

Exploring the Variation of Third Tone Sandhi in Native Chinese Mandarin: An Acoustic Analysis

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Abstract: Tone is one of the most prominent, distinctive, and significant properties of the Chinese language. In the realm of tone sandhi, one of the most interesting phenomena is the Tone 3 sandhi (T3). T3 sandhi is one of the rules in the phonological change, a low T3 syllable inevitably changes to a rising tone (T2) when it is followed by another T3 syllable. This study aims to investigate the underlying mechanism of the third tone (T3) sandhi in Mandarin Chinese, comparing the acoustic features in both real words and pseudowords. The current study employed a qualitative descriptive method and PRAAT6310 acoustic analysis software. The findings of the study demonstrated that T3 sandhi in real words of the Chinese language resembles pseudowords and is likely computed naturally in a phonological cognition process. This research provides an important reference value for research in the fields of tonal variation in Chinese language and language acquisition.

Keywords: Mandarin Chinese, Tone Sandhi, Third Tone, Acoustic Analysis

1. Introduction

1.1. Background of Study

Tone is one of the most prominent, distinctive, and significant properties of the Chinese language. According to Goldsmith [1], tone refers to the inflection of pitch in the physical embodiment. It is an inherent feature of articulation; and thus every language is a tone language [1]. However, the factors that distinguish between Chinese, a tone language, and other languages lie in the variations in sounds[2] . Chinese has a considerably smaller range of sounds (approximately 400) compared to many other languages, such as English, which boasts around 12,000 variations. In addition, there are four tones to indicate the sound changes in Standard Mandarin Chinese, it consist of a tone 1 marked by a high level, a tone 2 characterized by a rising pitch contour, a tone 3 with a low pitch, and a tone 4 marked by a falling contour. An alternation in tone alters the meaning of a word in Chinese [3]. For example, if the utterance of the word *cha* in Chinese is in a rising tone, its meaning can be chá (茶; tea); while if it changes to a low tone, then the meaning becomes chà (差; worse). Therefore, in Chinese, tones play a vital role to differentiate words that can be identified with similar sounds.

Nevertheless, tones in Chinese can vary in speech beyond the standard four tones, this phenomenon can be referred to as tone sandhi [4][5][6]. As noted by Chen [4] and Yue-Hashimoto [7], tone sandhi is a phonological change governed by adjacent tones or by the prosodic or

morphosyntactic position in which the tone occurs. For instance, *nǐ hǎo* (你好; hello) is pronounced as *ní hǎo* in speech; the tone in *nǐ* alters from a low tone to a rising tone. Apart from that, there are a considerable amount of rules of tone sandhi; thus, researchers [8][9][4][7] dedicated to classifying the complex sandhi systems. One of the well-known systems is the tone sandhi directionality[4], it has categorizations of either “left-dominant” or “right-dominant.”

In terms of the left-dominant sandhi system, it refers to a situation where the tone on the left remains the same, while the right tone undergoes an alteration. The Chengdu dialect and Shanghainese are two branches in the left-dominant sandhi system [5][10]. Take the example of *dàjiā* (大家; everybody) in the Chengdu dialect, the only change lies in the right tone *jiā*, it alters from tone 1 to a rising tone 2. On the other hand, the right-dominant sandhi system is when the right tone is preserved but the left tone varies. This is typical in the Beijing Mandarin, Min, and Southern Wu dialects [11].

