A Comparative Study of Tone 4 Sandhi in Standard Mandarin and Luoyang Dialect

by

Huilin Chen

A Thesis submitted to the

School of Graduate Studies

in partial fulfillment of requirement for the degree of

Master of Arts

Linguistic Department

Memorial University of Newfoundland

May, 2018

St. John's Newfoundland and Labrador

Abstract

This thesis provides a comparison of tone sandhi patterns in Standard Mandarin and Luoyang Dialect, focusing on Tone 4 sandhi. Standard Mandarin is an official language promoted in China in the 1930s, which is based on the Beijing Dialect by adopting its syntactic, lexical and phonological systems, and taking some vocabulary from other Northern dialects. Luoyang Dialect is a dialect spoken in Luoyang and its adjacent areas. Both the Beijing Dialect and the Luoyang Dialect belong to the Northern Dialect Group. There are four tones both in Standard Mandarin and Luoyang Dialect, and each tone is one-to-one correlated, which indicates that a word marked as Tone 1 in one dialect will also be Tone 1 in another. Tone 4 in both dialects follows a high falling tendency.

As an official language, Standard Mandarin has been extensively studied by linguists. It has been documented that *bu* ('no, not'), as a Tone 4 word in Standard Mandarin, will dissimilate when it's followed by other Tone 4 words. This thesis will re-examine this sandhi rule, and collect acoustic data to investigate whether *bu*- sandhi exists in Luoyang Dialect and whether other Tone 4 words also go through tone dissimilation as well. In order to conduct this research, data was collected from four speakers, including two Standard Mandarin speakers and two Luoyang Dialect speakers. Praat was used to collect the data and extract pitch lists. In addition, an algorithm proposed by Shi (Shi & Wang, 2006) was used to convert pitch data to Chao digits, allowing the tone value of each word to be further compared.

My data confirms the existence of *bu*- sandhi in Standard Mandarin, and the observation that *bu* is the only Tone 4 word in Standard Mandarin that goes through tone dissimilation. In comparison with Standard Mandarin, my data shows that *bu* not only dissimilates in front of Tone 4 words in Luoyang Dialect, but also will be neutralized from a high falling tone into a level tone elsewhere. Additionally, different from Standard Mandarin, other Tone 4 words in Luoyang Dialect will also dissimilate in front of Tone 4 words.

This thesis contributes to the phonological study of the Luoyang Dialect, and may have implications for studies of the diachronic evolution of Luoyang Dialect, as well as the

historical relationship between Beijing Dialect and Luoyang Dialect. This study is the first to carry out a comparison between Standard Mandarin and Luoyang Dialect from the perspective of tone 4 sandhi. Not only will a tone 4 sandhi rule in Luoyang Dialect be proposed and added to the body of research on Chinese tone sandhi, but the relationship of tone sandhi with stress, duration and the OCP will also be discussed.
Keywords: tone sandhi; Standard Mandarin; Luoyang Dialect; OCP

Acknowledgements

I would first like to express my sincere gratitude to my supervisor Doctor Sara Mackenzie for her continuous support of my master study and research, for her patience, motivation, and immense knowledge. Her guidance helped me in all the time of research and writing of this thesis. I could not have finished this research without her help and support. She can always steer me in the right direction whenever I am in doubt of myself and hesitation.

I would also like to thank Professor Gerard Van Herk for his inspiration on sociolinguistics, and Professor Paul De Decker, for his excellent teaching in the methodology.

My gratitude also goes to my husband Qian Gao, who is always so supportive in my study and life.

My last thanks goes to my three-year-old son Yuebo. Without him, this thesis could have been finished two years earlier.

Table of Contents

List of Tables

List of Charts

Chapter 1 Introduction

1.1 Background

This thesis will investigate the Tone 4 sandhi in Standard Mandarin and Luoyang Dialect. There are seven major dialect groups in Chinese: *Guanhua* ('Northern Dialect'), *Wu*, *Xiang*, *Gan*, *Hakka*, *Yue* and *Min*, which are regionally represented by Beijing, Shanghai, Changsha, Nanchang, Meixian, Guangzhou and Fuzhou respectively (Yuan, 2001). These dialect groups are geographically divided according to the phonological, syntactic and lexical differences. The phonological and lexical differences between each dialect group are huge, which makes the mutual intelligibility challenging for people from different dialect groups. For instance, noted in IPA (International Phonetic Alphabet), 人 ('human, person') is pronounced as /ʐən/ in Northern dialect, /ɳʱin/ in Wu dialect, and /ŋin/ in Hakka dialect. Compared with differences among the various dialect groups, the difference of sub-dialects in each group is minor. Beijing Dialect and Luoyang Dialect both belongs to the Northern Dialect Group, and 人 ('human, person') is pronounced as /ʐən/ in both dialects, but marked as a rising tone in Beijing Dialect and a low falling tone in Luoyang Dialect.

To break the communication barriers brought by different dialects, the Chinese government started to promote a standardized language in the 1930s. This standardized language, which is called *Putonghua* or Standard Mandarin, is based on the Beijing Dialect. Standard Mandarin adopts the syntactic, lexical and phonological systems of the Beijing Dialect with vocabulary from Beijing and other Northern dialects. Since the promotion of Standard Mandarin, it has been used in media, broadcasting, schools, and other public areas, and has become the official language in China. In this thesis, a comparative study of tone will be carried out between Standard Mandarin and Luoyang Dialect. Unlike Standard Mandarin, Luoyang Dialect is a local dialect, mainly spoken by people who live in Luoyang and its adjacent regions. The following map shows the distribution of each dialect group and where Beijing and Luoyang are located, respectively.

Beijing Dialect and Luoyang Dialect both belong to the Northern Dialect Group. They share the same writing system of *Hanzi* ('Chinese characters'), and the pronunciation of most words in these two dialects are similar as well. However, Beijing and Luoyang are 800 kilometers away, and this distance offers a possibility for language variation. Beijing Dialect speakers perceive that Luoyang Dialect speakers sound distinct, though understandable, but with a very strong "accent". This "accent" is partly attributed to tones.

1.2 Tone

Tone is the use of pitch in language to distinguish lexical or grammatical meaning—that is, to distinguish or to inflect words (Yip, 2002). Chinese languages are tonal and thus use tones to distinguish different word forms and meanings. In China, different dialects tend to have different types of tonal inventories and often have distinct properties in their tone sandhi systems (J. Zhang, 2014).

Chao (1930) designed a tonal marking system that divides a speaker's pitch range into five equal levels, referred to, from the highest to the lowest, by the numbers 5, 4, 3, 2, and 1. Each tone is represented by a starting pitch and a final pitch, and optionally a middle pitch. Transcribed in Chao digits, the tone inventories of Standard Mandarin and Luoyang Dialect are as follows:

(1) Tone Inventory of Standard Mandarin (Chao, 1930)

Tone 1: [55] Level Tone

Tone 2: [35] Rising Tone

Tone 3: [214] Falling-Rising Tone

Tone 4: [51] Falling tone

(2) Tone Inventory of Luoyang Dialect (Q. Zhang, Chen, & Cheng, 1993)

Tone 1: [24] Rising tone

Tone 2: [31] Falling tone

Tone 3: [45] Rising tone

Tone 4: [41] Falling tone

There are four tones in each dialect, accordingly named as Tone 1, Tone 2, Tone 3 and Tone 4. Numbered tones in each dialect are one-to-one correlated, which means that a morpheme marked with Tone 1 in Standard Mandarin will be marked with Tone 1 in Luoyang Dialect as well. For instance, "妈" ('mom'), pronounced as /ma/ in both dialects, is assigned Tone 1. Tone 1 is a level tone [55] in Standard Mandarin and a rising tone [24] in Luoyang Dialect, so "妈" ('mom') is /ma55/ in Standard Mandarin and /ma24/ in Luoyang Dialect.

In both dialects, Tone 1, Tone 2 and Tone 3 tend to have different pitch contours: Tone 1 is a level tone in Standard Mandarin but a rising tone in Luoyang Dialect, Tone 2 is a rising tone in Standard Mandarin but a falling tone in Luoyang Dialect, and Tone 3 is a falling-rising tone in Standard Mandarin but a rising tone in Luoyang Dialect. Tone 4, however, tends to have the same falling tendency in both dialects. There is no concave tone (i.e. falling-rising tone) or level tone in Luoyang Dialect.

Tone is not stable in its form, and sometimes a tone changes based on the pronunciation of adjacent morphemes. This phonological alternation in tone languages is

called Tone Sandhi (Chen, 2000; Yip, 2002; Yue-Hashimoto, 1987). In Standard Mandarin, it has been well documented (Chao, 1930; Chen, 2000; Wu, 1984; Yip, 1980) that Tone 3 will change into Tone 2 ([35]) when followed by another Tone 3 and changes into a low falling tone [21] when followed by others. This process is named **Tone 3 Sandhi**, and can be illustrated with the following examples:

(3) Tone 3 Sandhi in Standard Mandarin (Chao, 1968; Chen, 2000; Wu, 1984; Yip, 1980)

a. Tone 3 → Tone 2/__ Tone 3
[214] → [35]/__ [214]
mei^{214} hao^{214}→ mei^{35} hao^{214} 'beautiful'
zhan^{214} lan^{214}→ zhan^{35} lan^{214} 'exhibition'

b. Tone 3→ Half Tone 3/__ {Tone 1, Tone 2, Tone 4}
[214] →[21]/__ {[55], [35], [51]}
lao^{214} shi^{55}→ lao^{21} shi^{55} 'teacher'
lao^{214} ren^{35}→ lao^{21} ren^{35} 'old man'
lao^{214} lian^{51}→ lao^{21} lian^{51} 'tact'

In (3a), the initial falling-rising tone [214] changes into a rising tone [35] when it is followed by another falling-rising tone [214]. In (3b), the initial falling-rising tone [214] changes into a low falling tone [21] when it is followed by a level tone [55], rising tone [35] and high falling tone [51].

In Standard Mandarin, other than **Tone 3 Sandhi**, another sandhi pattern has also been noticed (Chao, 1968; Chen, 2000; Duanmu, 2007b): ***Bu* ('no, not') Sandhi**. Marked as Tone 4 ([51]) —a high falling tone in Standard Mandarin, *bu* changes into Tone 2 ([35]) when followed by another Tone 4, which can be illustrated by the following group of words.

(4) *Bu*- Sandhi in Standard Mandarin

bu: [51] →[35]/_[51] (Chao, 1968; Chen, 2000; Duanmu, 2007b)
bu^{51} gou^{51} →bu^{35} gou^{51} 'not enough'
bu^{51} yao^{51} →bu^{35} yao^{51} 'not want'
bu^{51} kan^{51} →bu^{35} kan^{51} 'not look at'

In Standard Mandarin, followed by another falling-tone word, *bu* ('no, not') changes from Tone 4 ([51]) to Tone 2 ([35]), and remains as Tone 4 in front of other tones. According to Chao (1968), Chen (2000) Duanmu (2007b), *bu* is the only Tone 4 word in Standard Mandarin that goes through Tone sandhi.

In Luoyang Dialect, instead of a falling-rising tone, Tone 3 is transcribed as a rising tone [45]. In the general case, Tone 3 in Luoyang Dialect surfaces like the output of Tone 3 sandhi ([35]) in standard Mandarin, thus making the **Tone 3 Sandhi Rule** inapplicable in Luoyang Dialect. However, similarly, Tone 4 in Luoyang Dialect also has a falling contour, transcribed as [41], which is in accordance with the tendency of Tone 4 in Standard Mandarin. Since *bu* Sandhi in Standard Mandarin exists, whether it also exists in Luoyang Dialect will be looked at. This study will look at the tone sandhi rules which affect Tone 4 in both dialects. Since stress, co-articulation, and intonation might have the potential to influence the tone when it occurs in longer phrases, only disyllabic words will be considered in this paper.

1.3 Research Questions

In Standard Mandarin and Luoyang Dialect, Tone 4 is the only tone that shows similar pitch contours. Considering the existence of *bu-* sandhi in Standard Mandarin, the following questions will be addressed:

a) Tone 4 sandhi in Standard Mandarin has been well documented (Chao, 1968; Chen, 2000; Duanmu, 2007b) and it is established that *bu* is the only falling tone word undergoing tone dissimilation by changing from falling tone [51] to rising tone [35] when followed by another falling tone [51]. Will acoustic data from my speakers further validate this claim?

b) Since Tone 4 [41] in Luoyang Dialect has the same falling tendency as Standard Mandarin [51], do dissyllabic *bu-* words also undergo tone dissimilation in Luoyang Dialect?

c) In general, compared with Standard Mandarin, how does a Tone 4 word pattern when followed by another Tone 4 word in Luoyang Dialect, including both *bu-* words and other disyllabic words?

d) What could be the possible causes for the sandhi processes?

1.4 Research Objective and Significance

This thesis will look at the Tone 4 sandhi in Standard Mandarin and Luoyang Dialect. Standard Mandarin is the official language of China, and has attracted copious amount of research about its phonetic system and tonal systems. However, Luoyang Dialect is a local dialect from the Northern Dialect Group, and little research has been done on this dialect. In particular, little is known about its tone system.

This thesis will contribute to the research on Luoyang Dialect in several ways. First, for a long time, little research has been undertaken on the Luoyang Dialect, and most literature gives only a sketch of the tone inventory of this dialect without digging deeper to find out how its tones will pattern in multi-syllabic words. In this thesis, for the first time, the tones of disyllabic words in Luoyang Dialect are looked at. Secondly, the rules of Tone 4 sandhi in Luoyang Dialect will be written after a systematic data collection and analysis. These rules are not based only on the intuition but on the collection and analysis of acoustic data. Thirdly, the tone sandhi comparison between Luoyang Dialect and Standard Mandarin has made it possible for the future research on the historical relations of these two dialects, since Luoyang Dialect and Standard Mandarin both belong to the Northern Dialect Group, and share the same writing system. Additionally, some researchers (Liu, 2006; Qian, 2000) pointed out that tone sandhi patterns might reflect the historical evolution of the dialect change in the long term, so in future studies, a diachronic comparison of the tone or tone sandhi can be carried out to search for the historical origins of tone changing rules in Chinese.

Chapter 2 Literature Review

2.1 Tone

Almost 70% of the world's languages are tonal (Yip, 2002a). Tone is the use of pitch in language to distinguish lexical or grammatical meaning – that is, to distinguish or to inflect words (Yip, 2002a). Hyman (2001) defined a tonal language as a language in which an indication of pitch enters into the lexical realization of at least some morphemes. Tonal languages are very common in Africa, East Asia and middle America, but rare in other areas of Asia and Europe. In many tonal languages, such as most Bantu languages, tones are distinguished by their pitch level relative to each other, which is known as a register tone system (Odden, 1996). In Chinese, tones are distinguished by their distinctive shapes, known as contours, with each tone having a different internal pattern of rising and falling pitch (Yip, 2002a). The differences between Chinese and African languages were first noted by Pike (1948). Wan and Jaeger (1998) aptly summarized the differences as follows: 1) tones in Chinese are typically associated with individual syllables and predominantly serve a lexical function, while tone patterns in African languages are often associated with polysyllabic phonological words and serve grammatical functions; 2) Chinese languages generally have a contour-based system with multiple contour tones in the tonal inventory, while African languages usually have a register-based tone system with two or three tonal levels. J. Zhang (2014, p. 443) later added another difference that "Chinese languages often have complex patterns of tone alternation caused by adjacent tones or the prosodic/morphosyntactic environment in which a tone appears, commonly referred to as tone sandhi."

Tone is notorious for its independence from the segments on which it is realized, and this fact led Goldsmith (1976) to propose that it is represented autosegmentally, on a separate tier from the segments but linked to them by association lines. The associations between tone and the Tone Bearing Units (TBUs) were governed by a set of well-formedness conditions.

(5) Well-formedness Conditions

a. Every TBU must have a tone.

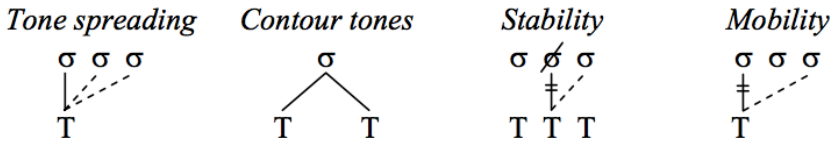
b. Every tone must be associated to some TBU.

c. Association proceeds one-to-one, left-to-right.

d. Association lines must not cross.

Well-formedness conditions allow tones to spread to more than one segment, and conversely allow a segment to have more than one tone, forming a contour. They also allow the tone to exist in the absence of a segmental host. The diagrams below will show how tone and TBUs are associated in the behaviors of spreading, contour tones, stability and mobility. Broken lines denote new affiliations, while solid lines are underlying ones.

(6) TBU Associations



(Yip, 2002a, p. 7)

For a long time, it has been a debatable question as to what the representation of tone is. According to J. Zhang (2010), proposals concerning the representation of tone attempt to answer the following questions:

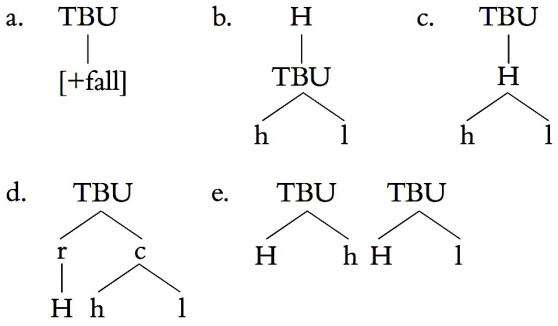
a. What is the TBU? Is it the syllable, the sonorous portion of the rhyme, or the mora?

b. What are the primitive features of tone? How many level-tone features are needed, and are contour tones represented by unitary features or sequences of level features?

c. If there are different layers of tonal features such as Register and Contour, what is the geometric relation among the features – independence, dominance, or sisterhood?

A variety of answers to these questions have been proposed. As illustration, the figure below shows how a high falling tone over a syllable can be represented according to different models of tonal representation.

(7) Representations of Tone



(J. Zhang, 2010, p. 1138)

According to Wang (1967), the contour tone is a single unit with the feature of [+fall] in (7a). Yip (1980) assumed that the tone has a binary features of Register and Contour, and the relation of these features are independent as in (7b). Register 'specifies the pitch level of the tone'; the contour node 'specifies how the tone behaves in the temporal duration of the tone bearing unit' (Yip, 1980). She further developed this idea in 1989 and 1996 by suggesting that Register and Contour are in a dominant relation as shown in (7c). Bao (1990, 1999) has a different opinion about the representation of tone. He agreed with the binary features of tone, but claimed that these two features are in a sisterhood relation as illustrated in (7d). Duanmu (1990), however, suggested that there is no contour tone unit, and the contour tone is composed of a sequence of level tones in (7e). The TBU can be the syllable, the rhyme, or the sonorous portion of the rhyme in (7a) - (7d), whereas the TBU is the mora in (7e).

As the previous discussion demonstrates, there is no consensus on the phonological representation of tone. In transcription, marking tones in Chao digits is the most common and convenient way to represent Chinese tones. The following group of words from Standard Mandarin can give a good illustration of Chinese tones:

Marked with	Hanzi	Pronunciation &Tone	Glossing
Tone 1	妈	ma^{55}	'mother'
Tone 2	麻	ma^{35}	'hemp'
Tone 3	马	ma^{213}	'horse'
Tone 4	骂	ma^{51}	'to scold'

Table 1 Illustration of Four Tones in Standard Mandarin

2.2 Tone Sandhi

Due to the collective efforts of Chinese dialectologists' descriptive study and theoretical linguists' generalizations of these studies, the typology of tone sandhi in Chinese languages is well studied. Influential works by Yip (1980), Wright (1983), Bao (1990), and Duanmu (1990), typological works by Yue- Hashimoto (1987) and Bao (2004), as well as a long line of work by Chen (1987, 1991, 2000, 2004) that culminated in his seminal tome on tone sandhi (Chen 2000) have all made important contributions to our understanding of Chinese tone sandhi.

In order to give a better explanation of tone sandhi, it is necessary to look at the representation of tones. J. Zhang (2010) argued that the influence of tone sandhi patterns on theories of tonal representation is multilayered. For instance, whether contour tones should be treated as representational units depends on whether there are cases of tone sandhi where the whole contour tone spreads onto adjacent syllables; the formal relation between Register and Contour rests on whether the register and contour shape of the tone can spread independently in tone sandhi.

