern dialect: 10, Central dialect: 9, Southern dialect: 11) were recruited from Michigan State University and Indiana University at Bloomington. These young attriters are Mandarin-dominant bilinguals who have Taiwanese exposure less than one hour per week in the recent decade. 15 older fluent speakers (10 males, 5 females; mean age: 40.2 years old; Northern dialect: 5, Central dialect: 5, Southern dialect: 5) were recruited from Taipei, Taichung, and Kaohsiung areas in Taiwan. These fluent speakers are Taiwanese-dominant bilinguals who speak Taiwanese every day, and ten of these participants speak Mandarin with heavy Taiwanese accents.

3.2. Stimuli

The stimuli include only five Taiwanese non-checked tones which do not occur with unaspirated voiceless stop codas, and consist of two syllables [hu] and [ti]. They were selected from the Taiwanese Soannteng Online Dictionary [9], and were recorded from one male fluent speaker (41 years old, southern dialect), by Praat version 5.1.43 [10]. These stimuli are presented in Table 2. In the [ti] row, these words, from T1 to T5, mean *pig*, *pool*, *wisdom*, *to cause*, and *to cure* respectively. In the [hu] row, these words, from T1 to T5, mean *husband*, *spell*, *fortune*, *government*, and *tofu* respectively.

Table 2. *Stimuli List in the Experiment*

	T1	T2	T3	T4	T5
[ti]	豬	池	智	致	治
	ti55	ti24	ti21	ti51	ti33
[hu]	夫	符	富	府	腐
	hu55	hu24	hu21	hu51	hu33

3.3. Tasks

There are four task types total, including three perception tasks and one production task, in the experiment. These tasks are conducted randomly to avoid potential priming or training effects on the results.

In the AXB discrimination task, participants hear three monosyllabic sounds separately in each trial, and they are instructed to tell if the second sound is more similar to the first sound or to the third. The inter-stimuli interval (ISI) is 300 ms, and the inter-trial interval (ITI) is self-paced. When participants respond to a trial, the next trial will be played in 500 ms. There are 160 (2 syllables x 10 tonal contrasts x 4 orders x 2 repetitions) trials total.

In the identification task, participants hear only one monosyllabic sound in each trial, and they are instructed to categorize the tonal types of each sound they hear as one of five Taiwanese non-checked tones, such as T1, T2, etc. Before the task, participants are trained to categorize these tones in terms of the pitch contour and pitch height. The particular T5 is explicitly instructed to be similar with T1 in pitch contour, and to be similar with T3 in pitch height. The ITI is also self-paced. The next trial will be played in 500 ms, as the response of the previous one has been made. There are 40 (2 syllables x 5 tones x 4 repetitions) trials total.

In the lexical task, participants hear only one monosyllabic sound in each trial, and they are instructed to recognize the word meaning of each sound they hear. The words, as illustrated in the Table 2, are explicitly instructed before the task. The procedure and the trials are the same as in the identification task, and there are also 40 (2 syllables x 5 tones x 4 repetitions) trials total.

In the production task, participants are instructed to read a word list of 20 (2 syllables x 5 tones x 2 word choices) Taiwanese disyllabic words, and are recorded using Praat [10]. The 20 disyllabic words are selected from the Taiwanese Soannteng Online Dictionary [9]. The two word choices refer to the familiar and less familiar word types based on the judgments of two informants (1 male and 1 female; mean age: 41 years old; 1 central dialect and 1 southern dialect).
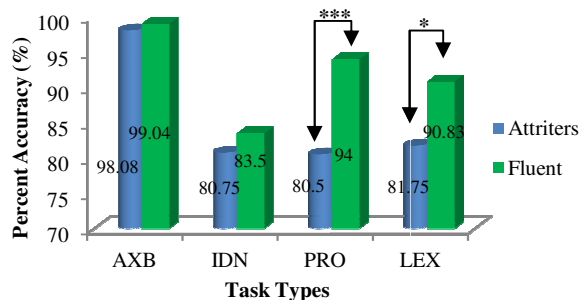
4. Results

The results were analyzed by ANOVA and T-test to answer the three research questions. First, the tonal errors of each category were calculated altogether in each task, and the one-way ANOVA was conducted to examine the effect of language attrition. Then, the tonal errors of the mid level category (T5) and those of any other tone (T1, T2, T3, and T4)

were assessed in contrast, and the two-sample T-test was conducted to examine if the T5 errors are significantly more than the others. At last, the T5 confusion matrix was analyzed. The T3 responses and the other tonal responses (T1, T2, and T4) were put in contrast, and the paired T-test was conducted to examine if the T5 is more likely to be confused with T3 than any other tone (T1, T2, and T4).