Furthermore, previous studies [12][13][14][15] reviewed various rules in tone sandhi in Chinese languages in terms of the directionality sandhi system. In the realm of tone sandhi, one of the most interesting phenomena is the Tone 3 sandhi (T3). T3 sandhi is one of the rules in the phonological change, a low T3 syllable inevitably changes to a rising tone (T2) when it is followed by another T3 syllable. For instance, when uttering the word *lǐjiě* (理解; to understand)', the first syllable *lǐ* becomes the rising tone *lí*. Additionally, T3 sandhi is computed in phonological process before articulation [13][16]. This could be associated with the productivity of novel disyllabic sequences of T3 sandhi in Mandarin [17]. In other words, the computation mechanism predicts that the presence of sandhi is rooted in a phonological automatic process, irrespective of whether it is an existing or a newly created word [18]. For example, *mǎ mǎ* (马马; horse-horse) is a nonsense disyllabic sequence that is applied with T3 sandhi [16]. Therefore, T3 sandhi provides important access to the lexus and the mental representation of Chinese words [12]. Hence, the current study aims to investigate the application of Third Tone sandhi (T3) in both real words and pseudowords in Standard Mandarin.

1.2. Statement of Problem

The T3 sandhi could lead to a discrepancy between the underlying representation (how the syllable is supposed to be pronounced based on its inherent tone) and the actual pronunciation (how it is realised in speech due to the influence of the sandhi rule). The sandhi process modifies the tone of the syllable, resulting in a change from T3 to T2 in the surface representation. It could further cause confusion and difficulties for Chinese language learners [19][20][21]. This is because the third tone in Chinese can be varied in many different ways. For example, according to Liu and Samuel [21], a huge divergence can lie in the naming of T3; some refer to it as "low falling", while others may call it “low dipping” or “low falling rising”. In such cases, Linge [22] indicated that the change of T3 usually is determined by its following syllable's tone.

To be more specific, Linge [22] further concluded three main pronunciation differences of T3. Firstly, the T3 is realised as a low and falling variety. This alteration appears when the T3 syllable is followed by any other tones except for the T3 syllable. Secondly, the T3 will be pronounced as a T2 sound if it is followed by another T3 syllable. Thirdly, the presence of T3 changes to a low falling rising tone when it occurs isolated or in the final position of the syllable.

Apart from that, Liao [23] believed that the final rise in the variation of T3 can also result from reading style. If the reader pronounces the T3 in a formal setting, it would have a clearer T3 with a rise at the end; while informal speech may not display such a feature as frequently.

Therefore, regarding these variations in T3, the T3 sandhi brings problems for Chinese language acquisition, especially for foreigners [20]. Its divergence between how the syllable is supposed to be pronounced based on its inherent tone and the actual pronunciation can cause misleading and chaos

when learning or communicating. Hence, the current study aims to indicate the existence of T3 sandhi in Standard Mandarin, attempts to reveal whether the T3 sandhi still happens in pseudowords, and further illustrates the potential mechanism behind the production of T3 sandhi. This study can be used as a reference for those who are confused with the T3 sandhi in Chinese and provides a clear explanation for how T3 sandhi works even in a nonsense word.

1.3. Research Objectives

1) This study aims to investigate study the T3 sandhi in native Mandarin Chinese by comparing the application of sandhi T3 in pseudo-words and real words.

2) Besides, the current study attempts to reveal the potential factors of the T3 sandhi in the standard Mandarin.

1.4. Research Questions

1) Is there any difference between the T3 sandhi of real words and pseudo-words in Mandarin Chinese?

2) What are qualitative aspects and patterns observed in standard Mandarin T3 sandhi that revealed potential associations with lexical or computational mechanisms?

2. Literature Review

2.1. Past Studies

Numerous empirical studies [24][25][18][17][15] have focused on the third-tone sandhi in various language variants in mainland China and places other than mainland China. First of all, pioneer research [16][18][26] clarified that the third tone sandhi is productive in novel words, particularly disyllabic words. For example, Zhang and Lai [26] demonstrated three types of production of novel words under the application of T3 sandhi, including a blend of dual morphemes that do not typically occur together, such as *chǐ sǎ* (尺洒); a collocation of an existing morpheme plus a newly created syllable, or a sequence of two novel syllables, with the example of *pǐng zhěng*. Based on this, Zhang and Peng [18] conducted an empirical study to affirm the capability of T3 sandhi to produce new words in the Tianjin dialect context. The results indicated a discrepancy in the production of novel words with T3 sandhi, showing a combination of insufficient learning, over-studying, and correct learning of the sandhi from the lexicon.