Yue-Hashimoto (1987) categorized tone sandhi into two types: left-dominant and right-dominant. Right-dominant sandhi patterns usually happen in Northern Dialect Groups, Southern Wu and Min Dialect groups, and it involves the insertion or simplification of non-final tones, such as alternating from a contour tone to a level tone, or the assimilation and dissimilation of the initial tone, such as changing from a rising tone to a falling tone in front of another rising tone. Right-dominant sandhi systems often involve tonal neutralization in non-final syllables due to their lack of final lengthening effects (J. Zhang, 2002). Different dialects vary in the size of their tonal inventory, with the Northern dialects and Cantonese tending to have less sandhi patterns than Southern Wu and Min dialects in which any tonal combination will trigger tone sandhi. Chan (1991) subsequently offered a diachronic explanation for the mismatch between stress and sandhi direction: the right-dominant sandhi pattern is a vestige of a historical stage of the language with final stress.

Left-dominant sandhi processes can be found in Northern Wu dialects, which exhibit the rightward extension or spreading of the initial tone. Zhang (2007) further points out

that there is an asymmetry in how the tone sandhi behaves based on directionality, in which right-dominant sandhi tends to involve local or paradigmatic tone change, while left-dominant sandhi tends to involve the extension of the initial tone rightward. This binary categorization has provided an insightful basis for analysis of tonal alternations in certain dialects.

A group of disyllabic tone sandhi patterns in Changzhou dialect can well illustrate left-dominant sandhi forms:

	Tones	**Dissyllabic Tone Pattern**	**Illustration with words**
a.	55	33-33	$tia^{55}\ tia^{55}\rightarrow tia^{33}tia^{33}$ 'Dad'
b.	13	11-33	$mi^{13}\ aw^{45}\rightarrow mi^{11}\ aw^{33}$ 'jacket'
c.	45	45-55	$xaw^{45}\ niŋ^{13}\rightarrow xaw^{45}\ niŋ^{55}$ 'nice person'
d.	523	55-23	$ka^{523}\ tsi^{45}\rightarrow ka^{55}\ tsi^{23}$ 'ring'
e.	24	11-24	$bi^{24}\ taŋ^{523}\rightarrow bi^{11}\ taŋ^{24}$ 'Bento'

Table 2 Tone Sandhi in Changzhou Dialect

(P. Wang, 1988, p. 186; J. Zhang, 2007, p. 1139)

Changzhou Dialect is a good example to show the left-dominant sandhi process, in which the initial tone extends its pitch pattern across the whole word. As shown in Table 2 above, in dissyllabic words, the initial tone will spread across the entire sandhi domain, taking over the original tones of the non-initial syllables. Take (b) for example, if the first syllable has a rising tone [13], then the entire word will become a rising melody [11-33] no matter which tone occurs following the first tone. In (d), a falling-rising tone [523] followed by any other tones will become [55-23] in all dissyllabic words.

Right-dominant tone sandhi can be illustrated with the following sandhi rules which are provided in Chen (2000):

a. Zhengzhou: [312] → [24]/_ [312]

b. Baoding: [214] → [21]/_ [214]

c. Nanjing: [41] → [44]/_ [41]

In Zhengzhou Dialect, a sub-dialect of the Northern Dialect Group, it is found that a falling-rising tone [312] will become a rising tone [24] when followed by another falling-rising tone [312]. Baoding dialect, which is also a sub-dialect of the Northern Dialect Group,

shows another sandhi process: a falling-rising tone [214] will dissimilate into a falling tone [21] in front of another [214]. Nanjing dialect belongs to Wu Dialect group, and its falling tone [41] will dissimilate into a level tone [44] when followed by another falling tone [41]. These tone sandhi rules all involve dissimilation of the initial tone in a sequence of identical contour tones. Similarities and differences between these processes raise questions that can be addressed by examining tone sandhi in other dialects.

J. Zhang (2007) discusses three barriers to reaching a consensus on the representation and analysis of tone sandhi. First, data sources of some Chinese tone sandhi are often based on impressionistic transcriptions, which are done by traditionally trained dialectologists. This kind of transcription tends to result in different transcription conventions in the tone sandhi processes in different dialects, leading to further disagreements on the tone features. Secondly, tone sandhi patterns are so complex that one dialect's sandhi process won't give the whole picture of the entire sandhi system. Thirdly, tone is fickle in nature, so diachronic sound changes in Chinese have erased the markedness motivation for the present tone sandhi, which makes many sandhi processes seem phonetically arbitrary synchronically.

2.3 Standard Mandarin

Standard Mandarin has drawn lots of attention by researchers because of its official status and nationwide use. Chao (1930) is the first one who noted the tone sandhi of Beijing Dialect, and the study of Standard Mandarin was further carried out by other researchers based on his contributions. For example, Wu (1984) continued this tonal research by giving a more detailed description of the tone sandhi patterns in Standard Mandarin and carried on his study with a series of papers published in the coming ten years. By adopting experimental approaches of modern phonetics, he broke a pioneering path to the comprehensive exploration of the phonetic features of Mandarin. He has not only systematically analyzed the acoustic and physiological characteristics of phonetic segments, but also made great contributions to the studies of prosodic features in Chinese and their applications in speech engineering.

In recent years' study of Standard Mandarin, one of the most influential one is Duanmu (2007b), who made a comprehensive study on the phonology of Standard Chinese, in which he introduced the historical evolution of Standard Chinese, and stated that the

current Standard Chinese, which is also called *Putonghua*, was based on Beijing Dialect and has been the official language ever since the 1930s. In his book, he gave a systematic description of major phonological facts in Standard Chinese, such as syllable patterns, properties of compounds, stress, word-length variation, word-order variation, and prosody in poetry. He also analyzed some issues from a theoretical perspective, by not only showing facts that Standard Chinese observes general linguistic principles, but also showing that the analysis of Standard Chinese has implications for several areas of linguistic theory, such as syllable structure, metrical phonology, tone, and phonology–syntax interaction. In the chapter on tone, he mentioned that Standard Chinese is a typical tone language in that the pitch contour over a syllable can distinguish word meanings (Duanmu, 2007b).

Besides the theoretical description of Standard Mandarin, there are also some empirical works. Shi &Wang (2006) made a statistical analysis of monosyllabic tones of Beijing Mandarin based on three social factors: age, gender and immigration status. Their results indicate that the intergroup differences are distributional variations in allotones which reflect sociolinguistic parameters, especially age.

According to Shi & Wang (2006), there are two sections in the pitch contour: stable and dynamic sections. The stable sections are: starting and ending points of level tone, ending point of rising tone, the bending point of falling-rising tone, starting point of falling tone. Dynamic sections are: starting points of rising tone, starting and ending points of falling-rising tone, ending points of falling tones.

Differences can be traced on the dynamic sections of each tone, and these differences are systematic. The analysis between each age group reflects the diachronic changes of tones, which have already been noticed by some linguists. The significant differences between native Bejing people of each age group suggest that the level tone might be undergoing a change in a sequence of 55 to 53 and then to 51.

Besides Duanmu and Shi, who focused on the tonal research of Standard Mandarin, there are other researchers who endeavor to study Standard Mandarin from different perspectives. For instance, Mao et al. (2004) overviewed the research on the intonation of Standard Mandarin by summarizing that there are significant insights to be gained by studying intonation for Standard Mandarin teaching and testing. Wan & Jaeger (1998) did

an analysis on the speech errors and representation of tone in Standard Mandarin by arguing that contour tones are represented in underlying forms as a sequence of two or more level tones, and function as tone sequences in tone rules. Yang (2015) studied the perception and production of Mandarin tones by native speakers and second language learners, and found that acoustic cues play important roles in non-native speakers' perception and production, and continued to find out how these acoustic cues connect to psychological cues and contextual cues.

2.4 Luoyang Dialect

Luoyang is a middle-sized city in China, and has over 6 million people residing there according to the census in 2016. Luoyang Dialect is basically spoken by its local people and people who live in its adjacent regions. With such a large number of speakers, Luoyang Dialect doesn't draw as much attention as Standard Mandarin does. However, some insightful research has nevertheless been done on the Luoyang Dialect.

Heh (Heh, 1984, 1994; Li & Heh, 1996) is the first person who did a comprehensive investigation on the phonetic system, vocabulary and grammar of Luoyang Dialect. Zeng et al. (1987) also attempted to give a detailed analysis in their book about Luoyang Dialect. Heh and Zeng have different opinions about the tone inventory of Luoyang Dialect, and this disagreement has led to recent research done by Chen et al. (2013), who attempted to investigate the tone inventory of Luoyang Dialect by collecting and analyzing acoustic data through Praat, and further direct their analysis to the influence on the tone change brought by gender and age. They concluded that there have been minor changes to the tonal system of Luoyang Dialect during the last 30 years, and there are notable differences to the pitch contours between male and female speakers.

From a perspective other than phonological, Xing (2008) conducted a comparative study of Luoyang Dialect and Standard Mandarin from the perspective of code-switching with the focus on six social psychological factors: communication scene, speaker roles, purpose, topic, social identity, and age. He mentioned that Luoyang Dialect has been highly influenced by Standard Mandarin in many aspects, such as its tone, pronunciation and lexicon. Wang (2011) studied 22 interjections of Luoyang Dialect by looking at their pronunciation, tones and meanings for the purpose of uncovering the comprehensive

features of interjections in Luoyang Dialect. She also discussed the role of interjection in the communication from the perspective of discourse communication. Tang (2013) gave a sketch of the phonetic system of Luoyang Dialect by investigating its tones, consonants and vowels for the purpose of bringing some pedagogical implications to Standard Mandarin teaching, as well as mentioning the importance of protecting this local dialect.

To sum up, in regards to the tonal research of Luoyang Dialect, most of the present studies are either based on the subjective evalutaion or from the perspective of social factors. There is no systematic analysis of the tone sandhi of Luoyang Dialect. Considering the relations with Standard Mandarin, Tone 4 sandhi in Luoyang Dialect might exist as well. However, there is no documentation about it, which makes the investigation of Tone 4 sandhi in Luoyang Dialect necessary. Meanwhile, the comparison of Tone 4 in Standard Mandarin and Luoyang Dialect may reveal some significant information pertaining to the historical relation of these two dialects.

Chapter 3 Methodology

This chapter will focus on how the study is carried out to investigate the Tone 4 sandhi patterns in Standard Mandarin and Luoyang Dialect. Since dissyllabic *bu-* words in Standard Mandarin have clearly shown evidence of falling tone dissimilation, how other dissyllabic Tone 4 words display tone variation in Standard Mandarin will be revisited. Meanwhile, as a falling tone, Tone 4 in Luoyang Dialect follows a similar pitch contour to Tone 4 in Standard Mandarin, so how disyllabic *bu-* words and other dissyllabic Tone 4 words pattern in Luoyang tone sandhi will also be investigated.

3.1 Data Collection

This study will consist of four participants (two males and two females), who will take part in the audio recordings. One male and one female are from Beijing (since Standard Mandarin is based on Beijing Dialect, so their spoken Standard Mandarin is considered as more standard). One male and one female are native speakers of Luoyang Dialect. Each participant is between 20-30 years old, so age will not affect the data.

Each participant will be recorded with Praat under the sampling frequency of 44100Hz, only mono channels will be used, and all the recordings will be saved as WAV files. Three groups of word lists were given to each participant to read, as shown below. The word lists given to the speakers will only include the Chinese characters since both dialects share the same writing system *Hanzi* (‘Chinese characters’).

Group I: *Bu-* sandhi has been well documented in Standard Mandarin (Chao, 1968; Chen, 2000; Duanmu, 2007b; Yang, 2015) by changing from a high falling tone into a rising tone when it is followed by another falling tone. In order to see whether this dissimilating rule also applies to *bu-* words in Luoyang Dialect, 12 dissyllabic *bu-* words were selected from the Xinhua Dictionary (“Xinhua Zidian (’Xinhua Dictionary’),” 2011), which is shown in Table 3 below. Not only *bu-* followed by Tone 4 will be looked at, but also those followed by Tone 1, Tone 2 and Tone 3 will be included as well.

***bu*+Tone 1**	*bu an* 不安 'not peaceful'	*bu ting* 不听 'not listen'	*bu gao* 不高 'not tall'
***bu*+Tone 2**	*bu xing* 不行 'not approve'	*bu fa* 不乏 'not lack'	*bu cai* 不才 'not smart'
***bu*+Tone 3**	*bu hao* 不好 'not good'	*bu zhun* 不准 'not allow'	*bu lao* 不老 'not old'
***bu*+Tone 4**	*bu kan* 不看 'not look'	*bu yao* 不要 'not want'	*bu dan* 不但 'not but'

Table 3 Three Sets of *bu*- followed by Four Tones

Group II: To see whether *bu*- is the only Tone 4 word in Standard Mandarin that undergoes tone dissimilation, other dissyllabic Tone 4 words will also be included. Except *bu*-, 10 monosyllabic Tone 4 word followed by another Tone 4 word creating dissyllabic sequences were randomly chosen from the Xinhua Dictionary (2011), as shown in Table 4. Since it is still unknown whether *bu*- sandhi exists in Luoyang Dialect, this group of words will also be looked at in Luoyang Dialect.

1	*sheng dan* 圣诞 holy birth 'Christmas'	**6**	*dao lu* 道路 way road 'road'
2	*qi dian* 气垫 air mat 'air mat'	**7**	*fan cuo* 犯错 make mistake 'make mistakes'
3	*guai shou* 怪兽 weird beast 'monster'	**8**	*gao su* 告诉 inform tell 'tell'
4	*bian hua* 变化 change convert 'change'	**9**	*jian she* 建设 build set 'build'
5	*chuang zao* 创造 establish make 'create'	**10**	*tui huo* 退货 return goods 'return goods'

Table 4 Ten dissyllabic words of Tone 4 followed by Tone 4

Group III: No matter whether the dissimilation of the initial falling tone in Group II is going to be realized or not, it is necessary to elicit data containing falling tones preceding the other three tones, where variation may or may not be expected. Three sets of words are given in Table 5, with the initial words selected from the initial falling-tone words in Table 4 above.

Tone 4 +Tone 1	*sheng du* 圣都 holy capital 'holy capital'	*guai sheng* 怪声 strange sound 'strange sound'	*gao zhi* 告知 tell know 'inform'
Tone 4 +Tone 2	*sheng jie* 圣洁 holy clean 'saintly'	*guai ren* 怪人 strange person 'strange person'	*gao ting* 告停 tell stop 'stop'
Tone 4 +Tone 3	*sheng li* 圣礼 holy ceremony 'holy ceremony'	*guai jiao* 怪脚 strange foot 'strange foot'	*gao jing* 告警 tell warn 'warn'

Table 5 Three groups of Tone 4 followed by non-Tone 4 words

3.2 Data Analysis

Praat will be used to look at each word, and extract the pitch lists at a time interval of 0.01 second. Since pitch ranges vary between speakers, just looking at absolute pitch values is not sufficient to characterize the tone of a particular example. In addition, Chao's five digits are used in this paper to mark the tone, ranging from 1 to 5 from the lowest to the highest pitch, so a method that can examine all the tones in Chao digits is also indispensable.

In order to assign Chao digits on the basis of acoustic data, Shi & Wang (2006) conducted a statistical study on the Beijing Dialect through analyzing variation in the realization of tone according to the following three variables: gender, age and immigration status. From 52 participants, they collected recordings of 10 words for each tone. Since the pitch values extracted from each person's recording is relative, they designed an algorithm that can transfer the tone pitch values into numbers that ranges from 1-5, which is in accordance with Chao's five digits to mark the tone. Meanwhile, since the time length for each word is different, in order to set all the pitch contours into the same length, in their study, 9 tone values (henceforth T values) on each contour were evenly selected.

Since Luoyang Dialect speakers are more rapid in speaking than Beijing Dialect speakers, there are some words in Luoyang Dialect collected in this study from which only 8 pitch values could be extracted by Praat. For this reason, the 9 values selected in Shi's experiment will not apply here. In this study, only 8 T values for each word will be equally selected so that tone contours using the same number of measurements can be generated and compared. The extracted pitch measurements range from 8 to 32, and by keeping the

beginning and the end measurements, the additional 6 values will be selected by hand at equal time intervals.

In this way, by adopting the beginning and ending T values, all the tones can be transcribed into Chao digits, and hence compared. Shi's algorithm is as follows:

(8) Shi's Algorithm

$$T = \frac{lgx - lgmin}{lgmax - lgmin} \times 5 \qquad \text{(Shi \& Wang, 2006, p. 326)}$$

In the algorithm, *max* is the maximum pitch value of a person, *min* is the minimum pitch value, and x is the pitch value being considered. A logarithm is used to normalize all the data in a comparable way, and since *lgx-lgmin* will always be smaller than *lgmax- lgmin*, when multiplied by 5, T value will only range from 0.1 to 5, which is in accordance with Chao's five digits (Shi, Ran, & Wang, 2010; Shi & Wang, 2006). An example is given below to further explain this process.

The word *Qi* ([51] 'air') was extracted from the male Standard Mandarin speaker. Table 6 is the pitch list of this word automatically extracted by Praat with the time interval of 0.01 second, which shows the pitch values range from 120Hz to 181Hz. 8 numbers were then picked out in the equality of time intervals, which is shown in Table 7. From all the words' pitch lists of this speaker, the maximum pitch and the minimum pitch can be obtained, which are 183.7Hz and 103.76Hz respectively. By using Shi's algorithm, each T value based on its correspondent F0 can be calculated, ranging from 4.90 to 1.29, as shown in Table 7. Since Chao digits are only in integers, all T values will be rounded off to their nearest whole numbers. In this case, T values of *Qi* should range from 5 to 1, which matches the transcribed tone value of [51] in Standard Mandarin. Chart 1 and 2 further give an illustration of the contours in the form of F0 and T values. It shows both contours are in the same shape, and each marked point is one to one correlated.

Time (s)	F0 (Hz)
21.87	181.53
21.88	168.82
21.89	161.22
21.90	157.82
21.91	155.21
21.92	152.64

21.93	150.06
21.94	145.52
21.95	140.26
21.96	137.70
21.97	135.33
21.98	132.66
21.99	123.01
22.00	121.66
22.01	119.87
22.02	120.28

Table 6 Pitch list of *Qi* in Standard Mandarin

Time (s)	F0 (Hz)	T
21.87	181.53	4.90
21.89	161.22	3.86
21.91	155.21	3.52
21.93	150.06	3.23
21.96	137.70	2.48
21.98	132.66	2.15
22.00	121.66	1.39
22.02	120.28	1.29

Table 7 Eight measurements selected from Table 6

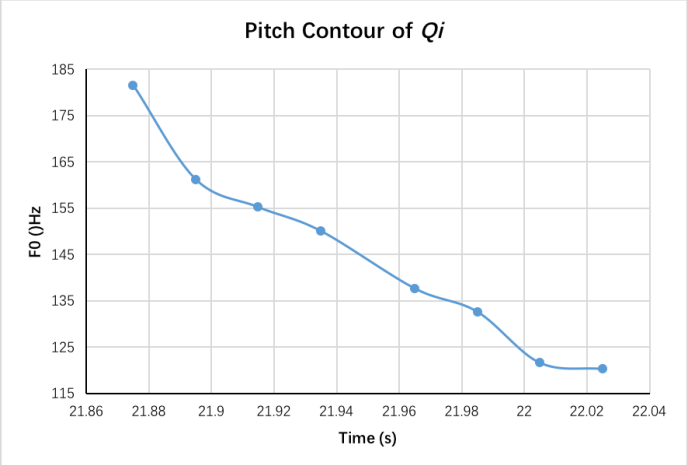


Chart 1 Pitch contour of *Qi* in Standard Mandarin

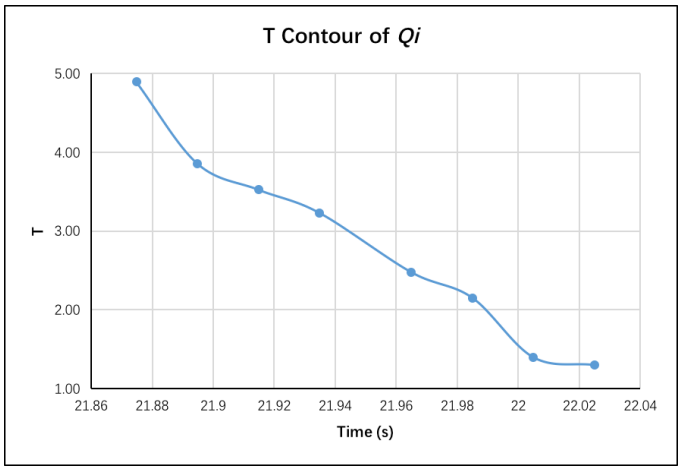


Chart 2 T contour of *Qi* in Standard Mandarin

In summary, in this study, four participants will take part in the recordings, two of them are Standard Mandarin speakers and the other two are Luoyang Dialect speakers, which consists of one male and one female speaker for each dialect. They will read the three groups of words listed above and Praat will be used to record the data. Then an acoustic analysis will be carried out using Praat, and all the pitches of each word will be extracted in the time interval of 0.01 second. Shi's algorithm will be further adopted to normalize all the pitch values into T values. Then the head and end values of each contour will be adopted and rounded off to its nearest integers. In this case, the T value of that word can be generated and a further comparison can be carried out based on the calculated T values.