4.1. ANOVA and the Attrition Effect

The results of percent accuracy are illustrated in Figure 2, and the results show that fluent speakers have fewer tonal errors in all tasks, and there is a significant difference in the production (PRO) task and the lexical (LEX) task, PRO: $F(1,43)= 28.215$, $p<0.001***$; LEX: $F(1,43)= 6.6034$, $p<0.05*$. In the AXB discrimination (AXB) task and the tonal identification (IDN) task, there is no significant difference, AXB: $F(1,43)= 3.9246$, $p>0.05+$; IDN: $F(1,43)= 0.6051$, $p>0.05$. The ANOVA results indicate that young attriters make more tonal errors than fluent speakers, especially in the production and lexical tasks, so it is verified that the effect of language attrition leads to more tonal errors and confusion.

Figure 2. *Estimation of Tonal Errors in Four Tasks*

4.2. Two-sample T-Test and the T5 Errors

The results of mid level tone (T5) errors are compared with those of any other tone, as shown in Figure 3. The comparison shows that T5 percent accuracy is lower than any other tone, so the T5 errors are more than any other tonal error in all tasks, except for the discrimination task, in both participant groups (A: attriters, F: fluent speakers). The AXB discrimination task examines perceptual distinction of tonal pairs rather than that of single tones, so the T5 errors itself cannot be compared with any other tone in the AXB task. In the AXB discrimination task, the most confusing pair is the T2-T3 contrast in both participant groups.

Figure 3. *Results of T5 and Any Other Tone Errors* (left- pink: T5 errors, right- red: any other tone errors)
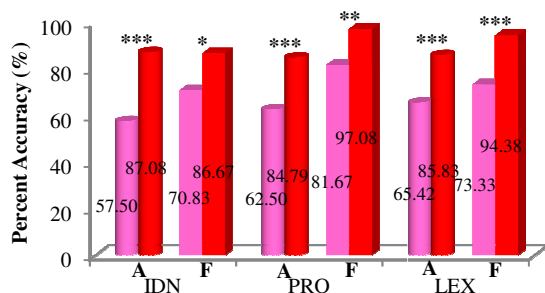
The comparison between T5 errors and the others was further analyzed by T-test, and the two-sample T-test results show that the T5 errors are significantly more than any other tone in both participant groups across the three tasks, for instance, in the tonal identification (IDN) task: attriters (A): $t(58)= 5.2557$, $p<0.001***$, fluent speakers (F): $t(28)= 2.0933$, $p<0.05*$; in the production (PRO) task, A: $t(58)= 7.0708$, $p<0.001***$, F: $t(28)= 3.2814$, $p<0.01**$; in the lexical (LEX) task, A: $t(58)= 4.0596$, $p<0.001***$, F: $t(28)= 3.6160$, $p<0.001***$. In other words, T5 is the most confusing category in both participant groups in all tasks, except for the AXB discrimination task.

## 4.3. Paired T-test and the T5 Confusion Matrix

The mid level tone (T5) errors are analyzed in the confusion matrix, as shown in Table 3. The matrix shows that both high level tone (T1) and low-falling tone (T3) are more likely to be confused with T5. In the three perception tasks, T5 is mostly categorized as T1, but in the production task, T5 is largely pronounced as T3.

Table 3. *Mid Level Tone (T5) Error Matrix* (AXB: discrimination task, IDN: identification task, LEX: lexical task, PRO: production task)

T5 Errors	As	T1	T2	T3	T4
Attriters	AXB	8	4	4	6
	IDN	96	8	2	1
	LEX	61	4	16	2
	PRO	4	0	35	6
Fluent Speakers	AXB	1	3	6	0
	IDN	23	2	10	0
	LEX	21	4	11	0
	PRO	0	0	11	0

The mid level tone (T5) confusion matrix is analyzed in two classes, low-falling tone (T3) responses and non-T3 (T1, T2, and T4) responses, as shown in Figure 4. The paired T-test results show that T5 is more likely to be confused with T3 to attriters (A) and fluent speakers (F) only in the production task, and there is a significant difference, (A): $t(29)= 7.977$, $p<0.001***$, (F): $t(14)= 4.0359$, $p<0.001***$. In the three perception tasks, T5 is not confused with T3 to attriters and fluent speakers, and there is no significant difference, for example, in the AXB discrimination task: (A): $t(58)= -2.2605$, $p>0.05$, (F): $t(28)= 1.2752$, $p>0.05$; in the identification (IDN) task: (A): $t(29)= -7.0166$, $p>0.05$, (F): $t(14)= 0.4163$, $p>0.05$; in the lexical (LEX) task: (A): $t(29)= -1.2688$, $p>0.05$, (F): $t(14)= 0.8605$, $p>0.05$. In other words, T5 is more likely to be replaced by T3 to both participant groups in the production task than in the perception tasks, which is dubbed as the perception-production asymmetry.