Additionally, with the pioneer's works, Zhang et al. [17] attempted to uncover the mechanism behind the T3 sandhi. Zhang et al. [17] revealed that the appearance of T3 sandhi lies in a computation mechanism rather than a lexical mechanism. It means that the T3 sandhi is generated computationally from the phonological context. Evidently, the findings of the research of Zhang et al. [17] illustrated that the T3 sandhi in both actual words and newly created words takes place during the phonological encoding stage before the actual utterance. It further supports the claims of Zhang and Lai [26] that the computation mechanism leads to the application of T3 sandhi in novel words.

Furthermore, in the study of Zhang and Peng [18], they investigated whether the production of Mandarin Third Tone (T3) sandhi is gradient or categorical, drawing upon the wug test. They showed that the application of T3 sandhi is less prominent than T2 in pseudo-words; while in real words condition, there are not critical distinctions between T3 and T2. Besides that, Mandarin speakers are not able to differentiate the T2 and sandhi T3 in both pseudo-words and real words, which is in accord with the categorical distribution. Specifically, real words are processed top-down, eliciting similar T2 and T3 responses; while the pseudo-words are processed in a bottom-up manner, with a preference for mapping rising pitch to T2. Overall, Zhang and Peng's [18] results echoed the investigation of

Zhang et al. [17], showing that due to the intermediary of computer mechanisms, sandhi T3 can appear in both real words and pseudowords [17].

Research of T3 sandhi contributed greatly to the Mandarin and other dialects in mainland China, as well as variants spoken in other regions. For instance, Chiew [24] highlighted the T3 rule in Malaysian Mandarin, it is not only the sole language used for teaching in Chinese schools but has also evolved into a lingua franca among Chinese Malaysians belonging to different dialect groups, such as Hokkian, Cantonese, etc. Chiew [24] found out that the T3 sandhi phenomenon in Malaysian Mandarin is generally consistent with the sandhi rule in Standard Chinese, with slight differences in the acoustic realisation in terms of pitch contour and voice quality. A similar observation arose in another Mandarin variant, Taiwanese. Cheng et al. [27] and Yin [28] consistently pointed out that the T3 sandhi rule in Taiwan Mandarin is paralleled with the standard Mandarin, despite that sandhi in Taiwan Mandarin is more like a tonal reduction.

3. Methodology

3.1. Research Design

This study applied a qualitative descriptive approach. Acoustic analysis using a qualitative description approach fits the purpose of the current study, as this approach provides a situational description and interpretation of phenomena, experiences, and perceptions [29][30]. Thus, this approach enables researchers to share the understanding and perceptions of others, and to explore how people organise and give meaning to their daily lives [31]. Therefore, the present study adopted a qualitative descriptive approach in order to describe and explain the acoustic features in terms of the sandhi T3 in standard Chinese.

3.2. Sample

This study employed a non-probability sampling method, which allowed for the purposeful selection of participants who could illustrate the research objectives and who had knowledge and experience of the phenomenon under study. Therefore, the current research recruited two native Chinese speakers, a female and a male.

3.3. Materials

Materials used in this study includes five real words and five pseudowords, which were adopted from Zhang and Peng's [18] study. As shown in the following table:

Table 1: The Words Adopted from Zhang and Peng[18]

T3+T3 Real Words	T3+T3 Pseudowords
ěr yǔ 耳语 (whisper)	tiang3 fua3
fǎn xiǎng 反响 (reaction)	tei3 bua3
rěn zhě 忍者 (ninja)	fai3 dua3
tǎo mǐ 讨米 (to ask for rice)	fian3 suang3