Chapter 4 Results

Tone 4 in Luoyang Dialect and Standard Mandarin both have a falling pitch contour, and the only difference lies in that they are marked differently in Chao digits. Tone 4 is transcribed as [41] in Luoyang Dialect and as [51] in Standard Mandarin. In Standard Mandarin, Tone 3 sandhi and *bu-* ('no, not') sandhi has been well documented (Chao, 1968; Chen, 2000; Duanmu, 2007b). *Bu-* ('no, not') is marked as Tone 4 in Standard Mandarin, and it is the only Tone 4 word that undergoes tone sandhi. It will change from Tone 4 into Tone 2 when it is followed by another Tone 4 word, which can be written as: [51] →[35]/_[51] (Chao, 1968; Chen, 2000; Duanmu, 2007b). Luoyang Dialect and Standard Mandarin both belongs to Northern Dialect Group, they both have four tones, and each tone is one-to-one correlated. Therefore, all Tone 4 words in Standard Mandarin will also be Tone 4 words in Luoyang Dialect.

Marked as [51] and [41] respectively in Standard Mandarin and Luoyang Dialect, Tone 4 in both dialects only differs in the tone height. Hence, it is possible that *bu-* ('no, not') in Luoyang Dialect will also change from Tone 4 into Tone 2 when followed by another Tone 4 word and no other Tone 4 words will undergo the same tone sandhi processes.

4.1 *Bu-* Sandhi

4.1.1 *Bu-* Sandhi in Standard Mandarin

Marked as Tone 4 ([51]) —a high falling tone in Standard Mandarin, *bu* changes into Tone 2 ([35]) when followed by another Tone 4, which can be illustrated by the following group of words.

(9) *Bu-* Sandhi Rule in Standard Mandarin

[51] → [35]/_ [51]

$\underline{\text{bu}}^{51}$ gou^{51} →$\underline{\text{bu}}^{35}$ gou^{51} 'not enough'

(Chao, 1968; Chen, 2000; Duanmu, 2007b)

It has been argued that when followed by another falling tone, *bu* changes from Tone 4 ([51]) to Tone 2 ([35]), and remains as Tone 4 in front of other tones. In this thesis, I will use acoustic data to verify that the sandhi rule reported in previous literature is active in

the phonology of my participants. In addition, by examining a sandhi process that is well-documented in the literature, I show that the acoustic measures collected here and the method for transforming these measures into Chao digits are able to identify sandhi processes consistent with previous reports.

Three groups of *bu* followed by Four Tones were given to each speaker, and in total, for each speaker, three lists of *bu* followed by Tone 1, three followed by Tone 2, three followed by Tone 3 and three followed by Tone 4 were collected.

Table 8 shows three lists of *bu* followed by Tone 1 collected from a female speaker and Table 9 shows three lists of *bu* followed by Tone 1 collected from a male speaker.

bu (an) **'not peaceful'**		***bu (ting)*** **'not listen'**		***bu (gao)*** **'not tall'**	
Time (s)	**F0 (Hz)**	**Time (s)**	**F0 (Hz)**	**Time (s)**	**F0 (Hz)**
1.34	274.54	2.72	276.64	4.07	252.88
1.35	263.77	2.73	258.95	4.08	238.87
1.36	257.71	2.74	252.18	4.09	236.74
1.37	256.97	2.75	249.58	4.10	235.69
1.38	255.40	2.76	244.90	4.11	233.15
1.39	253.91	2.77	240.14	4.12	228.46
1.40	250.40	2.78	235.40	4.13	223.37
1.41	245.66	2.79	229.97	4.14	217.88
1.42	239.87	2.80	224.64	4.15	212.52
1.43	234.21	2.81	218.63	4.16	208.03
1.44	228.42	2.82	213.66	4.17	204.43
1.45	222.74	2.83	208.18	4.18	201.12
1.46	217.82	2.84	204.19	4.19	198.01
1.47	213.24	2.85	191.60	4.20	195.21
1.48	209.15	2.86	189.26	4.21	192.54
1.49	206.27	2.87	187.06	4.22	191.44
1.50	209.32			4.23	199.52
1.51	201.12			4.24	199.03
1.52	189.46				
1.53	189.72				

Table 8 Pitch lists of *bu* when followed by Tone 1 in Standard Mandarin (Female)

bu (an) 'not peaceful'		*bu (ting)* 'not listen'		*bu (gao)* 'not tall'	
Time (s)	**F0 (Hz)**	**Time (s)**	**F0 (Hz)**	**Time (s)**	**F0 (Hz)**
2.30	179.89	8.35	172.67	14.22	177.77
2.31	177.77	8.36	173.79	14.23	176.19
2.32	171.54	8.37	167.32	14.24	168.23
2.33	169.77	8.38	162.80	14.25	164.62
2.34	169.90	8.39	160.84	14.26	162.30
2.35	170.27	8.40	159.46	14.27	159.83
2.36	169.55	8.41	157.33	14.28	157.75
2.37	167.79	8.42	154.50	14.29	155.60
2.38	165.45	8.43	151.09	14.30	153.25
2.39	163.18	8.44	146.87	14.31	150.71
2.40	160.45	8.45	142.70	14.32	146.80
2.41	156.91	8.46	139.29	14.33	142.49
2.42	153.02	8.47	135.65	14.34	139.08
2.43	150.13	8.48	129.81	14.35	136.57
2.44	147.12	8.49	126.88	14.36	133.60
2.45	144.76	8.50	123.78	14.37	125.23
2.46	144.05	8.51	121.00	14.38	120.90
2.47	143.98			14.39	116.23
2.48	143.86				
2.49	142.85				
2.50	141.81				
2.51	140.48				

Table 9 Pitch lists of *bu* when followed by Tone 1 in Standard Mandarin (Male)

As shown above, each list of *bu* has different time length, ranging from 0.15 seconds to 0.21 seconds. In the study of Beijing and Tianjin dialect (Shi & Wang, 2006), Shi equally picked out 9 measurements from each extracted pitch list so that each tone can be brought into the same length. In this thesis, the shortest pitch measurements collected from the speaker is 8, so for the convenience of analysis, 8 numbers will be equally picked out: the beginning and the end measurements will be kept, and the additional 6 measurements will be selected by hand at equal time intervals. After 8 measurements were equally selected from each list, Table 10 and 11 were generated from each speaker.

bu (an) 'not peaceful'		*bu (ting)* 'not listen'		*bu (gao)* 'not tall'	
Time (s)	**F0 (Hz)**	**Time (s)**	**F0 (Hz)**	**Time (s)**	**F0 (Hz)**
1.34	274.54	2.72	276.64	4.07	272.88
1.37	256.97	2.74	252.18	4.10	235.69
1.40	250.40	2.76	244.90	4.12	228.46
1.42	239.87	2.78	235.40	4.14	217.88
1.45	222.74	2.81	218.63	4.17	204.43
1.47	213.24	2.83	208.18	4.19	198.01
1.50	209.32	2.85	191.60	4.21	192.54
1.53	189.72	2.87	187.06	4.24	199.03

Table 10 Eight measurements selected from Table 8

bu (an) 'not peaceful'		*bu (ting)* 'not listen'		*bu (gao)* 'not tall'	
Time (s)	**F0 (Hz)**	**Time (s)**	**F0 (Hz)**	**Time (s)**	**F0 (Hz)**
2.30	179.89	8.35	172.67	14.22	177.77
2.33	169.77	8.38	162.80	14.25	164.62
2.36	169.55	8.40	159.46	14.27	159.83
2.39	163.18	8.42	154.50	14.29	155.60
2.42	153.02	8.44	146.87	14.32	146.80
2.45	144.76	8.46	139.29	14.34	139.08
2.48	143.86	8.48	129.81	14.36	133.60
2.51	123.48	8.51	121.00	14.39	116.23

Table 11 Eight measurements selected from Table 9

Data was collected in which *bu* is followed by three different Tone 1 words. Since only one T value for each tone will be needed to do the comparison, and we expect all Tone 1 words to behave alike with respect to tone sandhi, the pitch value of each point is first averaged across the collected data. Averages for *bu*'s pitch values taken from all examples in which *bu* is followed by Tone 1 are shown in Table 12 below.

***bu* + Tone 1**	**Female**	**Male**
Points	**Averaged F0 (Hz)**	**Averaged F0 (Hz)**
Point 1	274.68	176.78
Point 2	248.28	165.73
Point 3	241.25	162.95
Point 4	231.05	157.76
Point 5	215.27	148.90
Point 6	206.47	141.04
Point 7	197.82	135.76
Point 8	191.94	120.23

Table 12 Averaged pitch values of *bu* when followed by Tone 1 in Standard Mandarin

After determining the averaged pitch values of eight points for each speaker, Shi's algorithm is used to calculate the averaged T value for each point, as shown in Table 13. The pitch contour of *bu* followed by Tone 1 based on these T values is shown in Chart 3.

***bu* + Tone 1**	**Female**	**Male**
Points	**Averaged T**	**Averaged T**
Point 1	4.65	4.66
Point 2	3.62	4.10
Point 3	3.33	3.95
Point 4	2.89	3.66
Point 5	2.18	3.16
Point 6	1.76	2.69
Point 7	1.32	2.34
Point 8	1.02	1.29

Table 13 Averaged T values of *bu* when followed by Tone 1 in Standard Mandarin

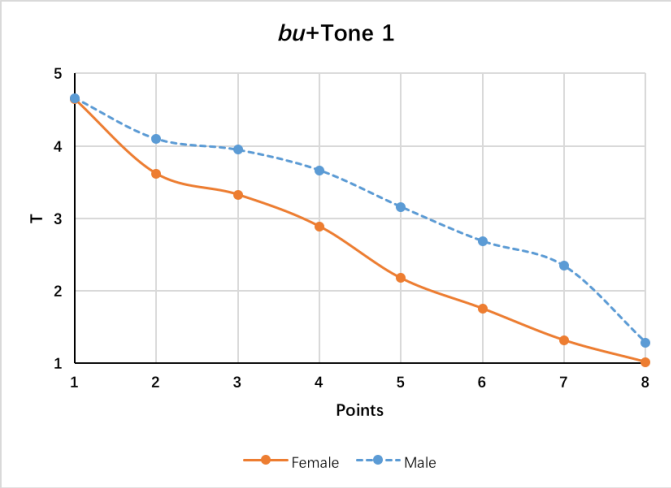


Chart 3 T contours of *bu* when followed by Tone 1 in Standard Mandarin

The procedure shown here for determining average pitch values, T values, and tone contours will be followed in all subsequent examples. T values determined by using Shi's algorithm on pitch values averaged across examples for each speaker as well as the corresponding contour charts will be shown for all following examples. The full set of pitch values for individual items are included in the appendix.

In Table 13 and Chart 3, both the male and female speaker starts at the same T value of about 4.65, the male speaker goes all the way down to 1.29 and the female speaker goes

down to 1.02. The T values of the female speaker keep under the male speaker all the way through, which indicates that the male speaker has a higher tone than the female speaker. However, this gender difference is minor, and the tone of *bu* can be still written as [51] according to Chao's Five Digits. Since all the T values are in integers, all the numbers will be rounded off to the nearest whole number. My data shows that in Standard Mandarin, when *bu* is followed by Tone 1, there is no change in the tone [51].

Based on the method mentioned above, the averaged T values of *bu* in front of Tone 2, Tone 3 and Tone 4 can be successively obtained, which will be shown in the following Table 14, Table 15 and Table 16. Each table will be followed with a chart of T values showing how the tone contour of *bu* varies in front of different tones.

***bu* + Tone 2**	**Female**	**Male**
Points	**Averaged T**	**Averaged T**
Point 1	4.67	4.76
Point 2	3.67	4.11
Point 3	3.47	3.73
Point 4	3.06	3.40
Point 5	2.58	2.81
Point 6	2.25	2.50
Point 7	1.77	2.04
Point 8	1.00	1.46

Table 14 Averaged T values of *bu* when followed by Tone 2 in Standard Mandarin

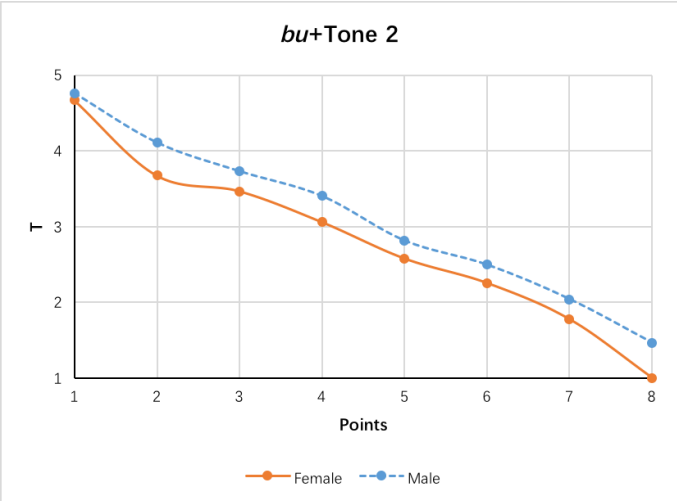


Chart 4 T contours of *bu* when followed by Tone 2 in Standard Mandarin

When *bu* is followed by Tone 2, my data above shows that although the T values of the male speaker still range higher than the female speaker, it is still [51] in Chao's Five Digits. Therefore, in Standard Mandarin, when *bu* is followed by Tone 2, no tone sandhi process has been found.

***bu* + Tone 3**	**Female**	**Male**
Points	**Averaged T**	**Averaged T**
Point 1	4.67	4.76
Point 2	3.67	4.11
Point 3	3.47	3.73
Point 4	3.06	3.40
Point 5	2.58	2.81
Point 6	2.25	2.50
Point 7	1.77	2.04
Point 8	1.00	1.46

Table 15 Averaged T values of *bu* when followed by Tone 3 in Standard Mandarin

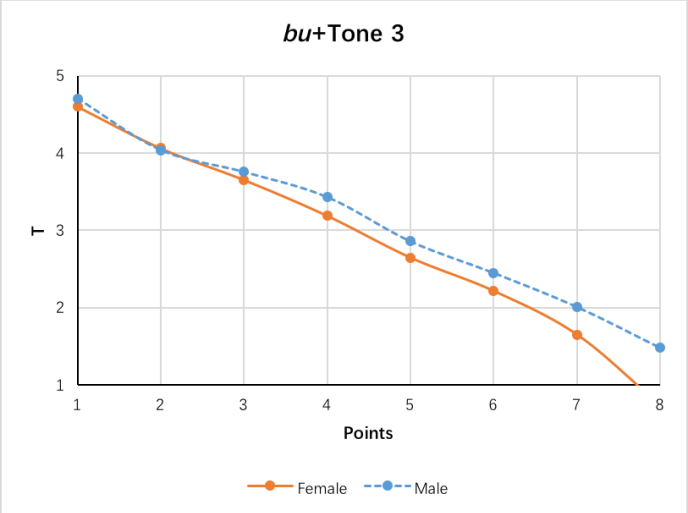


Chart 5 T contours of *bu* when followed by Tone 3 in Standard Mandarin

The same thing happens when *bu* is followed by Tone 3. It still keeps its tone [51] as indicated above in Table 14 and Chart 5. Therefore, in Standard Mandarin, when *bu* is followed by Tone 3, this falling tone does not change.

bu + Tone 4	Female	Male
Points	**Averaged T**	**Averaged T**
Point 1	2.70	2.82
Point 2	2.96	2.96
Point 3	3.56	3.27
Point 4	3.81	3.57
Point 5	3.82	3.73
Point 6	4.00	3.92
Point 7	4.31	4.40
Point 8	4.81	4.66

Table 16 Averaged T values of *bu* when followed by Tone 4 in Standard Mandarin

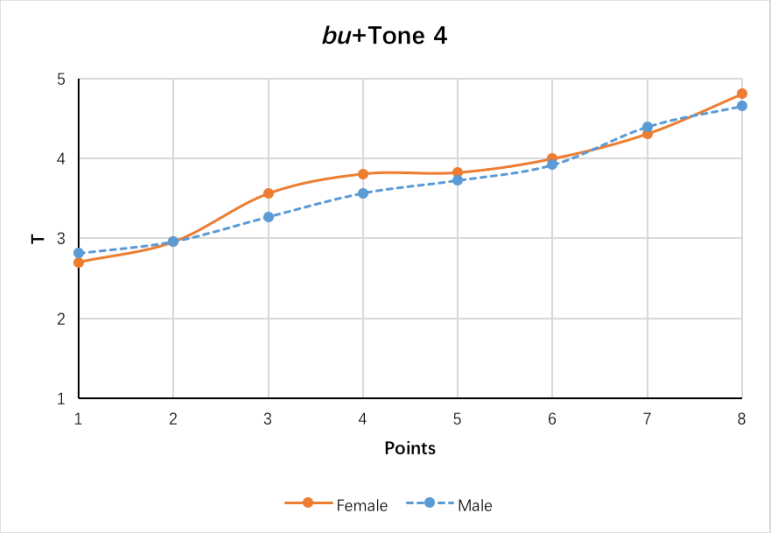


Chart 6 T contours of *bu* when followed by Tone 4 in Standard Mandarin

Table 15 and Chart 6 show a different tendency of tone contour. When *bu* is followed by Tone 4, it changes. Both contours of the male and female speaker indicate that the tone has become a rising one instead of falling. It rises from 3 to 5, and can be marked as [35] in Chao's Five Digits. Therefore, in Standard Mandarin, *bu* will change from a falling tone [51] into a rising tone [35] when it is followed by another falling tone.

In conclusion of *bu*- sandhi in Standard Mandarin, my data shows that there is no change on the tone of *bu* when it is followed by Tone 1, Tone 2 and Tone 3, and *bu* keeps its underlying tone and show a high falling tendency. However, it changes into a rising tone [35] when followed by Tone 4 for both male and female speakers, which is in accordance with the results reported in Chao (1968), Chen (2000) and Duanmu (2007b).

4.1.2 *Bu-* Sandhi in Luoyang Dialect

In Luoyang Dialect, as a monosyllabic word, *bu* is marked as a high falling tone ([41]), and the following chart shows the pitch contour of *bu*, recorded from a female and a male Luoyang Dialect speaker.

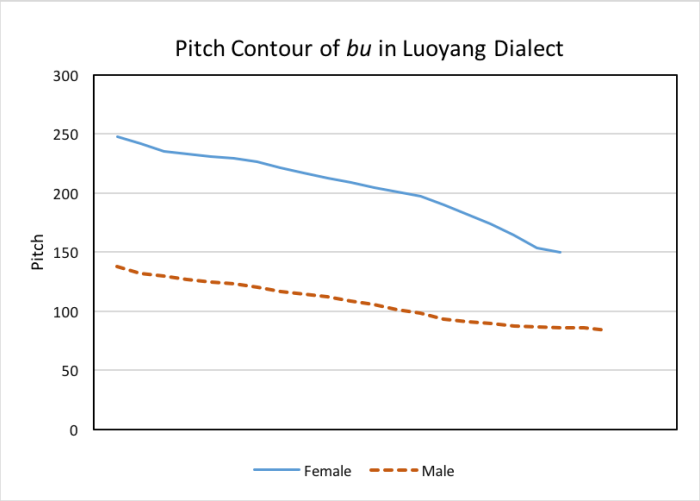


Chart 7 Pitch contour of *bu* in Luoyang Dialect

Apart from the difference in the pitch height and length, both pitches of *bu* show a falling tendency, ranging from 250Hz to 150Hz for the female speaker, and from135Hz to 85 Hz for the male speaker. By using Shi's algorithm, the T values can be calculated, and both T contours are shown below.