Figure 4. *Results of T5 Error Patterns* (left- pink: T3 responses, right- red: any other tone responses)
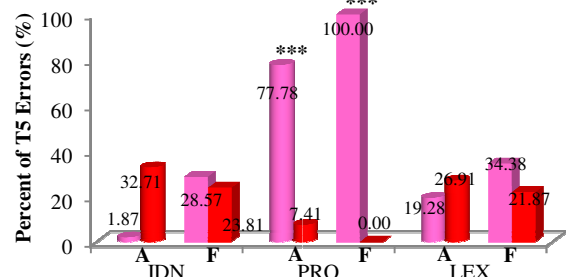
5. Discussion

The results generally support the effect of language attrition, tone sandhi, and phonetic similarity on Taiwanese tonal processing. The three research questions are discussed as follows. The perception-production asymmetry in the T5 confusion matrix is a particular finding, and is also discussed.

5.1. Tonal Confusion and the Mid Level Tone

The effect of language attrition on Taiwanese tonal processing is verified by the fact that attriters make more tonal errors than fluent speakers in all the perception and production tasks. The attrition effect is more significant in the production and lexical tasks, and less significant in the identification task, since the four tasks require participants to apply different sorts of knowledge, such as phonetic, phonological, and lexical cues. As to the identification task, all participants are equally trained to categorize the types of Taiwanese tones right before the task. The equal and timely access to Taiwanese tonal knowledge may reduce the effect of language attrition, so there is no significant difference in the identification results.

Second, the mid level tone (T5) is verified as the most confusing category in Taiwanese by the fact that both attriter and fluent speaker groups make significantly more T5 errors than any other tone in the perception and production tasks, except for the AXB discrimination task. In the discrimination task, the tonal pair of low-falling tone (T3) and rising tone (T2) is the most confusing one. As Chiung [3] finds that young Taiwanese speakers tend to produce rising tone as dipping tone (first falling, then rising), the similar pitch contour of dipping and rising tones may account for the T2-T3 confusion. The findings verify the prediction and suggest that phonetically similar tones are more confusing, so the effect of phonetic similarity is also crucial to Taiwanese tonal processing. Finally, T5 is verified to be largely confused with high level tone (T1) in the perception tasks and with low-falling tone (T3) in the production task. The confusion matrix results also support the phonetic similarity effect, since T1 has similar pitch contour to T5, and T3 has similar pitch height to T5.

5.2. The Perception-Production Asymmetry

However, the effect of phonetic similarity itself does not explain the perception- production asymmetry in the mid level tone (T5) confusion matrix, which refers to the fact that T5 is mostly confused with T1 in the perception tasks, whereas in the production one, T5 is more likely to be replaced by T3. The asymmetry is also found in the confusion matrix of low-falling tone (T3), the second most confusing category. Likewise, T3 is mostly confused with T5 in the perception tasks, whereas in the production task, T3 is more likely to be replaced by high-falling tone (T4). The asymmetry, to some extent, is defined by the tone sandhi system, as illustrated in Figure 1. As to the production errors, participants' responses tend to be one step ahead, namely over-application of tone sandhi errors. As to the perception errors, their responses are usually one step behind, namely under-application errors. Tone sandhi refers to the post-lexical tonal change, as suggested by Chen [11]. The post-lexical process is computed within the production mechanism, so the over-application errors tend to occur in the production process. On the contrary, in the perception tasks, sounds are judged in isolation where a non-sandhi form occurs. The isolated condition tends to result in the under-application errors. The asymmetry is highly correlated with the tone sandhi, so the effect of tone sandhi on Taiwanese tonal processing is supported.

6. Conclusion

Our study argues that the effect of language attrition results in tonal confusion and can be a crucial cause of tonal change. The confusion matrix is largely determined by the effect of tone sandhi and phonetic similarity, so the findings suggest that both phonetic and phonological factors exert an influence on Taiwanese tonal processing, including processing-related confusion, errors, and subsequent sound change. However, the tone sandhi account is challenged by the fact that the non-high level tone tends to be replaced by low-falling tone in other Chinese languages which have no mid level tone sandhi, such as Hakka [8] and Cantonese. The cross-linguistic co-occurrence needs further investigation, and the comparison may shed light on the current argument on the perception-production asymmetry.

7. Acknowledgements

8. References

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