Table 1: (continued)

bǎi mǎ 百马 (one hundred horses)	tiu3 ruang3
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3.4. Data Collection

During the data collection stage, first, the sample speech was collected from two native Chinese Mandarin speakers respectively. The recordings of sample speech are according to the sequence in the list of real words and pseudowords. Secondly, the speech samples were transcribed phonetically, marking the tones in terms of the rules of Mandarin Chinese phonetic transcription. Thirdly and lastly, the sets of audio recordings were converted into a suitable format (e.g., WAV) using the Macbook Pro music device. In total, there were four different audio files, consisting of two files containing recordings of real words and pseudowords from the male participant, and another two files containing recordings of real words and pseudowords from the female participant.

3.5. Data Analysis

The transcription data that contains Mandarin tone features were processed in the computer program PRAAT6310. PRAAT6310 version is the software that is used to analyse flexible sound analysis and reconstruction, its functions can range from spectrogram analysis, the sound reconstruction itself, making diagrams, to drawings that can be used in scientific work [31]. The application of PRAAT6310 in the current research is to analyse intonation patterns, revealing the variations of pitch contours in terms of the T3 sandhi rule.

To start with, normalising the audio files is necessary for ensuring consistent loudness levels across the recordings, with the standard of 70 dB. Then, the window length in spectrogram settings is adjusted to 0.03.

After normalisation, further acoustic analysis was proceeded and the pitch contour is shown in the spectrograms in each audio file.

Next, four different audio files were annotated with the two tiers respectively. One tier presented the original standard tone T3+T3 in existing words and newly created words; while another bottom tier showed the variation of the tone in the first syllable, from T3 to T2 tone.

Lastly, the acoustic characteristics of each T3 syllable were examined using a framework developed by Chiew [24]. The framework underlines three factors: pitch level, pitch contour, and voice quality [24]. Specifically, there are three pitch levels: high (H), mid (M), or low (L). These levels are related to the pitch height of each utterance and the pitch range of the participant. Besides, pitch contour encompasses falling, level, rising, and falling levels, which can be determined by comparing neighbouring syllables and employing auditory justification. Chiew [24] noted that if the pitch variation on the rhyme of a syllable (whether rising or falling) is less than 20 Hz, it is classified as level. Finally, the voice quality relates to the presence of an extra-low f_0 that often occurs in T3 production, as T3 is a lexical tone with a low-pitch target.

4. Findings and Discussion

4.1. Findings

4.1.1. T3 Sandhi in Real Words

The acoustic feature in the utterances of each real word qualitatively displayed a resembling pattern, starting from a curving contour shape and altering to a falling shape. As shown in Figure 1, the initial T3 syllable in the T3+T3 disyllabic sequence experiences tone sandhi. To be specific, according to

Chiew [24], the narrowband spectrogram in Figure 1 qualitatively showed that the pitch level in the initial T3 syllable is firstly at a low level and then rises. As for the pitch contour in this syllable, the pitch variation undergoes two stages; first is a level tone, with less than 20HZ alternation in pitch; second it is visually clear that the contour climbs, and the pitch variation is more than 300 HZ to 500 HZ until the ending points of the utterance of the ǐr syllable. Thus the pitch contour is a level-rising tone.