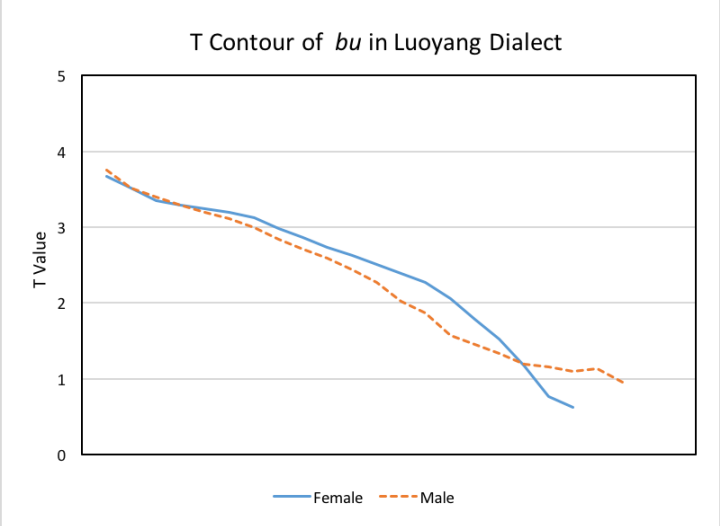


Chart 8 T contour of *bu* in Luoyang Dialect

By getting the numbers of the head and tail, the above chart shows that *bu* in Luoyang Dialect is a falling tone, marked as [41], which is in accordance with the transcription done by former researchers (Q. Zhang, Chen, & Cheng, 1993).

Tables of the averaged T values for each speaker and charts showing the tone contours of *bu* followed by Four Tones will be given below. Each table will be followed by a chart that shows the tone contour of *bu* for each speaker in different contexts.

***bu* + Tone 1**	**Female**	**Male**
Points	**Averaged T**	**Averaged T**
Point 1	3.57	3.25
Point 2	3.28	3.17
Point 3	3.32	3.33
Point 4	3.35	3.47
Point 5	3.34	3.42
Point 6	3.38	3.31
Point 7	3.24	3.29
Point 8	3.22	3.23

Table 17 Averaged T values of *bu* when followed by Tone 1 in Luoyang Dialect

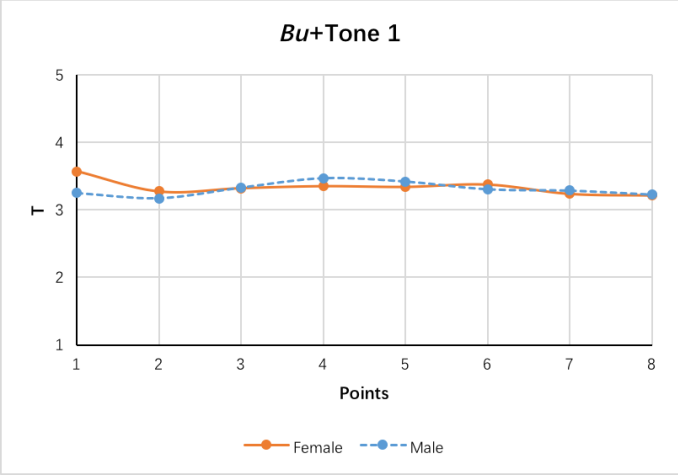


Chart 9 T contours of *bu* when followed by Tone 1 in Luoyang Dialect

My data shows that when *bu* is followed by Tone 1, it changes into a level tone, which is consistent in both male and female speakers, although with minor difference on the onset where the female speaker has a higher tone value 3.57 than the male speaker's 3.25. Here I consider the starting point value of the female speaker as 3 instead of 4, although 3.57 should be rounded off to 4. The reason for this is that the whole contour of the female

speaker shows a stable level tone around 3.3 except the starting point, and it should not be considered as a falling tone [43] due to the minor difference between the starting point and ending point of 0.37. The T value of the female speaker should be [33]. In Luoyang Dialect, *bu* changes from [41] to [33] when it is followed by Tone 1 [24].

***bu* + Tone 2**	**Female**	**Male**
Points	**Averaged T**	**Averaged T**
Point 1	3.39	3.16
Point 2	2.98	3.09
Point 3	2.95	3.20
Point 4	2.97	3.30
Point 5	3.07	3.35
Point 6	3.17	3.48
Point 7	3.01	3.50
Point 8	3.01	3.34

Table 18 Averaged T values of *bu* when followed by Tone 2 in Luoyang Dialect

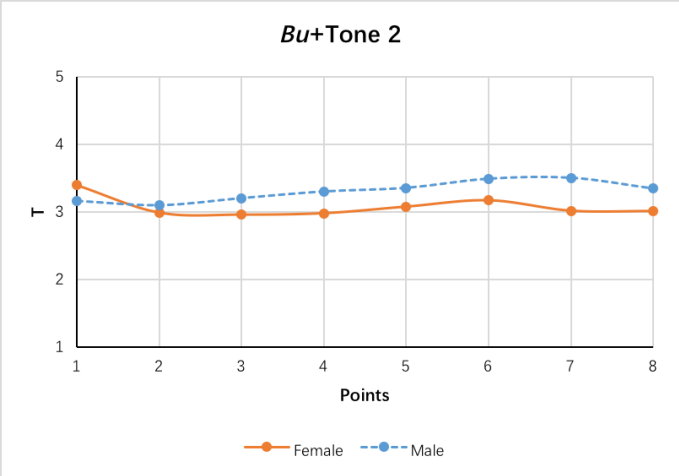


Chart 10 T contours of *bu* when followed by Tone 2 in Luoyang Dialect

Table 18 and Chart 10 above indicate that *bu* also changes into a level tone when followed by Tone 2. Based on the Chart 10 shown above, T values for the female speaker has a slightly higher onset and goes all the way under the male speaker, but both T values of the female and male speaker range around 3, which can be both marked as [33] according to Chao's five-digit tone marking system. In Luoyang Dialect, *bu* changes from [41] to [33] when it is followed by Tone 2 [31].

bu + Tone 3	Female	Male
Points	**Averaged T**	**Averaged T**
Point 1	3.55	3.07
Point 2	3.01	3.02
Point 3	3.04	3.12
Point 4	3.11	3.24
Point 5	3.13	3.35
Point 6	3.22	3.48
Point 7	3.04	3.41
Point 8	2.86	3.37

Table 19 Averaged T values of *bu* when followed by Tone 3 in Luoyang Dialect

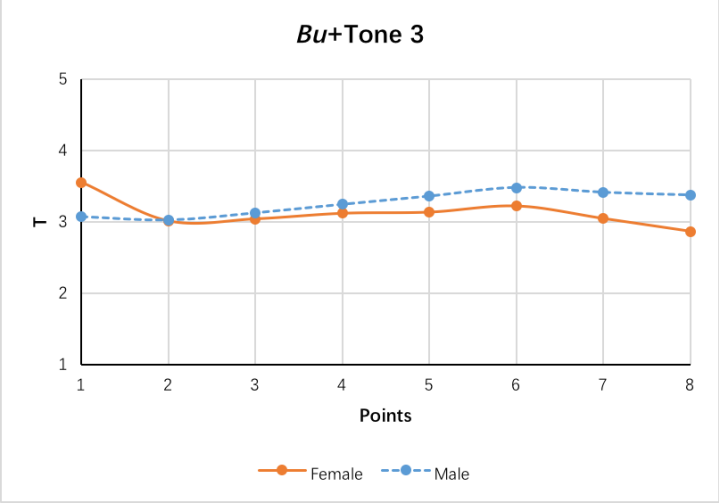


Chart 11 T contours of *bu* when followed by Tone 3 in Luoyang Dialect

When *bu* is followed by Tone 3, a similar tone contour was obtained, which suggests that *bu* changed into a level tone. In Chart 11 shown above, there is also slight gender difference in which the female has a higher onset tone than the male speaker, and lower tone afterwards. However, the gender difference is minor since both lists of T values range around 3, which indicates *bu* has changed to [33] both for female and male speakers. *Bu* changes from [41] to [33] when it is followed by Tone 3 [45] in Luoyang Dialect.

bu + Tone 4	Female	Male
Points	**Averaged T**	**Averaged T**
Point 1	3.80	4.11
Point 2	3.55	3.97
Point 3	3.60	3.99
Point 4	3.60	4.05
Point 5	3.58	4.05
Point 6	3.55	3.97
Point 7	3.55	4.02
Point 8	3.58	4.01

Table 20 Averaged T values of *bu* when followed by Tone 4 in Luoyang Dialect

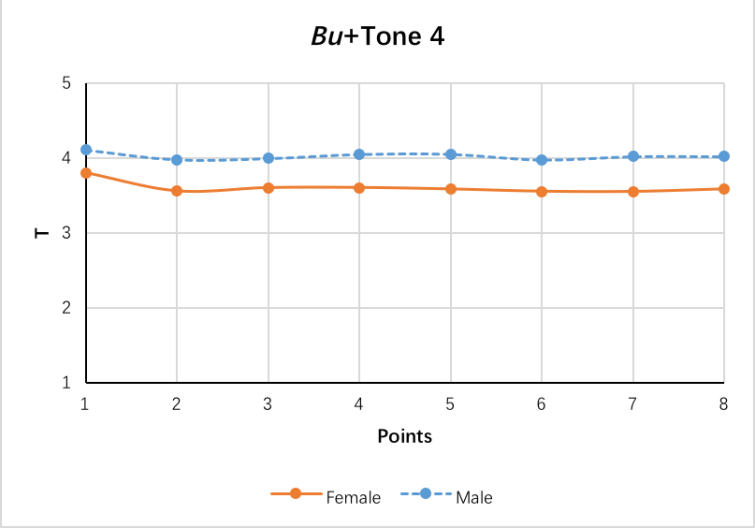


Chart 12 T contours of *bu* when followed by Tone 4 in Luoyang Dialect

In Table 24 and Chart 12, *bu* shows a different way of leveling, and the male speaker has a slightly higher tone than the female speaker all the way through. However, both lists of T values range around 4, which can be marked as [44]. Therefore, as a falling tone [41], *bu* will change to [44] when it is followed by another Tone 4.

In conclusion of the *bu*- sandhi in Luoyang dialect, *bu* will change from a falling tone into a level tone no matter which tone is following behind. However, it will change into a high level tone [44] when it's followed by another falling tone and change into a middle level tone [33] elsewhere. The underlying falling tone specification for *bu* is confirmed by

the pitch contours obtained when *bu* is produced in isolation as in Charts 8. *Bu-* sandhi in Luoyang Dialect exists and the rule for *bu* sandhi can be written as follows:

(10) *Bu-* Sandhi Rule in Luoyang Dialect

[41] → [33]/__ [24, 31, 45]

[41] → [44]/__ [41]

4.2 Tone 4 Sandhi

4.2.1 Tone 4 Sandhi in Standard Mandarin

Although some researchers have mentioned that *bu* is the only Tone 4 word in Standard Mandarin that undergoes tone sandhi, I will still look at other Tone 4 words when they are followed by another Tone 4 word in order to confirm that the reported pattern is demonstrated by speakers in this study. In addition, my data suggests that Tone 4 in Luoyang Dialect will change into a rising tone when it is followed by another Tone 4, and since Tone 4 in Luoyang Dialect and Standard Mandarin both are falling tones, it is possible that Tone 4 in Standard Mandarin will undergo the similar tone sandhi process like it does in Luoyang Dialect.

Ten dissyllabic words that are composed of Tone 4 and Tone 4 were randomly selected from the dictionary, and were given to the male and female speakers to read. Therefore, for each speaker, ten pitch lists of Tone 4 when followed by another Tone 4 will be obtained. In order to bring all the lists into the same length, 8 values of each list will be extracted, and the T value of each pitch will be calculated by using Shi's algorithm. All the pitch lists and T lists for each speaker are included in the Appendix. Table 21 below is the averaged T value of the 8 points for Tone 4, and Chart 13 is the T contour based on the lists of T values based on the same 10 words used in the Luoyang Dialect data.

Tone 4 + Tone 4	Female	Male
Points	**Averaged T**	**Averaged T**
Point 1	4.64	4.79
Point 2	3.74	3.69
Point 3	3.19	3.26
Point 4	2.66	2.75
Point 5	2.11	2.15
Point 6	1.66	1.74
Point 7	1.45	1.46
Point 8	1.26	1.23

Table 21 Averaged T values of Tone 4 when followed by Tone 4 in Standard Mandarin

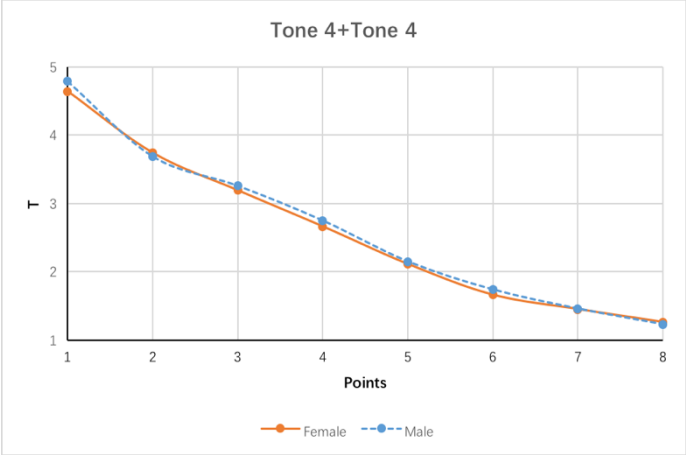


Chart 13 T contours of Tone 4 when followed by Tone 4 in Standard Mandarin

As shown above, there is not much gender difference in the T values and T contour since there is a huge overlap on the contours for each speaker. Both T values for the initial Tone 4 show a high falling tendency, gradually dropping from 5 to 1. This is in accordance with previous literature stating that no other Tone 4 words show tone dissimilation except *bu-* initial dissyllabic words.

4.2.2 Tone 4 Sandhi in Luoyang Dialect

Tone 4 in Luoyang Dialect is a falling tone, and *bu-* words not only dissimilate in front of another falling tone word, but also change into a level tone in front of other tones. This sandhi pattern is distinct from what has been found in Standard Mandarin, where *bu-* sandhi applies only before falling tone words and its underlying tone specification is unaltered in other contexts. Although there are no reports of tone sandhi applying to words

other than *bu-* in Standard Mandarin, the differences in the patterning of *bu-* sandhi across the two dialects raise the question of whether differences in the behavior of Tone 4 may be found in other words as well. Therefore, it is necessary to look at other Tone 4 words in Luoyang Dialect to see whether tone sandhi processes will apply.

In order to get the final Tone 4 contour of each speaker, each number will be averaged based on the T value lists of the ten words. However, before doing the averaging, there is one word *jian she* ('construction') in both male and female speakers' lists showing an abnormal pattern, which is very different from the other nine words. All the nine words show a rising tendency, but *jian she* is a falling tone, which is shown below.

jian (she)	**Male**		***jian (she)***	**Female**	
Points	**F0 (Hz)**	**T**	**Points**	**F0 (Hz)**	**T**
Point 1	112.57	2.44	Point 1	188.01	2.23
Point 2	104.34	1.98	Point 2	176.81	1.74
Point 3	99.82	1.72	Point 3	172.96	1.56
Point 4	95.90	1.48	Point 4	170.87	1.46
Point 5	95.78	1.47	Point 5	165.93	1.23
Point 6	95.70	1.46	Point 6	165.48	1.21
Point 7	95.36	1.44	Point 7	165.64	1.21
Point 8	98.45	1.63	Point 8	169.59	1.40

Table 22 Pitch values and T values of *jian she* in Luoyang Dialect

Both tables show that the tone values of *jian* is falling from 2.44 to 1.63 for the male speaker, and falling from 2.23 to 1.40 for the female speaker. One possible reason for the distinct behavior of *jian she* ('construction') is that it is a loan word from Japanese, borrowed in 1930s and spread by broadcasting and newspaper. In Luoyang Dialect, this word was highly influenced by Standard Mandarin, since both *jian* and *she* are both falling tone words in Standard Mandarin. Hence, when averaging the 8 points, *jian she* will be excluded, and the following table is the averaged T values for the female and male speaker using the remaining nine words included in the lists of Tone 4 words.

Tone 4 + Tone 4	Female	Male
Points	**Averaged T**	**Averaged T**
Point 1	2.15	1.88
Point 2	1.76	1.68
Point 3	1.66	1.77
Point 4	1.83	2.08
Point 5	2.12	2.54
Point 6	2.71	3.01
Point 7	3.28	3.51
Point 8	3.78	3.67

Table 23 Averaged T values of Tone 4 when followed by Tone 4 in Luoyang Dialect

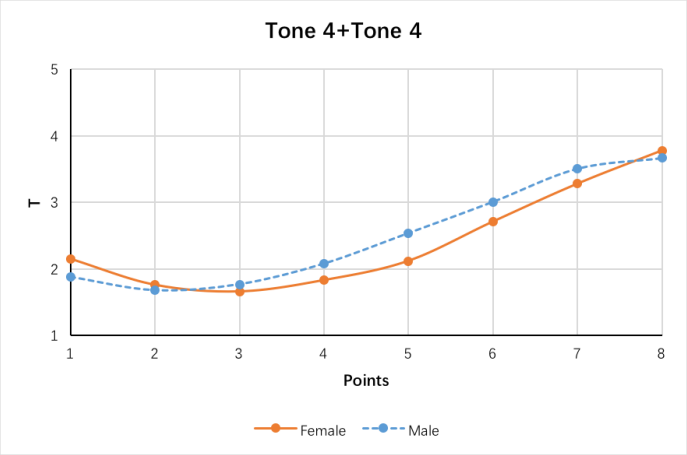


Chart 14 T contours of Tone 4 when followed by Tone 4 in Luoyang Dialect

Both the table and chart above show that when followed by another Tone 4, Tone 4 becomes a rising tone, and T values for both the female and male speaker range from 2 to 4. According to Chao's five digits, it can be marked as [24]. Therefore, in Luoyang Dialect, my data suggested that Tone 4 will change from a falling tone [41] into a rising tone [24] when it is followed by another Tone 4 word, and the rule can be written as: [41] → [24]/__ [41]. Note that while this pattern was found in the 9 words included in the data above, this process does not apply to *bu*, as demonstrated in section 4.1.

In summary, except for *bu*, in Standard Mandarin, Tone 4 will not change when it is in front of other Tone 4 words, while in Luoyang Dialect, Tone 4 will change from a falling

tone [41] into a rising tone [24] when it is followed by other Tone 4 words with the exception that this process does not apply to *bu*.

4.3 Tone 4 + other Tones

4.3.1 Tone 4 + other Tones in Standard Mandarin

Except for *bu*, Tone 4 words in Standard Mandarin will not dissimilate in front of other Tone 4 words. However, whether there is tone sandhi involved with other tones is unknown. In this section, I will use my data to investigate how Tone 4 patterns in front of non-Tone 4 words. Tables of the averaged T values of Tone 4 in each context will be given below, and each table will be followed with a chart that shows the tone contour of each Tone 4 followed by different tones.