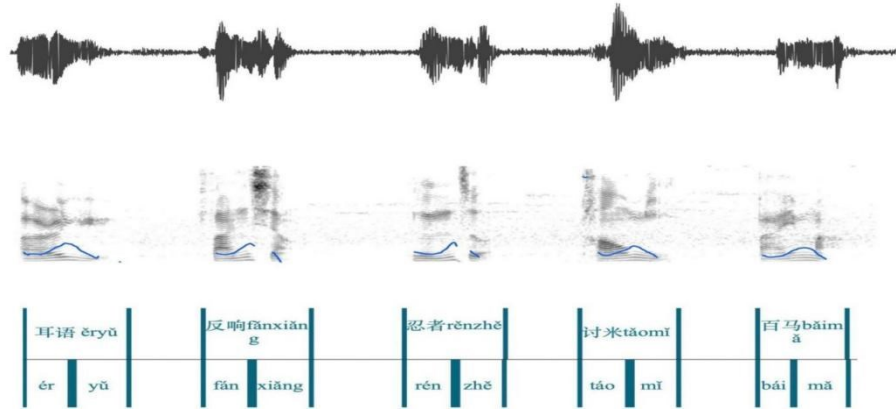


Figure 1: T3 Sandhi in Real Words from Participant 1

Additionally, the acoustic features in Figure 1 are relatively consistent in the spectrogram of the real words pronunciation from Participant 2. In Figure 2, the pitch feature, including pitch level and contour, visually displayed a similar pattern to the previous participant. However, there still are slight differences regarding the pitch level and contour. Each utterance's pitch height of Participant 2 is higher than their counterparts of Participant 1, and the highest pitch of Participant 2 is up to around 4800 HZ in the third real word *rěnzhe* (忍者).

While, in terms of the contour in pitch, each utterance undergoes a roughly level-rising tone in the first T3 syllable, but it appears to be a relatively small curving shape at the very beginning of the narrowband spectrogram in the first T3 syllable. It might suggest that subtle tonal changes or modifications occur during the sandhi process.

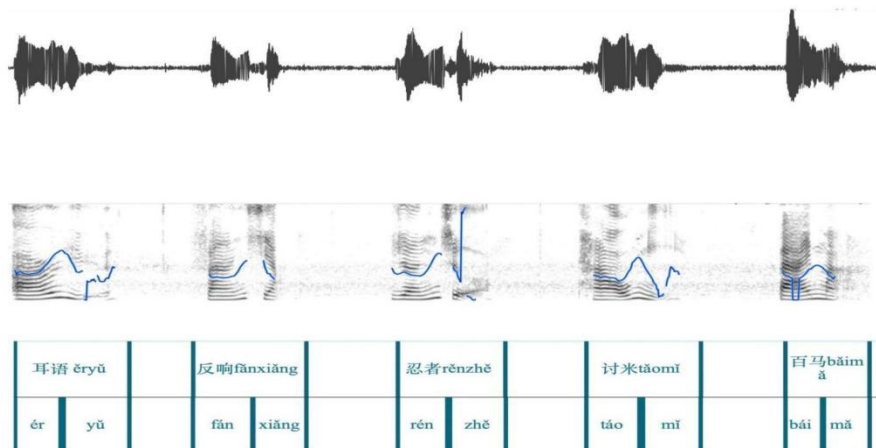


Figure 2: T3 Sandhi in Real Words from Participant 2

In both spectrograms, only the real words were read by participants without other contexts given. Despite this, the T3 sandhi still occurred and the first T3 syllable is joined with the second syllable in order to produce a completed lexical meaning [24], therefore, these results indicated that the T3 sandhi in the first syllable alters from a falling tone to a rising tone, with the combination of the following second T3 syllable. This echoed the study of Chiew [24] and Zhang et al. [17]. Furthermore, in both Figure 1 and Figure 2, the F0 values in the initial T3 syllable of the real words consistently exhibit lower pitch levels compared to the second T3 syllable, which supports the characterization of an extra-low F0 in the initial T3 syllable during T3 sandhi [24][17]. Hence, it can be inferred that the occurrence of Third Tone sandhi manifested in the native Mandarin speakers' articulation of the real words.

4.1.2. T3 Sandhi in Pseudowords

Figures 3 and 4 illustrate the sandhi T3 in pseudowords, as observed in two participants, respectively. As shown in Figure 3, the narrowband spectrogram in each newly created word visually exhibited a low-level in each initial T3 syllable with a curving rising pitch contour, followed by a segmental tonal contour in the duration of the second T3 syllable. For instance, in the pseudowords *tei3bua3*, it is visually clear that the initial T3 syllable *tei3* firstly appears to be an evident low-level pitch with less than a 20 HZ pitch variation on the rhyme, as clarified by Chiew [24]; followed by a rapid rising tonal alternation. In the subsequent T3 syllable *bua3*, it can be seen that the pitch contour becomes intermittent segments. This might suggest that there is an unexpected pitch pattern of that syllable compared to its counterpart in real words.

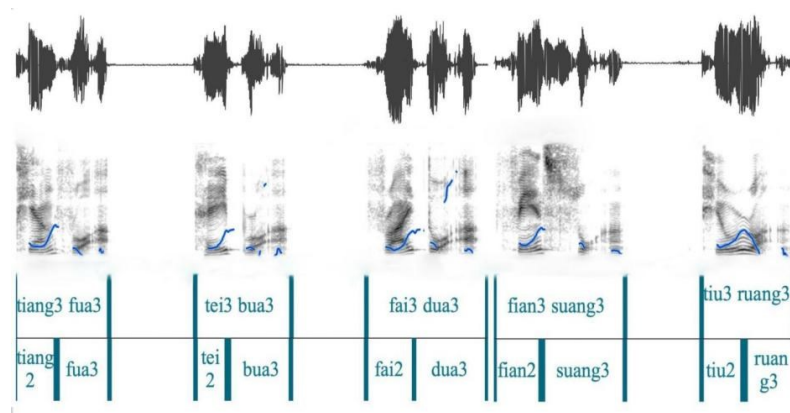


Figure 3: T3 Sandhi in Pseudowords from Participant 1

In Figure 4, the tonal variation in each nonsense disyllabic sequence is consistent with the previous sample data. Specifically, the narrowband spectrogram of pseudoword in Figure 4 visibly depicted that the first syllable in T3 + T3 sequence surfaces as a mid-level rising pitch, which confirms Chiew's [24] claims that a mid-level sandhi tone can be produced by some Mandarin speakers. Additionally, it is noticeable that the pitch contour in the following second T3 syllable is segmented, which is similar with that of Participant 1.

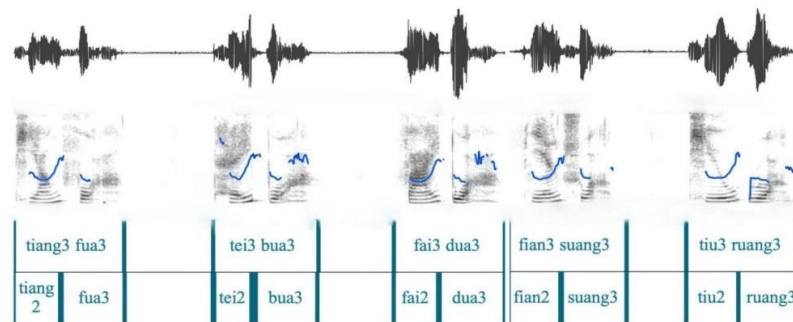


Figure 4: T3 Sandhi in Pseudowords from Participant 2

Overall, the production of T3 sandhi, from both Participant 1 and 2, appeared to be steady across all five pseudowords, with the absence of additional contexts, such as syntactic or lexical context. Also, the F0 in the first T3 syllable of all pseudowords exhibited a lower value than the counterpart of the second T3 syllable in a row. In this case, the first T3 syllable still qualitatively experienced a relatively low-level rising tonal change, and the next T3 syllable remains unchanged. Therefore, according to Zhang et al. [17], it can be assumed the appearance of T3 sandhi in the initial syllable relies on the remaining tone context (the second T3 syllable) irrespective of lexical or syntactic context.

4.2. Discussion

The present research explored T3 sandhi in native Mandarin Chinese and compared T3 sandhi patterns in pseudowords and real words. In addition, the current study attempts to ask whether the application of T3 sandhi is laid by the foundation of the computational mechanism or lexical mechanism of standard Mandarin.