Tone 4+Tone 1	Female	Male
Points	**Averaged T**	**Averaged T**
Point 1	4.72	4.55
Point 2	3.04	3.82
Point 3	2.46	3.44
Point 4	2.03	2.93
Point 5	1.66	2.39
Point 6	1.42	1.96
Point 7	1.26	1.63
Point 8	1.48	1.09

Table 24 Averaged T values of Tone 4 when followed by Tone 1 in Standard Mandarin

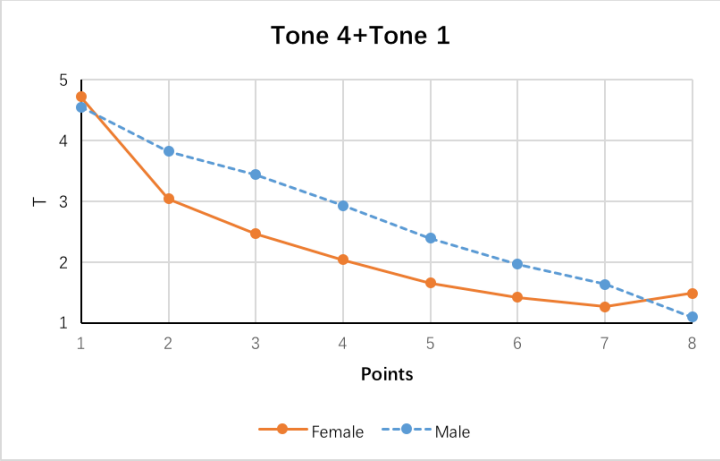


Chart 15 T contours of Tone 4 when followed by Tone 1 in Standard Mandarin

When Tone 4 is followed by Tone 1, as shown in Table 23 and Chart 15, both T values for the female and male speakers range from 5 to 1 in a falling trend. Tone 4 is still a high falling tone [51] when it is followed by Tone 1 in Standard Mandarin.

Tone 4+Tone 2	Female	Male
Points	**Averaged T**	**Averaged T**
Point 1	4.69	4.75
Point 2	3.92	3.87
Point 3	3.30	3.32
Point 4	2.72	2.73
Point 5	2.15	2.14
Point 6	1.59	1.67
Point 7	1.19	1.35
Point 8	1.09	0.98

Table 25 Averaged T values of Tone 4 when followed by Tone 2 in Standard Mandarin

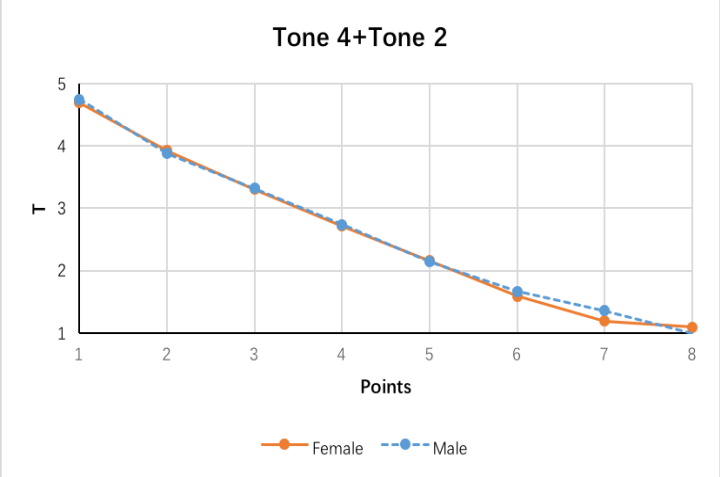


Chart 16 T contours of Tone 4 when followed by Tone 2 in Standard Mandarin

As shown above, there is huge overlap on the T contours of Tone 4, and both contours fall from 5 to 1. Therefore, Tone 4 will not change in front of Tone 2 in Standard Mandarin. It is marked as [51] in Chao's five Digits.

Tone 4+Tone 3	Female	Male
Points	**Averaged T**	**Averaged T**
Point 1	4.75	4.53
Point 2	3.85	3.54
Point 3	3.18	3.10
Point 4	2.62	2.72
Point 5	2.02	2.19
Point 6	1.50	1.70
Point 7	1.14	1.37
Point 8	0.64	0.86

Table 26 Averaged T values of Tone 4 when followed by Tone 3 in Standard Mandarin

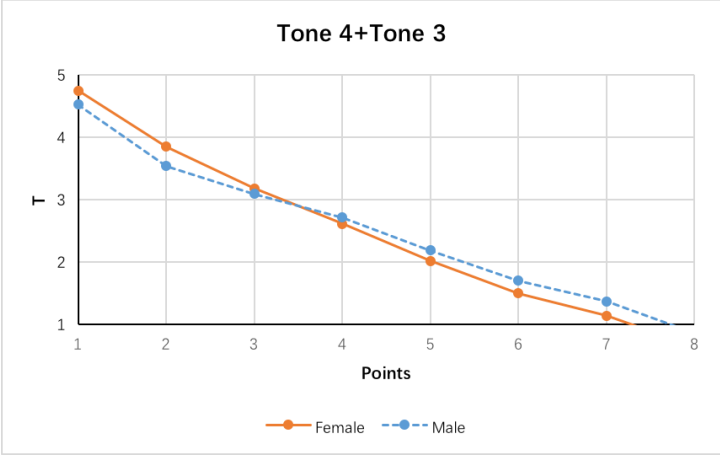


Chart 17 T contours of Tone 4 when followed by Tone 3 in Standard Mandarin

When tone 4 is followed by Tone 3 in Standard Mandarin, it keeps its original tone, which can be marked as [51] according to the above Table and Chart.

In summary, according to the data obtained, Tone 4 will not change in front of Tone 1, Tone 2 and Tone 3. *Bu* is the only Tone 4 word that undergoes tone dissimilation in Standard Mandarin.

4.3.2 Tone 4 + other Tones in Luoyang Dialect

My data shows that Tone 4 in Luoyang Dialect will dissimilate when it is followed by another Tone 4. In order to give a more explicit explanation, Tone 4 followed by non-tone 4 words will also be investigated. The following charts will show the averaged T values of Tone 4 when it is followed by non-Tone 4 words, and each table will be followed with a chart indicating the tone contour of Tone 4 in different contexts.

Tone 4+Tone 1	Female	Male
Points	**Averaged T**	**Averaged T**
Point 1	3.92	3.67
Point 2	3.15	2.80
Point 3	2.65	2.11
Point 4	2.04	1.79
Point 5	1.65	1.59
Point 6	1.43	1.56
Point 7	1.30	1.57
Point 8	1.40	1.13

Table 27 Averaged T values of Tone 4 when followed by Tone 1 in Luoyang Dialect

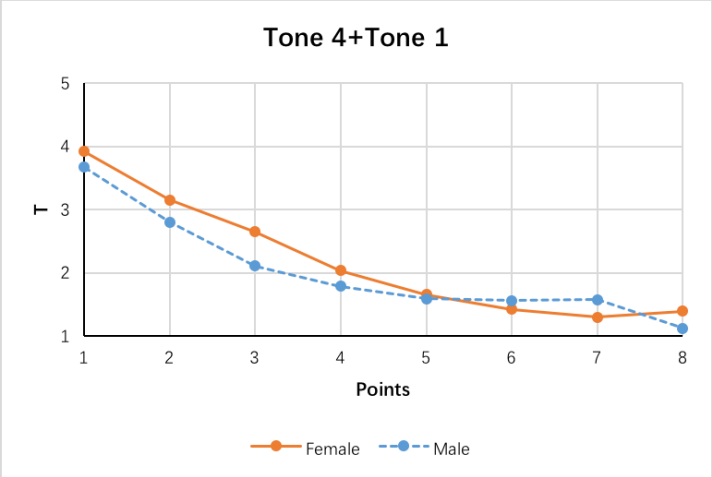


Chart 18 T contours of Tone 4 when followed by Tone 1 in Luoyang Dialect

In Luoyang Dialect, when Tone 4 is followed by Tone 1, there is no change on the falling tendency of Tone 4, which is shown in the above Table 27 and Chart 18. Tone 4 is still [41] when it is followed by Tone 1.

Tone 4+Tone 2	Female	Male
Points	**Averaged T**	**Averaged T**
Point 1	3.95	3.81
Point 2	3.13	2.37
Point 3	2.54	1.82
Point 4	2.21	1.67
Point 5	1.76	1.51
Point 6	1.63	1.39
Point 7	1.52	1.28
Point 8	1.35	1.39

Table 28 Averaged T values of Tone 4 when followed by Tone 2 in Luoyang Dialect

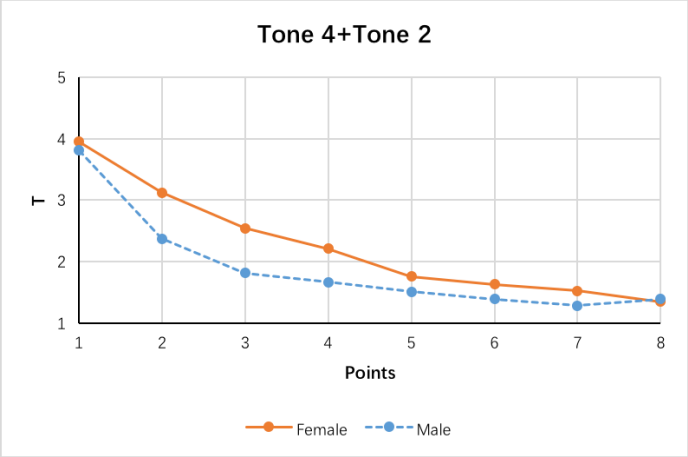


Chart 19 T contours of Tone 4 when followed by Tone 2 in Luoyang Dialect

For the female and male speaker, Tone 4 still keeps its falling trend when it is followed by Tone 2, which ranges from 4 to 1. Therefore, Tone 4 will not change when it is followed by Tone 2 in Luoyang Dialect.

Tone 4+Tone 3	Female	Male
Points	**Averaged T**	**Averaged T**
Point 1	3.90	3.67
Point 2	3.28	2.66
Point 3	2.52	1.80
Point 4	1.79	1.41
Point 5	1.68	1.37
Point 6	1.65	1.34
Point 7	1.56	1.29
Point 8	1.35	1.28

Table 29 Averaged T values of Tone 4 when followed by Tone 3 in Luoyang Dialect

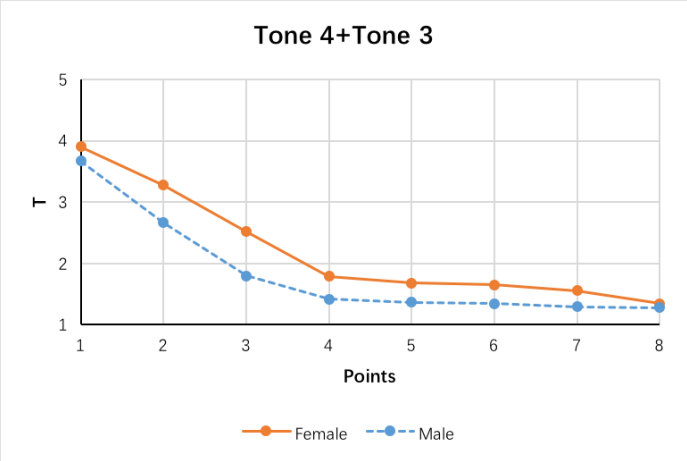


Chart 20 T contours of Tone 4 when followed by Tone 3 in Luoyang Dialect

When Tone 4 is followed by Tone 3, there is no change on the falling tendency of Tone 4, which is shown in the above Table 29 and Chart 20. Tone 4 is still [41] when it is followed by Tone 3.

To sum up for this chapter, the Standard Mandarin data presented here shows evidence of *bu-* sandhi and no evidence of Tone 4 sandhi in other contexts. This is consistent with reports in previous literature and the replication of previous studies supports the validity of Shi's algorithm for transforming pitch values into Chao's five digits. Although Tone 4 in both Standard Mandarin and Luoyang has a falling contour, Tone 4 words in the Luoyang Dialect show a different picture of sandhi processes. *Bu* in Luoyang Dialect not only dissimilates in front of falling tones, but is also neutralized into a level tone elsewhere.

Except *bu*, the other Tone 4 words also undergo sandhi processes when they are followed by another Tone 4 word. Possible reasons for the distinction in tone 4 sandhi between these two dialects will be discussed in the next chapter.

Chapter 5 Discussion

The analysis in Chapter 4 has given a clear illustration of how Tone 4 patterns when it is followed by Tone 1, Tone 2, Tone 3 and Tone 4 in dissyllabic words in Standard Mandarin and Luoyang Dialect. These two dialects both belong to the Northern Dialect Group, they both have four tones in their tonal system, and each tone is one-to-one correlated, as illustrated in Section 1.2. Tone 4 in these two dialects both follow a falling trend, and according to Chao's Five Digits, the underlying value of Tone 4 in Standard Mandarin is [52] and the underlying value for Tone 4 in Luoyang Dialect is [41].

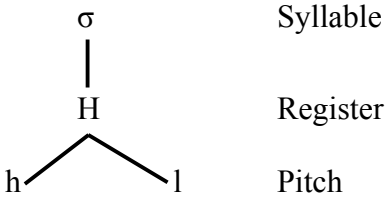
Bu ('no, not') is a Tone 4 word in both dialects, and *bu-* sandhi in Standard Mandarin has been well documented by Chao (1968), Chen (2000), and Duanmu (2007). Their works all mentioned that the falling tone of *bu* will change into a rising tone when it is followed by another falling tone. This tone dissimilation in Standard Mandarin triggered the investigation of Tone 4 sandhi of Luoyang Dialect in this thesis, since both Tone 4 in these two dialects show a falling tendency. This chapter will provide a brief discussion of the tone sandhi patterning in Standard Mandarin and the Luoyang Dialect in the context of theoretical studies of tonal phonology and representation.

5.1 Representation of Tone

I will adopt the tonal representations in Yip (1996), although the tone patterns documented here are potentially compatible with a range of proposals regarding representation of tone. This is partly due to the fact that the tone sandhi processes found in this study do not involve tone spreading and tone spreading has been shown to be the clearest source of evidence on tonal representations (e.g. Yip 1980, Duanmu 2002).

According to Yip (1996), tone has binary features classified as Register and Pitch, which is denoted by High/Low and high/low respectively. Register is the overall pitch range of the whole syllable, and keeps constant. Pitch specifies how the tone behaves in the temporal duration of the tone bearing unit (Yip, 1980). Contour tones are sequences of Pitch values, with a single Register value. Register dominates Pitch. For example, a high falling tone can be represented as follows:

(11) High Falling Tone Representation



Two binary features can produce four combinations, giving four level tones. Each tone is either H or L with respect to Register and may have one or two feature specifications for Pitch. If there is one value for the Pitch, that is a level tone. If there are two feature specifications for Pitch, the resulting tone will be a contour. Therefore, the following eight-tone inventory can be achieved:

(12) Tone Inventory Based on Yip's Proposal

[H, h]	[L, h]
[H, l]	[L, l]
[H, hl]	[L, hl]
[H, lh]	[L, lh]

(Yip, 1996)

Yip (1996) further illustrated the transcription of Cantonese tones from Chao digits as follows:

(13) Tone Inventory of Cantonese

[H, h]	[55];	[L, h]	[22]
[H, l]	[33];	[L, l]	—
[H, hl]	[53];	[L, hl]	[21]
[H, lh]	[35];	[L, lh]	[24]

According to this tone inventory mentioned above, the tone inventories of Standard Mandarin and Luoyang Dialect can be transcribed as follows:

(14) Tone Inventory of Standard Mandarin

Tone 1:	[55]	[H, h]	High level Tone
Tone 2:	[35]	[H, lh]	High rising Tone
Tone 3:	[214]	[L, lh]	Falling-Rising Tone
Tone 4:	[51]	[H, hl]	High falling tone

(15) Tone Inventory of Luoyang Dialect

Tone 1: [24] [L, lh] Low rising tone

Tone 2: [31] [H, hl] High falling tone

Tone 3: [45] [H, lh] High rising tone

Tone 4: [41] [H, hl] High falling tone

Using the representations shown above, Tone 4 sandhi rules in Standard Mandarin and Luoyang Dialect can be formalized as shown in the following table.

	***Bu*- Sandhi**	**Tone 4 Sandhi (except *bu*)**
Standard Mandarin	**51→35/__51** [H, hl]→[H, lh]/_ [H, hl]	N/A
Luoyang Dialect	**41→44/__42** [H, hl] →[H, h]/_[H, hl] **41→33/__24, 31, 45** [H, hl] →[H, l]/_ [L, lh], [H, hl], [H, lh]	**41→24/__41** [H, hl] →[L, lh]/_[H, hl]

Table 30 Tone 4 sandhi rules in Standard Mandarin and Luoyang Dialect

5.2 *Bu*- Sandhi and Stress

As discussed above, Tone 4 sandhi patterns differ substantially between Standard Mandarin and Luoyang Dialect, but in both dialects, *bu* was treated differently from other Tone 4 words. In both dialects, as a high falling tone, *bu* will dissimilate in front of another high falling tone. In Standard Mandarin, the falling contour of Tone 4 in *bu* changes to rising when it is followed by another Tone 4 word. Other words specified as Tone 4, however, do not undergo sandhi in Standard Mandarin. In Luoyang Dialect, the falling contour of Tone 4 is realized as a level tone, [44] in Chao digits, before other Tone 4 words. Unlike in Standard Mandarin, *bu* is also altered before non-Tone 4 words, changing to a level tone characterized as [33] in the Chao's digits system. This study is concerned primarily with identifying tone sandhi patterns and comparing them across the two dialects. However, given the distinct patterning of *bu* relative to other words in both dialects, a question that naturally arises is, what is the reason for the special behavior of *bu*.

The Information-Theory indicates that the information of a word depends on the probability of its occurrence (Duanmu, 2007a). The more frequently a word is found, the less information load it will have; the lower frequency a word has for a given syntactic position, and the more information load it has for that position (Duanmu, 2007a). According to the Information-Stress Principle, a word or phrase that carries more information than its neighbor(s) should be stressed (Bybee, 2001; Duanmu, 2004), and it is a general rule in Chinese dialects that only stressed syllables can keep their underlying tones (Duanmu, 2004). This is consistent with Yip (2002a) who states that tones tend to be attracted to prominent positions, such as stressed syllables and word edges while non-head positions such as unstressed syllables may reject tones, resulting in tone deletion or tone lowering.

As a function word, *bu* is usually followed by verbs (such as *bu-kan* 'not see') and adjectives/adverbs (such as *bu-gao* 'not tall') to produce negation effects in dissyllabic words. Given the role of *bu* in these constructions, there are two reasons for *bu* lacking stress. First, compared to other content words, function words have a higher rate of occurrence. The information load is low, and thus does not attract stress. Secondly, in all the *bu*-initial disyllabic words, *bu* is usually the syntactic head, and according to Non-head Stress Theory[1] (Duanmu, 2007a) that a non-head should be assigned with stress, *bu* does not receive stress. For example,

(16) Stress of dissyllabic *bu*- words

(*)	(*)	(*)
bu hao	*bu ting*	*bu yao*
'not good'	'not listen'	'not want'

In all of these examples, it is always the neighbor of *bu* that receives stress. The obligatory contour principle (OCP) bans adjacent identical elements in underlying representations, originally observed for phenomena of tonal dissimilation in African tone languages (Goldsmith, 1976; Leben, 1973). When two falling tones are adjacent to each

1 In a syntactic structure [A B], one is the head and the other the non-head. Phrasal stress is assigned to the non-head.

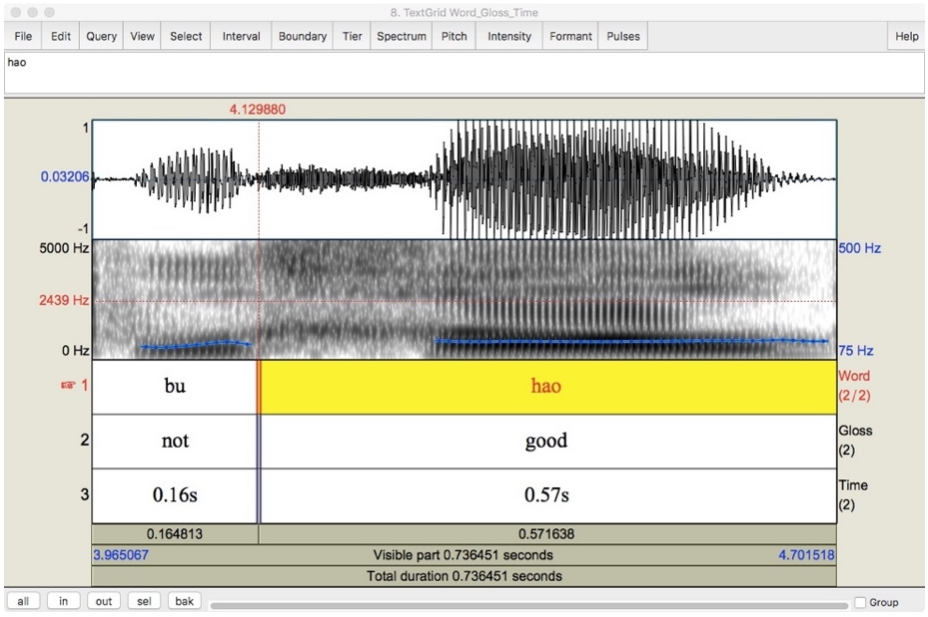
other, one tone will change. *Bu* is always unstressed while its neighbor is stressed. Therefore, it is the neighbor that will keep its tone, and it is *bu* that will undergo tone change.