To answer research question 1, the results of this study displayed that the phonological processing in both real words and pseudowords may qualitatively exhibit similar characteristics, which supports the prior studies of Zhang and Peng [18], and Zhang et al. [17]. To be specific, in the real words context, the five disyllabic T3 + T3 sequences are all the existing Chinese words and produced a similar variation in the first T3 syllable to a low or mid-rising tone. This corresponds to the rule of T3 sandhi in Mandarin that the variation in T3 is usually determined by its following syllable's tone [32].

Besides that, in the condition of pseudowords, Mandarin speakers encountered five disyllabic T3 + T3 sequences, such as *tei3bua3*, which are newly created words that they have never been exposed to before. The results consistently showed that the initial T3 syllable alters to a low or mid-level rising tone, in resemblance to that of real word case. This confirms the study of Zhang et al. [17], the subsistence of the ability of T3 sandhi to create new words is certain.

To answer research question 2, the appearance of T3 sandhi in pseudowords further substantiated that such a phonological change originated from a computational mechanism before the actual articulation. This is because the use of non-occurring T3 + T3 sequences, such as *fian3suang3*, sufficiently controls and minimises the lexical effects [17]. Mandarin participants produce the T3 sandhi relies on internal knowledge or rules in terms of the observation of the recurring tone patterns of T3 sandhi instead of a mere rigidly memorising the rules. As noted by prior studies [16][26], the computed internalised rules of T3 sandhi allow speakers to effectively apply them not only to combinations of morphemes that do not occur together, but also to syllables that would appear in such combinations [17].

Interestingly, the Praat spectrograms of Mandarin Participant 2 in the current study presented a higher pitch level in comparison with the first subject, with a mid-level tone throughout all the real words and pseudowords. The possible reason for this could be associated with gender differences. Females usually produce a higher pitch —about an octave higher than men. Apart from that, Chiew [24] also clarified that speakers can have a mid-level tone in the variation of the third tone, although the T3 sandhi is usually related to a low tone. Hence, the T3 sandhi does apply in both existing words and novel word conditions, with slight differences across individuals.

Another noticeable phenomenon can be visually observed in the narrowband spectrograms of the pseudowords from both Mandarin subjects; there are segmental pitch contours in pseudowords. It might suggest that there is an unforeseen pitch pattern when compared to that of real words. The possible reasons might be that subjects were unfamiliar and uncertain when producing these novel words that they never encountered before. Additionally, it could also be related to the way how the pseudowords were presented to the participants. In contrast to the real words, the pseudowords have no corresponding Chinese characters, thus the letters were shown in Pinyin. Therefore, such a discrepancy lies in the different ways of demonstrating the two kinds of words to the subjects.

Overall, this study revealed qualitatively that the phonological alternation in first T3 syllable remains consistent in pseudowords and real words. It further supports the possibility that T3 phonological coding is dominated by general computing mechanisms.

5. Conclusion

To summarise, T3 sandhi in real words of the Chinese language resembles pseudowords and is likely computed naturally in a phonological cognition process. However, a few limitations are necessary to declare and clarify. First, the sample size is too small because this study is only a mini research project. Second, it lacks a systematic normalisation process in Praat analysis. For instance, the noise in the audio files was not minimised by normalising in Praat. Instead, it was controlled by asking Mandarin participants to record in a quiet room. Third and the most important one is the lack of quantitative data. Relying only on a qualitative descriptive approach in Praat analysis might fail to produce objective and reliable statistical data to support the findings. Therefore, with the consideration of these limitations, future studies can establish more reliable research on T3 sandhi in the Chinese language with a larger population sample data and quantitative research approach. Also, future studies can aim to investigate other varieties of Chinese languages, such as Singaporean Chinese, Taiwanese, and Malaysian Chinese, which still await detailed and systematic investigations.

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