In Standard Mandarin and Luoyang Dialect, stress and tone sandhi interact with each other, and the OCP will trigger the dissimilation when *bu* is followed by another high falling tone. This has validated the interaction of tonal domain and stress domain in Standard Mandarin and Luoyang Dialect, and the stress can determine the change of tones. Due to the uniqueness of *bu*, the stress rule which applies to *bu* will not apply to other non-*bu* words, as will be discussed in 5.4.

5.3 *Bu*- Sandhi and Duration

If the OCP bans adjacent identical tones, and *bu* tends to lose its tone due to its unstressed condition, why would *bu* still change from a high falling tone into a low level tone in Luoyang Dialect even though it is not followed by high falling tones?

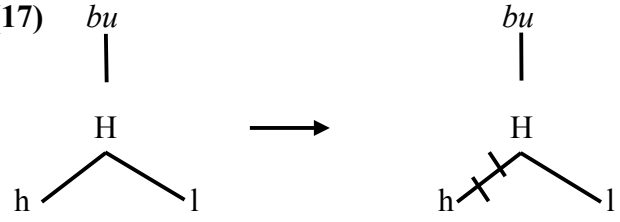
Consider the following image of a waveform, spectrogram, and textgrid, captured from the male Luoyang Dialect speaker with Praat, and the word shown below is *bu-hao* (‘not good’).



In this waveform, *bu* is much shorter than the following word *hao* with a time difference of 0.41 seconds. As a matter of fact, in Luoyang Dialect, for the male speaker,

the average time length of *bu* is only 0.1s while the time length of its neighbor is 0.49s, and its neighbor is almost five times longer than *bu*. For the female speaker, *bu*'s average time length is 0.1s while its neighbors can usually last for 0.38s, and this difference is almost four times longer. No matter if it is for the male or the female, compared with its neighbors, *bu* always has the shorter duration. In addition, the duration of *bu* is also shorter than its isolation forms, which will last for 0.3s or longer. Yang (2008) carried out an empirical study to see whether a neutral tone will change into a citation tone (level, rising, falling-rising and falling tone) in Standard Mandarin, and concluded that the neutral tones and citation tones can be altered based on the duration and pitch. His results indicate that the neutral tone has the shortest duration, and the duration of other sandhi tone is shorter than that of the normal citation tones. Other researchers, such as Yip (1989), Duanmu (2007b), Zhang (2002), also found that the duration of the syllable will have an effect on the realization of tone. In Luoyang Dialect, such a short duration of *bu* will not allow complex contour tones, which is one of the reasons why *bu* will be simplified to a level tone even though a non-falling tone follows, as shown below:

(17)



However, in Standard Mandarin, the time length of *bu* and its following words is not as distinctive as in Luoyang Dialect. In Standard Mandarin, for the female speaker, the average time length of *bu* is 0.23s and its following word is 0.39s, while for the male speaker, the average time length is 0.19s and 0.27s. The neighbor is only 1.7 times longer than *bu* for the female speaker, and 1.4 times longer for the male speaker. The duration difference between *bu* and its following words are not as large as in Luoyang Dialect, and this longer duration of *bu* in Standard Mandarin will give it more time for contour tones.

5.4 Tone 4 Sandhi and OCP

Tone 4 Sandhi except *bu* in Luoyang Dialect is similar to the sandhi process of *bu* in Standard Mandarin, both involve change from a high falling tone into a rising tone when it

is followed by another high falling tone. This can be analyzed as tone dissimilation triggered by the OCP since the OCP bans two identical elements in their underlying forms, in which two high falling tones are forbidden.

The difference between these two dialects is that Tone 4 sandhi in Standard Mandarin, though triggered by the OCP, is lexicon-contextualized, which only applies to *bu*, but *bu*-sandhi in Luoyang Dialect, however, is triggered by OCP with the influence of Information-Stress Principle. As to other Tone 4 dissyllabic words except *bu* in Standard Mandarin, the stress is more unpredictable since they have various compounding forms. For example,

(18) Stress of dissyllabic non-*bu* words in Standard Mandarin

(*)	(*)	(*)
fan cuo	*gao su*	*guai shou*
verb noun	verb verb	adjective noun
'make mistakes'	'tell'	'monster'

The words cited above are all composed of content words, in the forms of verb phrase, verb compound, and adjective phrase, and each word varies on the position of the stress with initial stress on *gao su* and *guai shou*, and final stress on *fan cuo*. Compared with function words, a content word shows lower occurrence, and carries more information. Therefore, the stress of each syllable is not predictable and cannot be generalized in Standard Mandarin. Moreover, according to the Optimality Theory, the OCP here is a violable constraint since the requirement that the content words maintain their underlying tonal contrasts ranks higher than the OCP.

Dissyllabic words in Luoyang Dialect, however, have a right-headed foot, and the word on the right usually has heavy syllables (Liu, 2006). Take the same group of words cited above for example,

(19) Stress of dissyllabic non-*bu* words in Luoyang Dialect

(*)	(*)	(*)
fan cuo	*gao su*	*guai shou*
verb noun	verb verb	adjective noun
'make mistakes'	'tell'	'monster'

Stressed syllables tend to keep their underlying tones while the unstressed ones tend to lose it (Duanmu, 2007a). Since the OCP bans identical elements in underlying representations, the first unstressed syllable will undergo changes, and the second syllable will keep its underlying tone. Therefore, in Luoyang Dialect, the falling tone (except *bu*) changes into a rising tone when it is followed by another falling tone.

To sum up the discussion, there are similarities of Tone 4 Sandhi between Standard Mandarin and Luoyang Dialect, since they both have *bu*- sandhi, which is triggered by the OCP with the influence of Information-Stress Principle. Meanwhile, the sandhi process differs greatly between these two dialects. *Bu*- simplification in Luoyang Dialect was not expected by the author before the research was carried out, and my data shows that it does exist. Meanwhile, my data also suggests that tone 4 sandhi except *bu* in Luoyang Dialect is similar to the *bu*- sandhi process in Standard Mandarin. All rules involving identity of target and trigger with an output in which they are no longer identical and adjacent are OCP-triggered rules (Yip, 1989). The OCP applies to the dissimilation rules in both dialects, and the tonal domain and stress domain are interwoven in Luoyang Dialect.

Chapter 6 Conclusion

In this thesis, I compared Tone 4 sandhi in Standard Mandarin and Luoyang Dialect. These two dialects both belong to the same dialect group and have the same falling tendency in Tone 4, but differ in the tone 4 sandhi processes. This thesis has answered the three questions raised in Section 1.3.

a) My acoustic data has again validated that *bu* is the only falling tone word in Standard Mandarin that undergoes tone 4 sandhi, by changing from a falling tone [51] to a rising tone [35] when followed by another falling tone [51].

b) As a high falling tone, compared with Standard Mandarin, *bu* in Luoyang Dialect undergoes tone sandhi in a different tonal domain. It will be dissimilated into a level tone in front of another high falling tone, and will also be neutralized into a level tone elsewhere.

c) In Luoyang Dialect, other Tone 4 words except *bu* will undergo a similar tone sandhi process to the *bu* sandhi process of Standard Mandarin, by changing from a falling tone [41] into a rising tone [24] when followed by another falling tone [41].

This thesis has provided acoustic analysis of the tone 4 sandhi of Standard Mandarin and Luoyang Dialect, and it also has some theoretical contributions.

Chao's Five Digits has been adopted and, in combination with Shi's algorithm, has provided an effective system for comparing tones. The Chao digit system has been criticized in work arguing that it is not a scientific way to analyze tone in Chinese dialects due to its relativeness (Bao, 1990; Chen, 2000; Duanmu, 1994). However, Shi's algorithm can bring all the tones into a comparable level. By using this method, all the transcription will not be based on the authors' intuition, but on the fundamental frequency determined by acoustic analysis. The data that I analyzed in this way provides evidence of *bu* sandhi in Standard Mandarin that is in accordance with the results reported by other researchers (Chao, 1968; Chen, 2000; Duanmu, 2007a).

Meanwhile, this thesis has argued that stress plays a key role in the tone sandhi of Standard Mandarin and Luoyang Dialect. Stressed syllables tend to keep their tone and

unstressed ones tend to undergo changes in tones in cases where tone dissimilation occurs under the influence of the OCP. For a long time, the interaction of stress and tone has been doubted, and this thesis has provided evidence that stress and tone can coexist in Chinese dialects. In addition, duration also influences the realization of tones, and short duration of syllables could be a reason for the simplification of tones. Results presented here show a difference in the relative duration of *bu* and following words between Standard Mandarin and Luoyang Dialect. In Luoyang, the difference in duration between *bu* and a following word is much greater than in Standard Mandarin and the very short duration of *bu* may be a factor in the general application of *bu's* tone neutralization in the Luoyang Dialect.

The thesis did not specifically contribute to theories regarding the representation of tone, since no tone spreading was found in Luoyang Dialect. Yip (1980), Duanmu (1990) and others argue that evidence regarding the representation of tone lies in the analysis of tone spreading. A subject for future research could include investigation of the entire tone sandhi patterns in Luoyang Dialect, in addition to the Tone 4 sandhi discussed in this thesis. Such a study might provide some implications for theories of TBUs, tonal representations, and contour tones.

References

Bao, Z. (1990). *On the nature of tone* (Ph.D. Dissertation). Massachusetts Institute of Technology, MA.

Bao, Z. (1999). *The structure of tone*. Oxford: Oxford University Press.

Bao, Z. (2004). Accentualism in Chinese. *Language and Linguistics*, *5*(4), 863–889.

Bybee, J. (2001). *Phonology and language use*. Cambridge University Press.

Chan, M. K. M. (1991). Contour tone spreading and tone sandhi in Danyang Chinese. *Phonology*, *8*(2), 237–259.

Chao, Y. (1930). A System of tone letters. *Le Maˆıtre Phon´etique*, (45), 24–27.

Chao, Y. (1968). *A grammar of spoken Chinese*. Berkeley and Los Angeles: University of California Press.

Chen, M. Y. (1987). The syntax of Xiamen tone sandhi. *Phonology*, *4*(01), 109–149.

Chen, M. Y. (1991). An overview of tone sandhi phenomena across Chinese dialects. *Languages and Dialects of China*, *3*, 113–158.

Chen, M. Y. (2000). *Tone Sandhi patterns across Chinese dialects*. Cambridge: Cambridge University Press.

Chen, M. Y. (2004). Changting Hakka tone sandhi: analytical challenges. *Language and Linguistics*, *5*, 799–820.

Duanmu, S. (1990). *A formal study of syllable, tone, stress and domain in Chinese languages* (Ph.D. Dissertation). Massachusetts Institute of Technology, MA.

Duanmu, S. (1994). Against contour tone units. *Linguistic Inquiry*, *25*(4), 555–608.

Duanmu, S. (2004). The tone-syntax interface in Chinese: some recent controversies. In S. Kaji (Ed.), *Cross-Linguistic Studies of Tonal Phenomena, Historical Development, Tone-Syntax Interface, and Descriptive Studies* (pp. 221–254). Tokyo University of Foreign Studies.

Duanmu, S. (2007a). Stress, information and language typology. *Language Science*, *6*(5), 3–16.

Duanmu, S. (2007b). *The phonology of Standard Chinese* (2nd ed.). New York: Oxford University Press.

Goldsmith, J. A. (1976). *Autosegmental phonology* (Ph. D. Dissertation). Massachusetts Institute of Technology, MA.

Heh, W. (1984). Luoyang fangyan jilue ('A sketch of Luoyang Dialect'), *4*, 278–299.

Heh, W. (1994). *Luoyang fangyan yanjiu ("Study on Luoyang Dialect")*. Beijing: Kexue Wenxian Chubanshe.

Hyman, L. (2001). Tone system. In M. Haspelmath, E. König, W. Oesterreicher, & W. Raible (Eds.), *Language typology and language universals: An international handbook* (Vol. 2, pp. 1367–1380). Berlin & New York: Walter de Gruyter.

Leben, W. R. (1973). *Suprasegmental phonology* (Ph. D. Dissertation). Massachusetts Institute of Technology, Cambridge.

Li, R., & Heh, W. (Eds.). (1996). Luoyang fangyan cidian('Dictionary of Luoyang Dialect'). Nanjing: Jiangsu Education Publishing House.

Liu, X. (2006). *Henan fangyan yuyin de yanbian yu cengci ('The phonological evolution of Henan dialects')* (Dissertation). Fudan University, Shanghai.

Mao, S., Zeng, Y., & Shen, B. (2004). Putonghua yudiao yanjiu zongshu (An overview on the intonation of Standard Mandarin). Presented at the The 2nd Standard Mandarin Test Conference, Zhuhai.

Odden, D. (1996). Tone: African languages. In J. A. Goldsmith (Ed.), *Handbook of Phonological Theory* (pp. 444–475). Oxford: Basil Blackwell.

Pike, K. L. (1948). Tone languages. *University of Michigan Publications in Linguistics*, *3*.

Qian, Z. (2000). Cong hanyu fangyan kan hanyu shengdiao de fazhan ("The development of Chinese tone from the perspective of dialects"). *Yuyan Jiaoxue Yu Yanjiu*, (2), 1–9.

Shi, F., Ran, Q., & Wang, P. (2010). Lun yuyin geju ('An overview of Chinese phonological structure'). *Nankai Yuyan Xuekan*, (1), 1–14.

Shi, F., & Wang, P. (2006). Beijinghua danziyin shengdiao de fenzu tongji fenxi ("A statistic analysis of tone in monosyllabic words of Beijing Dialect"), (8), 324–333.

Tang, M. (2013). Luoyang fanyan yinxi diaocha ('An investigation in the phonetic ststem of Luoyang Dialect'). *Youth Literator*, *11*, 139,141.

Wang, J. (2011). *Inerjections of Luoyang Dialect* (MA Thesis). Central China Normal University, Wuhan.

Wang, P. (1988). Changzhou fangyan de liandu biandiao (’Tone sandhi in Changzhou dialect’). *Fangyan (Dialects)*, 177–194.

Wang, W. S.-Y. (1967). Phonological features of tone. *International Journal of American Linguistics*, *33*, 93–105.

Wan, I.-P., & Jaeger, J. (1998). Speech errors and the representation of tone in Mandarin Chinese. *Phonology*, *15*(3), 417–461.

Wright, M. S. (1983). *A metrical approach to tone sandhi in Chinese dialects* (Ph. D. Dissertation). University of Massachusetts, Amherst.

Wu, Z. (1984). Putonghua Sanzizu Biandiao Guilv (“Tone sandhi in tri-syllabic words of Standard Mandarin”). *Zhongguo Yuyan Xuebao*, (2), 70–92.

Xing, L. (2008). A comparative study of Putonghua and Luoyang Dialect from the perspective of code switching. *Journal of Zhengzhou University*, *41*(5), 141–143.

Xinhua Zidian (’Xinhua Dictionary’). (2011) (11th ed.). Beijing: Commerce Press.

Yang, B. (2008). Duration of tone sandhi in Mandarin Chinese. *The Journal of the Acoustical Society of America*, *124*(4).

Yang, B. (2015). *Perception and production of Mandarin tones by native speakers and L2 learners*. Springer.

Yip, M. (1980). *The tonal phonology of Chinese* (Ph.D. Dissertation). Massachusetts Institute of Technology, MA.

Yip, M. (1989). Contour tones. *Phonology*, *6*(1), 149–174.

Yip, M. (1996). Tone in east Asian languages. In J. A. Glodsmith (Ed.), *The handbook of phonological theory*. Oxford: Blackwell Publishing Ltd.

Yip, M. (2002). *Tone*. Cambridge: Cambridge University Press.

Yuan, J. (2001). *Hanyu Fangyan Gaiyao (A Brief Introduction of Chinese Dialects)* (2nd Edition). Beijing: Yuwen Chubanshe.

Yue-Hashimoto, A. (1987). Tone Sandhi across Chinese Dialects. *Asian Language & Literature*, 445–474.

Zeng, G., Zhang, Q., & Xu, L. (1987). *Luoyang fangyan zhi (A study of Luoyang Dialect)*. Zhengzhou: Henan People Publishing House.

Zhang, J. (2002). *The effects of duration and sonority on contour tone distribution: A*

typological survey and formal analysis. New York: Routledge.

Zhang, J. (2007). A directional asymmetry in Chinese tone sandhi systems. *Journal of East Asian Linguistics*, *16*(4), 259–302.

Zhang, J. (2010). Issues in the analysis of Chinese tone. *Language and Linguistics Compass*, *4*(12), 1137–1153.

Zhang, J. (2014). Tones, tonal phonology, and tone sandhi. In C.-T. J. Huang, Y.-H. A. Li, & A. Simpson (Eds.), *The Handbook of Chinese Linguistics*. John Wiley & Sons, Inc.

Zhang, Q., Chen, T., & Cheng, Y. (1993). *Henan fangyan yanjiu ('Phonological study of Henan dialects')*. Kaifeng: Henan Daxue Chubanshe.

Appendix

(1) Lists of pitch values and T values of *bu* when followed by Tone 2 in Standard Mandarin (Female)

bu (xing) **'not approve'**			***bu (fa)*** **'not lack'**			***bu (cai)*** **'not smart'**		
Time (s)	**F0 (Hz)**	**T**	**Time (s)**	**F0 (Hz)**	**T**	**Time (s)**	**F0 (Hz)**	**T**
6.00	273.03	4.59	7.56	271.44	4.53	9.09	251.17	3.75
6.01	252.70	3.81	7.57	252.76	3.81	9.10	251.43	3.76
6.02	245.39	3.51	7.58	252.02	3.78	9.11	251.70	3.77
6.03	245.67	3.52	7.59	252.63	3.80	9.12	249.89	3.69
6.04	244.66	3.48	7.60	251.70	3.77	9.13	248.09	3.62
6.05	242.32	3.38	7.61	250.92	3.74	9.14	245.35	3.51
6.06	238.81	3.23	7.62	248.99	3.66	9.15	242.39	3.38
6.07	235.12	3.08	7.63	246.17	3.54	9.16	238.80	3.23
6.08	231.31	2.91	7.64	242.42	3.39	9.17	234.85	3.07
6.09	227.36	2.74	7.65	238.08	3.20	9.18	229.05	2.81
6.10	223.54	2.57	7.66	234.29	3.04	9.19	222.73	2.53
6.11	220.41	2.42	7.67	230.31	2.87	9.20	217.23	2.28
6.12	218.57	2.34	7.68	226.41	2.69	9.21	212.72	2.06
6.13	217.48	2.29	7.69	222.82	2.53	9.22	208.42	1.86
6.14	216.60	2.25	7.70	219.21	2.37	9.23	205.58	1.72
6.15	214.89	2.17	7.71	215.93	2.21	9.24	202.57	1.57
6.16	211.55	2.01	7.72	211.65	2.01	9.25	196.09	1.24
6.17	207.93	1.83	7.73	206.60	1.77	9.26	183.74	0.58
6.18	203.07	1.59	7.74	202.78	1.58			
6.19	199.63	1.42	7.75	203.56	1.62			
6.20	190.72	0.96	7.76	199.50	1.41			
6.21	187.85	0.80	7.77	187.99	0.81			
			7.78	183.21	0.55			

(2) Lists of pitch values and T values of *bu* when followed by Tone 2 in Standard Mandarin (Male)

bu (xing) **'not approve'**			***bu (fa)*** **'not lack'**			***bu (cai)*** **'not smart'**		
Time (s)	**F0 (Hz)**	**T**	**Time (s)**	**F0 (Hz)**	**T**	**Time (s)**	**F0 (Hz)**	**T**
3.75	177.90	4.72	9.88	179.07	4.78	15.67	179.40	4.79
3.76	177.30	4.69	9.89	170.34	4.34	15.68	176.40	4.65
3.77	170.55	4.35	9.90	164.50	4.03	15.69	169.44	4.29
3.78	166.68	4.15	9.91	161.82	3.89	15.70	161.14	3.85
3.79	164.33	4.02	9.92	159.95	3.79	15.71	157.28	3.64
3.80	161.85	3.89	9.93	157.64	3.66	15.72	154.36	3.48
3.81	158.78	3.72	9.94	155.19	3.52	15.73	151.23	3.30
3.82	155.33	3.53	9.95	152.65	3.38	15.74	147.84	3.10
3.83	151.46	3.31	9.96	149.97	3.22	15.75	144.02	2.87
3.84	147.13	3.06	9.97	146.44	3.02	15.76	141.81	2.73
3.85	142.34	2.77	9.98	142.96	2.81	15.77	139.79	2.61
3.86	139.63	2.60	9.99	140.10	2.63	15.78	136.90	2.43
3.87	136.94	2.43	10.00	137.25	2.45	15.79	133.22	2.19
3.88	133.58	2.21	10.01	133.46	2.20	15.80	129.30	1.93
3.89	130.87	2.03	10.02	128.95	1.90	15.81	121.38	1.37
3.90	127.35	1.79	10.03	126.33	1.72			
3.91	124.90	1.62	10.04	125.03	1.63			
3.92	123.37	1.52	10.05	123.23	1.51			

(3) Lists of pitch values and T values of *bu* when followed by Tone 3 in Standard Mandarin (Female)

bu (hao) **'not good'**			***bu (zhun)*** **'not allow'**			***bu (lao)*** **'not old'**		
Time (s)	**F0 (Hz)**	**T**	**Time (s)**	**F0 (Hz)**	**T**	**Time (s)**	**F0 (Hz)**	**T**
11.39	269.17	4.45	12.91	277.56	4.76	14.33	273.25	4.60
11.40	255.40	3.91	12.92	275.78	4.69	14.34	266.23	4.33
11.41	251.13	3.74	12.93	273.60	4.61	14.35	265.02	4.29
11.42	250.32	3.71	12.94	270.79	4.51	14.36	263.46	4.23
11.43	248.90	3.65	12.95	267.52	4.38	14.37	261.34	4.15
11.44	247.10	3.58	12.96	263.49	4.23	14.38	259.07	4.06
11.45	244.85	3.49	12.97	259.08	4.06	14.39	256.79	3.97
11.46	242.26	3.38	12.98	254.56	3.88	14.40	254.63	3.88
11.47	239.57	3.27	12.99	249.79	3.69	14.41	251.92	3.78
11.48	236.90	3.15	13.00	244.49	3.47	14.42	248.62	3.64
11.49	234.50	3.05	13.01	239.06	3.24	14.43	244.93	3.49
11.50	231.73	2.93	13.02	233.77	3.02	14.44	241.21	3.34
11.51	228.52	2.79	13.03	228.50	2.79	14.45	237.62	3.18
11.52	225.52	2.65	13.04	222.67	2.53	14.46	233.31	3.00
11.53	222.57	2.52	13.05	217.40	2.28	14.47	229.34	2.82
11.54	219.82	2.40	13.06	213.38	2.09	14.48	225.98	2.68
11.55	217.27	2.28	13.07	208.99	1.88	14.49	222.48	2.52
11.56	215.03	2.17	13.08	208.21	1.85	14.50	218.13	2.32
11.57	212.56	2.06	13.09	210.28	1.95	14.51	212.19	2.04
11.58	210.52	1.96	13.10	208.56	1.86	14.52	203.24	1.60
11.59	203.90	1.63	13.11	198.40	1.36	14.53	198.92	1.38
11.60	201.12	1.50	13.12	198.89	1.38	14.54	195.62	1.21
11.61	189.46	0.89	13.13	192.58	1.06	14.55	187.93	0.81
11.62	189.72	0.90	13.14	191.05	0.98	14.56	182.21	0.50
			13.15	188.99	0.87			
			13.16	187.51	0.79			

(4) Lists of pitch values and T values of *bu* when followed by Tone 3 in Standard Mandarin (Male)

bu (hao) **'not good'**			***bu (zhun)*** **'not allow'**			***bu (lao)*** **'not old'**		
Time (s)	**F0 (Hz)**	**T**	**Time (s)**	**F0 (Hz)**	**T**	**Time (s)**	**F0 (Hz)**	**T**
5.27	178.51	4.75	11.41	176.65	4.66	17.21	177.60	4.70
5.28	173.25	4.49	11.42	168.08	4.22	17.22	178.12	4.73
5.29	163.68	3.99	11.43	164.04	4.01	17.23	170.70	4.36
5.30	160.44	3.82	11.44	162.72	3.94	17.24	167.57	4.20
5.31	158.46	3.71	11.45	161.21	3.86	17.25	165.02	4.06
5.32	156.06	3.57	11.46	159.17	3.75	17.26	161.81	3.89
5.33	153.38	3.42	11.47	157.03	3.63	17.27	158.67	3.72
5.34	150.36	3.25	11.48	154.45	3.48	17.28	155.80	3.56
5.35	146.13	3.00	11.49	151.65	3.32	17.29	152.50	3.37
5.36	142.47	2.78	11.50	148.14	3.12	17.30	148.91	3.16
5.37	139.65	2.60	11.51	143.55	2.84	17.31	144.25	2.88
5.38	137.02	2.43	11.52	140.12	2.63	17.32	141.55	2.72
5.39	133.29	2.19	11.53	137.32	2.45	17.33	139.98	2.62
5.40	128.92	1.90	11.54	133.26	2.19	17.34	138.08	2.50
5.41	126.62	1.74	11.55	127.23	1.78	17.35	125.26	1.65
5.42	124.47	1.59	11.56	120.12	1.28	17.36	113.10	0.75
5.43	122.05	1.42	11.57	124.88	1.62			
			11.58	129.53	1.94			
			11.59	128.94	1.90			
			11.60	134.36	2.26			

(5) Lists of pitch values and T values of *bu* when followed by Tone 4 in Standard Mandarin (Female)

bu (kan) **'not look'**			***bu (yao)*** **'not want'**			***bu (dan)*** **'not but'**		
Time (s)	**F0 (Hz)**	**T**	**Time (s)**	**F0 (Hz)**	**T**	**Time (s)**	**F0 (Hz)**	**T**
16.35	224.23	2.60	17.83	227.35	2.74	19.31	228.07	2.77
16.36	223.45	2.56	17.84	235.36	3.09	19.32	226.57	2.70
16.37	222.56	2.52	17.85	236.63	3.14	19.33	234.95	3.07
16.38	221.34	2.47	17.86	242.07	3.37	19.34	233.81	3.02
16.39	231.84	2.93	17.87	242.36	3.38	19.35	232.58	2.97
16.40	232.15	2.95	17.88	248.65	3.64	19.36	233.05	2.99
16.41	243.38	3.43	17.89	247.17	3.58	19.37	238.99	3.24
16.42	244.85	3.49	17.90	256.58	3.96	19.38	237.51	3.18
16.43	246.04	3.54	17.91	258.02	4.02	19.39	246.45	3.55
16.44	246.94	3.57	17.92	259.57	4.08	19.40	246.55	3.56
16.45	248.48	3.64	17.93	260.77	4.12	19.41	247.41	3.59
16.46	250.22	3.71	17.94	266.16	4.33	19.42	249.51	3.68
16.47	252.28	3.79	17.95	267.06	4.37	19.43	252.34	3.79
16.48	255.09	3.90	17.96	269.26	4.45	19.44	255.33	3.91
16.49	257.87	4.01	17.97	261.60	4.16	19.45	257.53	4.00
16.50	260.91	4.13	17.98	262.39	4.19	19.46	258.74	4.05
16.51	263.18	4.22	17.99	263.10	4.22	19.47	261.15	4.14
16.52	273.74	4.62	18.00	265.14	4.29	19.48	263.29	4.22
16.53	281.47	4.90	18.01	268.26	4.41	19.49	273.39	4.60
			18.02	270.18	4.48	19.50	276.12	4.70
			18.03	273.64	4.61			
			18.04	274.97	4.66			
			18.05	273.91	4.62			
			18.06	278.99	4.81			
			18.07	277.42	4.75			
			18.08	279.53	4.83			

(6) Lists of pitch values and T values of *bu* when followed by Tone 4 in Standard Mandarin (Male)

bu (kan) **'not look'**			***bu (yao)*** **'not want'**			***bu (dan)*** **'not but'**		
Time (s)	**F0 (Hz)**	**T**	**Time (s)**	**F0 (Hz)**	**T**	**Time (s)**	**F0 (Hz)**	**T**
6.76	141.35	2.71	12.76	140.13	2.63	18.52	148.02	3.11
6.77	143.16	2.82	12.77	144.27	2.88	18.53	144.24	2.88
6.78	147.24	3.06	12.78	146.15	3.00	18.54	142.85	2.80
6.79	148.21	3.12	12.79	146.59	3.02	18.55	151.91	3.34
6.80	149.60	3.20	12.80	147.69	3.09	18.56	152.72	3.38
6.81	155.07	3.52	12.81	149.13	3.18	18.57	153.71	3.44
6.82	158.27	3.70	12.82	150.09	3.23	18.58	154.25	3.47
6.83	161.23	3.86	12.83	153.10	3.40	18.59	155.05	3.52
6.84	161.97	3.90	12.84	154.28	3.47	18.60	156.44	3.59
6.85	163.82	4.00	12.85	156.04	3.57	18.61	175.72	4.61
6.86	164.86	4.05	12.86	158.22	3.69	18.62	179.05	4.78
6.87	164.88	4.05	12.87	159.50	3.76	18.63	178.54	4.75
6.88	172.67	4.46	12.88	161.17	3.85			
6.89	175.81	4.62	12.89	164.12	4.01			
			12.90	168.15	4.23			
			12.91	168.66	4.25			
			12.92	169.49	4.30			
			12.93	171.45	4.40			
			12.94	174.17	4.53			
			12.95	177.26	4.69			
			12.96	171.42	4.39			
			12.97	175.62	4.61			

(7) Lists of pitch values and T values of *bu* when followed by Tone 1 in Luoyang Dialect (Female)

bu (an) **'not peaceful'**			***bu (ting)*** **'not listen'**			***bu (gao)*** **'not tall'**		
Time (s)	**F0 (Hz)**	**T**	**Time (s)**	**F0 (Hz)**	**T**	**Time (s)**	**F0 (Hz)**	**T**
1.04	263.96	3.53	4.91	244.32	3.54	9.10	250.35	3.64
1.05	248.53	3.65	4.92	243.68	3.52	9.11	247.65	3.63
1.06	241.21	3.45	4.93	232.23	3.20	9.12	235.72	3.30
1.07	239.34	3.40	4.94	233.56	3.24	9.13	229.56	3.13
1.08	239.04	3.39	4.95	236.56	3.33	9.14	230.57	3.16
1.09	238.40	3.38	4.96	238.99	3.39	9.15	231.44	3.18
1.10	237.52	3.35	4.97	240.77	3.44	9.16	231.37	3.18
1.11	237.93	3.36	4.98	241.39	3.46	9.17	231.31	3.18
1.12	239.54	3.41	4.99	241.01	3.45	9.18	232.18	3.20
1.13	240.79	3.44	5.00	240.33	3.43	9.19	232.79	3.22
1.14	240.93	3.45	5.01	239.17	3.40	9.20	233.57	3.24
1.15	238.48	3.38	5.02	238.40	3.38	9.21	234.72	3.27
1.16	235.32	3.29	5.03	236.68	3.33	9.22	236.11	3.31
			5.04	223.60	2.96	9.23	237.09	3.34
			5.05	220.54	2.87	9.24	237.65	3.36
			5.06	228.19	3.09	9.25	237.48	3.35
						9.26	236.16	3.32
						9.27	233.33	3.24
						9.28	227.08	3.06
						9.29	234.39	3.27

(8) Lists of pitch values and T values of *bu* when followed by Tone 1 in Luoyang Dialect (Male)

bu (an) **'not peaceful'**			***bu (ting)*** **'not listen'**			***bu (gao)*** **'not tall'**		
Time (s)	**F0 (Hz)**	**T**	**Time (s)**	**F0 (Hz)**	**T**	**Time (s)**	**F0 (Hz)**	**T**
1.07	124.10	3.02	7.31	133.45	3.46	14.14	126.35	3.13
1.08	122.06	2.92	7.32	131.35	3.36	14.15	123.62	3.00
1.09	121.97	2.92	7.33	131.43	3.37	14.16	124.52	3.04
1.10	123.21	2.98	7.34	131.92	3.39	14.17	126.33	3.13
1.11	124.98	3.07	7.35	131.78	3.38	14.18	128.07	3.21
1.12	127.30	3.18	7.36	129.76	3.29	14.19	128.45	3.23
1.13	129.47	3.28	7.37	125.83	3.11	14.20	127.88	3.20
1.14	132.36	3.41	7.38	130.10	3.31	14.21	126.50	3.14
1.15	134.89	3.52	7.39	130.95	3.35	14.22	124.29	3.03
1.16	137.90	3.66				14.23	123.92	3.01
1.17	141.80	3.82				14.24	126.93	3.16
1.18	147.37	4.05				14.25	126.59	3.14
1.19	151.55	4.22						
1.20	154.08	4.32						
1.21	155.17	4.36						
1.22	154.98	4.36						
1.23	154.13	4.32						
1.24	152.17	4.25						
1.25	135.00	3.53						
1.26	132.38	3.41						
1.27	124.78	3.06						

(9) Lists of pitch values and T values of *bu* when followed by Tone 2 in Luoyang Dialect (Female)

bu (xing) **'not approve'**			***bu (fa)*** **'not lack'**			***bu (cai)*** **'not smart'**		
Time (s)	**F0 (Hz)**	**T**	**Time (s)**	**F0 (Hz)**	**T**	**Time (s)**	**F0 (Hz)**	**T**
1.97	243.61	3.52	6.00	232.95	3.23	10.16	240.63	3.44
1.98	233.24	3.23	6.01	219.46	2.83	10.17	231.75	3.19
1.99	232.60	3.22	6.02	220.90	2.88	10.18	220.17	2.86
2.00	234.67	3.27	6.03	220.47	2.86	10.19	218.02	2.79
2.01	235.06	3.28	6.04	217.50	2.78	10.20	218.61	2.81
2.02	235.18	3.29	6.05	214.47	2.68	10.21	220.47	2.86
2.03	234.82	3.28	6.06	213.85	2.66	10.22	224.22	2.97
2.04	233.60	3.24	6.07	216.14	2.73	10.23	228.63	3.10
2.05	231.03	3.17	6.08	219.34	2.83	10.24	230.28	3.15
2.06	222.29	2.92	6.09	223.19	2.95	10.25	222.31	2.92
			6.10	227.78	3.08	10.26	209.39	2.53
			6.11	232.39	3.21	10.27	219.36	2.83
			6.12	234.37	3.27	10.28	225.65	3.02
			6.13	232.25	3.21			
			6.14	227.99	3.08			

(10) Lists of pitch values and T values of *bu* when followed by Tone 2 in Luoyang Dialect (Male)

bu (xing) **'not approve'**			***bu (fa)*** **'not lack'**			***bu (cai)*** **'not smart'**		
Time (s)	**F0 (Hz)**	**T**	**Time (s)**	**F0 (Hz)**	**T**	**Time (s)**	**F0 (Hz)**	**T**
2.46	132.93	3.44	8.95	120.17	2.83	15.71	125.12	3.07
2.47	128.53	3.23	8.96	120.56	2.85	15.72	123.81	3.01
2.48	129.39	3.27	8.97	121.80	2.91	15.73	124.16	3.03
2.49	131.95	3.39	8.98	123.84	3.01	15.74	124.40	3.04
2.50	135.67	3.56	8.99	127.01	3.16	15.75	119.85	2.81
2.51	139.43	3.72	9.00	130.44	3.32	15.76	115.63	2.60
2.52	140.77	3.78	9.01	133.56	3.46	15.77	121.38	2.89
2.53	140.21	3.76	9.02	136.31	3.59	15.78	122.03	2.92
2.54	132.07	3.40	9.03	137.44	3.64	15.79	123.79	3.01
			9.04	138.38	3.68			
			9.05	138.17	3.67			
			9.06	135.52	3.55			
			9.07	133.70	3.47			

(11) Lists of pitch values and T values of *bu* when followed by Tone 3 in Luoyang Dialect (Female)

bu (hao) **'not good'**			***bu (zhun)*** **'not allow'**			***bu (lao)*** **'not old'**		
Time (s)	**F0 (Hz)**	**T**	**Time (s)**	**F0 (Hz)**	**T**	**Time (s)**	**F0 (Hz)**	**T**
2.95	240.54	3.44	7.04	244.03	3.53	11.16	249.30	3.67
2.96	233.39	3.24	7.05	230.33	3.15	11.17	243.67	3.52
2.97	219.08	2.82	7.06	225.20	3.00	11.18	232.05	3.20
2.98	219.30	2.83	7.07	228.04	3.09	11.19	228.22	3.09
2.99	219.69	2.84	7.08	229.97	3.14	11.20	229.54	3.13
3.00	220.14	2.85	7.09	231.46	3.18	11.21	231.26	3.18
3.01	222.66	2.93	7.10	232.40	3.21	11.22	232.14	3.20
3.02	223.34	2.95	7.11	232.50	3.21	11.23	232.20	3.20
3.03	223.72	2.96	7.12	232.39	3.21	11.24	232.56	3.21
3.04	225.72	3.02	7.13	232.65	3.22	11.25	232.89	3.22
3.05	228.24	3.09	7.14	233.84	3.25	11.26	233.93	3.25
3.06	229.22	3.12	7.15	235.64	3.30	11.27	234.01	3.26
3.07	229.95	3.14	7.16	235.60	3.30	11.28	230.81	3.16
3.08	227.81	3.08	7.17	218.90	2.82	11.29	229.45	3.13
3.09	218.97	2.82	7.18	215.79	2.72	11.30	225.01	3.00
			7.19	217.38	2.77			

(12) Lists of pitch values and T values of *bu* when followed by Tone 3 in Luoyang Dialect (Male)

bu (hao) **'not good'**			***bu (zhun)*** **'not allow'**			***bu (lao)*** **'not old'**		
Time (s)	**F0 (Hz)**	**T**	**Time (s)**	**F0 (Hz)**	**T**	**Time (s)**	**F0 (Hz)**	**T**
4.02	121.18	2.88	10.74	129.95	3.30	17.31	121.36	2.89
4.03	118.78	2.76	10.75	130.51	3.33	17.32	119.29	2.79
4.04	118.74	2.76	10.76	131.41	3.37	17.33	120.51	2.85
4.05	120.76	2.86	10.77	131.75	3.38	17.34	123.23	2.98
4.06	123.26	2.98	10.78	131.63	3.38	17.35	125.78	3.10
4.07	126.75	3.15	10.79	128.98	3.25	17.36	128.17	3.22
4.08	130.86	3.34	10.80	128.15	3.22	17.37	130.49	3.32
4.09	135.09	3.53	10.81	128.62	3.24	17.38	132.25	3.40
4.10	137.97	3.66	10.82	128.61	3.24	17.39	132.21	3.40
4.11	136.82	3.61				17.40	128.41	3.23
4.12	131.05	3.35				17.41	130.55	3.33
						17.42	131.70	3.38

(13) Lists of pitch values and T values of *bu* when followed by Tone 4 in Luoyang Dialect (Female)

bu (kan) **'not look'**			***bu (yao)*** **'not want'**			***bu (dan)*** **'not but'**		
Time (s)	**F0 (Hz)**	**T**	**Time (s)**	**F0 (Hz)**	**T**	**Time (s)**	**F0 (Hz)**	**T**
3.96	249.92	3.69	8.03	244.88	3.55	12.18	268.66	4.16
3.97	240.30	3.43	8.04	254.82	3.81	12.19	256.81	3.86
3.98	239.45	3.41	8.05	245.87	3.58	12.20	249.52	3.68
3.99	242.24	3.48	8.06	242.80	3.50	12.21	250.82	3.71
4.00	245.12	3.56	8.07	242.69	3.49	12.22	251.94	3.74
4.01	246.21	3.59	8.08	244.00	3.53	12.23	251.34	3.72
4.02	245.80	3.58	8.09	244.63	3.55	12.24	249.46	3.67
4.03	244.89	3.55	8.10	245.13	3.56	12.25	246.39	3.59
4.04	243.65	3.52	8.11	245.90	3.58	12.26	241.69	3.47
4.05	242.00	3.48	8.12	246.28	3.59	12.27	239.98	3.42
4.06	239.84	3.42	8.13	247.38	3.62	12.28	242.95	3.50
4.07	234.67	3.27	8.14	248.84	3.66	12.29	245.40	3.57
4.08	240.83	3.44	8.15	250.18	3.69	12.30	247.36	3.62
			8.16	251.16	3.72			
			8.17	251.24	3.72			
			8.18	249.55	3.68			

(14) Lists of pitch values and T values of *bu* when followed by Tone 4 in Luoyang Dialect (Male)

bu (kan) **'not look'**			***bu (yao)*** **'not want'**			***bu (dan)*** **'not but'**		
Time (s)	**F0 (Hz)**	**T**	**Time (s)**	**F0 (Hz)**	**T**	**Time (s)**	**F0 (Hz)**	**T**
5.70	150.76	4.19	12.43	151.40	4.22	18.99	139.73	3.74
5.71	147.11	4.04	12.44	143.71	3.90	19.00	141.26	3.80
5.72	147.64	4.07	12.45	143.09	3.88	19.01	142.56	3.86
5.73	148.85	4.11	12.46	143.66	3.90	19.02	144.04	3.92
5.74	149.64	4.15	12.47	144.49	3.94	19.03	145.08	3.96
5.75	149.02	4.12	12.48	145.07	3.96	19.04	146.51	4.02
5.76	145.83	3.99	12.49	145.05	3.96	19.05	148.01	4.08
5.77	138.26	3.67	12.50	144.67	3.94	19.06	148.92	4.12
5.78	138.90	3.70	12.51	144.06	3.92	19.07	148.86	4.12
5.79	141.63	3.82						
5.80	142.22	3.84						

(15) Lists of pitch values and T values of Tone 4 when followed by Tone 4 in Standard Mandarin (Female)

Female	*sheng (dan)* 'Christmas'		*qi (dian)* 'air mat'		*guai (shou)* 'monster'		*bian (hua)* 'change'		*chuang (zao)* 'create'	
Points	**F0 (Hz)**	**T**	**F0 (Hz)**	**T**	**F0 (Hz)**	**T**	**F0 (Hz)**	**T**	**F0 (Hz)**	**T**
Point 1	278.48	4.79	266.10	4.33	267.52	4.38	279.73	4.84	268.54	4.42
Point 2	262.10	4.18	247.93	3.61	245.30	3.51	249.41	3.67	253.20	3.83
Point 3	253.65	3.84	242.77	3.40	221.39	2.47	241.76	3.36	232.22	2.95
Point 4	241.92	3.37	238.07	3.20	210.18	1.94	225.58	2.66	219.51	2.38
Point 5	229.17	2.82	226.39	2.69	199.82	1.43	205.16	1.70	211.49	2.00
Point 6	219.54	2.38	220.50	2.43	187.20	0.77	190.11	0.93	208.49	1.86
Point 7	211.51	2.01	213.78	2.11	186.96	0.76	199.07	1.39	203.63	1.62
Point 8	203.56	1.62	203.85	1.63	193.74	1.12	186.57	0.74	202.58	1.57
Female	*dao (lu)* 'road'		*fan (cuo)* 'make mistake'		*gao (su)* 'tell'		*jian (she)* 'build'		*tui (huo)* 'return goods'	
Points	**F0 (Hz)**	**T**	**F0 (Hz)**	**T**	**F0 (Hz)**	**T**	**F0 (Hz)**	**T**	**F0 (Hz)**	**T**
Point 1	277.11	4.74	278.88	4.80	270.13	4.48	278.33	4.78	280.68	4.87
Point 2	251.25	3.75	258.16	4.02	244.60	3.48	248.90	3.65	250.62	3.72
Point 3	236.29	3.13	239.70	3.27	230.34	2.87	239.67	3.27	240.11	3.29
Point 4	226.75	2.71	227.72	2.75	222.33	2.51	219.64	2.39	226.59	2.70
Point 5	215.45	2.19	218.23	2.32	213.27	2.09	206.39	1.76	212.69	2.06
Point 6	206.27	1.75	205.94	1.74	206.65	1.77	194.55	1.16	206.92	1.78
Point 7	199.16	1.40	195.68	1.22	197.07	1.29	194.85	1.18	201.22	1.50
Point 8	199.16	1.40	190.05	0.92	195.51	1.21	197.16	1.29	194.15	1.14

(16) Lists of pitch values and T values of Tone 4 when followed by Tone 4 in Standard Mandarin (Male)

Male	*sheng (dan)* 'Christmas'		*qi (dian)* 'air mat'		*guai (shou)* 'monster'		*bian (hua)* 'change'		*chuang (zao)* 'create'	
Points	**F0 (Hz)**	**T**	**F0 (Hz)**	**T**	**F0 (Hz)**	**T**	**F0 (Hz)**	**T**	**F0 (Hz)**	**T**
Point 1	183.50	4.99	181.60	4.90	180.76	4.86	178.56	4.75	179.71	4.81
Point 2	168.60	4.25	158.89	3.73	159.32	3.75	154.59	3.49	155.91	3.56
Point 3	156.62	3.60	153.51	3.43	154.04	3.46	151.26	3.30	143.62	2.85
Point 4	148.35	3.13	147.40	3.07	145.50	2.96	139.15	2.57	136.49	2.40
Point 5	143.32	2.83	138.23	2.51	134.80	2.29	126.41	1.73	126.89	1.76
Point 6	137.44	2.46	133.93	2.23	126.75	1.75	121.49	1.38	119.86	1.26
Point 7	130.73	2.02	121.05	1.35	123.59	1.53	119.57	1.24	116.57	1.02
Point 8	122.22	1.43	123.73	1.54	116.10	0.98	119.75	1.25	114.17	0.84
Male	*dao (lu)* 'road'		*fan (cuo)* 'make mistake'		*gao (su)* 'tell'		*jian (she)* 'build'		*tui (huo)* 'return goods'	
Points	**F0 (Hz)**	**T**	**F0 (Hz)**	**T**	**F0 (Hz)**	**T**	**F0 (Hz)**	**T**	**F0 (Hz)**	**T**
Point 1	180.18	4.83	179.21	4.78	180.31	4.84	176.39	4.64	174.29	4.54
Point 2	163.27	3.97	157.19	3.64	153.55	3.43	153.61	3.43	157.93	3.68
Point 3	154.76	3.50	148.33	3.13	144.30	2.89	149.72	3.21	149.78	3.21
Point 4	146.45	3.02	141.14	2.69	138.08	2.50	140.54	2.66	137.85	2.49
Point 5	141.44	2.71	130.71	2.02	127.27	1.79	133.90	2.23	125.63	1.67
Point 6	135.12	2.31	124.46	1.59	122.75	1.47	126.19	1.71	118.99	1.20
Point 7	131.75	2.09	123.49	1.52	118.72	1.18	123.55	1.53	118.04	1.13
Point 8	128.75	1.89	116.21	0.99	116.29	1.00	119.25	1.22	118.22	1.14

(17) Lists of pitch values and T values of Tone 4 when followed by Tone 4 in Luoyang Dialect (Female)

Female	*sheng (dan)* 'Christmas'		*qi (dian)* 'air mat'		*guai (shou)* 'monster'		*bian (hua)* 'change'		*chuang (zao)* 'create'	
Points	**F0 (Hz)**	**T**	**F0 (Hz)**	**T**	**F0 (Hz)**	**T**	**F0 (Hz)**	**T**	**F0 (Hz)**	**T**
Point 1	176.52	1.72	185.15	2.11	185.03	2.10	185.22	2.11	192.50	2.42
Point 2	179.27	1.85	184.59	2.08	182.43	1.99	175.36	1.67	178.71	1.82
Point 3	188.25	2.24	185.26	2.11	183.46	2.03	172.17	1.52	169.89	1.42
Point 4	190.98	2.36	189.00	2.27	186.03	2.15	176.07	1.70	170.42	1.44
Point 5	211.79	3.19	197.01	2.61	191.29	2.37	190.10	2.32	177.39	1.76
Point 6	228.99	3.81	205.25	2.94	201.50	2.79	214.75	3.30	196.80	2.60
Point 7	240.87	4.22	199.83	2.72	220.53	3.51	239.59	4.18	213.03	3.23
Point 8	176.52	1.72	227.28	3.75	226.15	3.71	250.15	4.52	210.95	3.16
Female	*dao (lu)* 'road'		*fan (cuo)* 'make mistake'		*gao (su)* 'tell'		*jian (she)* 'build'		*tui (huo)* 'return goods'	
Points	**F0 (Hz)**	**T**	**F0 (Hz)**	**T**	**F0 (Hz)**	**T**	**F0 (Hz)**	**T**	**F0 (Hz)**	**T**
Point 1	186.37	2.16	186.22	2.15	187.75	2.22	188.01	2.23	185.57	2.13
Point 2	172.67	1.55	171.31	1.48	177.26	1.76	176.81	1.74	176.88	1.74
Point 3	166.73	1.27	169.35	1.39	168.40	1.35	172.96	1.56	181.80	1.96
Point 4	168.01	1.33	171.59	1.50	170.48	1.45	170.87	1.46	190.99	2.36
Point 5	173.85	1.60	174.42	1.63	171.70	1.50	165.93	1.23	206.13	2.97
Point 6	179.67	1.87	193.71	2.47	177.27	1.76	165.48	1.21	219.06	3.46
Point 7	193.12	2.45	213.72	3.26	195.59	2.55	165.64	1.21	228.71	3.81
Point 8	212.06	3.20	206.65	2.99	218.71	3.45	169.59	1.40	265.17	4.99

(18) Lists of pitch values and T values of Tone 4 when followed by Tone 4 in Luoyang Dialect (Male)

Male	***sheng (dan)*** **'Christmas'**		***qi (dian)*** **'air mat'**		***guai (shou)*** **'monster'**		***bian (hua)*** **'change'**		***chuang (zao)*** **'create'**	
Points	**F0 (Hz)**	**T**	**F0 (Hz)**	**T**	**F0 (Hz)**	**T**	**F0 (Hz)**	**T**	**F0 (Hz)**	**T**
Point 1	104.29	1.98	104.92	2.02	95.67	1.46	109.63	2.28	100.82	1.78
Point 2	99.67	1.71	107.21	2.15	94.14	1.36	99.28	1.68	100.11	1.73
Point 3	100.86	1.78	110.84	2.34	96.35	1.50	96.41	1.51	100.97	1.78
Point 4	110.24	2.31	114.10	2.52	103.32	1.92	94.99	1.42	106.38	2.10
Point 5	116.67	2.65	117.90	2.72	110.10	2.30	110.86	2.35	118.62	2.75
Point 6	126.87	3.16	119.61	2.80	127.96	3.21	121.26	2.88	130.92	3.34
Point 7	133.96	3.48	119.69	2.81	148.28	4.09	137.45	3.64	137.03	3.62
Point 8	128.01	3.21	115.21	2.58	129.90	3.30	145.70	3.99	146.61	4.02
Male	***dao (lu)*** **'road'**		***fan (cuo)*** **'make mistake'**		***gao (su)*** **'tell'**		****jian (she)*** **'build'**		***tui (huo)*** **'return goods'**	
Points	**F0 (Hz)**	**T**	**F0 (Hz)**	**T**	**F0 (Hz)**	**T**	**F0 (Hz)**	**T**	**F0 (Hz)**	**T**
Point 1	98.73	1.65	108.03	2.19	108.08	2.19	112.57	2.44	95.46	1.45
Point 2	93.76	1.34	98.47	1.63	103.03	1.91	104.34	1.98	98.35	1.63
Point 3	96.75	1.53	99.43	1.69	99.16	1.68	99.82	1.72	106.96	2.13
Point 4	105.97	2.08	103.97	1.96	101.47	1.81	95.90	1.48	120.13	2.83
Point 5	119.02	2.77	111.53	2.38	102.66	1.88	95.78	1.47	128.57	3.24
Point 6	131.79	3.38	119.01	2.77	111.47	2.38	95.70	1.46	132.35	3.41
Point 7	138.22	3.67	132.12	3.40	128.04	3.21	95.36	1.44	141.23	3.80
Point 8	139.65	3.73	148.43	4.10	145.69	3.99	98.45	1.63	143.21	3.88

(19) Lists of pitch values and T values of Tone 4 when followed by Tone 1 in Standard Mandarin (Female)

sheng (du) 'holy capital'			*guai (sheng)* 'strange sound'			*gao (zhi)* 'inform'		
Time (s)	**F0 (Hz)**	**T**	**Time (s)**	**F0 (Hz)**	**T**	**Time (s)**	**F0 (Hz)**	**T**
40.11	260.94	4.13	41.74	257.90	4.01	43.39	247.85	3.61
40.12	257.69	4.00	41.75	244.00	3.45	43.40	233.02	2.99
40.13	254.11	3.86	41.76	239.48	3.26	43.41	225.38	2.65
40.14	248.80	3.65	41.77	238.37	3.22	43.42	220.50	2.43
40.15	244.53	3.47	41.78	235.58	3.10	43.43	216.47	2.24
40.16	240.91	3.32	41.79	228.99	2.81	43.44	212.01	2.03
40.17	236.96	3.16	41.80	225.64	2.66	43.45	207.35	1.80
40.18	232.70	2.97	41.81	221.58	2.48	43.46	204.07	1.64
40.19	228.13	2.77	41.82	217.61	2.29	43.47	200.57	1.47
40.20	224.07	2.59	41.83	212.59	2.06	43.48	197.65	1.32
40.21	221.05	2.45	41.84	209.10	1.89	43.49	195.74	1.22
40.22	217.87	2.31	41.85	205.09	1.69	43.50	193.90	1.13
40.23	214.99	2.17	41.86	202.29	1.55	43.51	192.05	1.03
40.24	212.61	2.06	41.87	198.78	1.38	43.52	190.66	0.95
40.25	210.44	1.95	41.88	194.51	1.16	43.53	189.47	0.89
40.26	208.20	1.85	41.89	190.70	0.96	43.54	188.90	0.86
40.27	205.95	1.74	41.90	189.69	0.90	43.55	189.85	0.91
40.28	204.07	1.64				43.56	188.52	0.84
40.29	202.33	1.56				43.57	188.26	0.83
40.30	200.22	1.45				43.58	192.11	1.03
40.31	198.79	1.38				43.59	203.67	1.62
40.32	198.91	1.38				43.60	213.17	2.08
40.33	200.55	1.47				43.61	210.98	1.98
40.34	206.03	1.74						
40.35	206.38	1.76						
40.36	202.56	1.57						

(20) Lists of pitch values and T values of Tone 4 when followed by Tone 1 in Standard Mandarin (Male)

sheng (du) 'holy capital'			*guai (sheng)* 'strange sound'			*gao (zhi)* 'inform'		
Time (s)	**F0 (Hz)**	**T**	**Time (s)**	**F0 (Hz)**	**T**	**Time (s)**	**F0 (Hz)**	**T**
35.47	179.20	4.78	39.87	168.82	4.26	44.36	175.84	4.62
35.48	173.37	4.49	39.88	162.48	3.93	44.37	171.16	4.38
35.49	169.05	4.27	39.89	162.02	3.90	44.38	166.23	4.13
35.50	165.06	4.06	39.90	161.97	3.90	44.39	160.10	3.80
35.51	162.17	3.91	39.91	159.27	3.75	44.40	157.29	3.64
35.52	158.91	3.73	39.92	156.02	3.57	44.41	156.22	3.58
35.53	156.41	3.59	39.93	153.87	3.45	44.42	155.03	3.51
35.54	153.49	3.43	39.94	151.58	3.32	44.43	153.22	3.41
35.55	150.54	3.26	39.95	147.37	3.07	44.44	150.56	3.26
35.56	147.39	3.07	39.96	144.56	2.90	44.45	147.90	3.10
35.57	145.28	2.95	39.97	141.80	2.73	44.46	145.83	2.98
35.58	142.91	2.80	39.98	139.42	2.59	44.47	143.47	2.84
35.59	140.79	2.67	39.99	136.33	2.39	44.48	140.73	2.67
35.60	138.78	2.55	40.00	133.60	2.21	44.49	137.63	2.47
35.61	137.05	2.44	40.01	132.70	2.15	44.50	134.60	2.28
35.62	134.78	2.29	40.02	130.94	2.04	44.51	131.54	2.08
35.63	133.12	2.18	40.03	129.15	1.92	44.52	128.82	1.89
35.64	132.38	2.13	40.04	127.70	1.82	44.53	126.00	1.70
35.65	131.52	2.08	40.05	127.34	1.79	44.54	124.62	1.60
35.66	128.81	1.89	40.06	126.16	1.71	44.55	122.59	1.46
35.67	124.50	1.59	40.07	123.78	1.54	44.56	121.14	1.36
35.68	121.94	1.41	40.08	121.75	1.40	44.57	120.62	1.32
35.69	119.29	1.22	40.09	119.02	1.20	44.58	119.95	1.27
			40.10	119.44	1.23	44.59	118.82	1.19
			40.11	114.50	0.86			

(21) Lists of pitch values and T values of Tone 4 when followed by Tone 2 in Standard Mandarin (Female)

sheng (jie) 'saintly'			*guai (ren)* 'strange person'			*gao (ting)* 'stop'		
Time (s)	**F0 (Hz)**	**T**	**Time (s)**	**F0 (Hz)**	**T**	**Time (s)**	**F0 (Hz)**	**T**
45.83	280.46	4.86	47.28	269.40	4.45	48.72	277.36	4.75
45.84	269.32	4.45	47.29	269.93	4.47	48.73	264.69	4.28
45.85	262.33	4.19	47.30	262.91	4.21	48.74	255.41	3.91
45.86	255.00	3.90	47.31	261.45	4.15	48.75	250.80	3.73
45.87	248.29	3.63	47.32	261.00	4.13	48.76	247.04	3.58
45.88	242.37	3.38	47.33	261.20	4.14	48.77	243.46	3.43
45.89	236.97	3.16	47.34	261.49	4.15	48.78	239.62	3.27
45.90	233.45	3.00	47.35	257.84	4.01	48.79	235.21	3.08
45.91	227.94	2.76	47.36	250.89	3.73	48.80	231.74	2.93
45.92	222.88	2.54	47.37	248.94	3.66	48.81	228.99	2.81
45.93	220.48	2.43	47.38	244.52	3.47	48.82	226.11	2.68
45.94	217.17	2.27	47.39	240.04	3.29	48.83	223.14	2.55
45.95	212.41	2.05	47.40	236.05	3.12	48.84	220.19	2.41
45.96	207.71	1.82	47.41	231.96	2.94	48.85	216.51	2.24
45.97	204.08	1.64	47.42	228.81	2.80	48.86	213.29	2.09
45.98	200.57	1.47	47.43	224.79	2.62	48.87	210.59	1.96
45.99	197.70	1.32	47.44	220.71	2.44	48.88	207.78	1.83
46.00	195.48	1.21	47.45	216.80	2.26	48.89	203.95	1.64
46.01	193.29	1.09	47.46	213.21	2.09	48.90	200.74	1.48
46.02	190.43	0.94	47.47	208.84	1.88	48.91	199.98	1.44
46.03	188.32	0.83	47.48	204.94	1.69	48.92	197.83	1.33
46.04	193.23	1.09	47.49	201.07	1.49			
46.05	196.52	1.26	47.50	198.19	1.35			
			47.51	194.70	1.17			
			47.52	193.03	1.08			
			47.53	192.74	1.06			
			47.54	191.55	1.00			
			47.55	191.40	0.99			
			47.56	190.79	0.96			
			47.57	190.46	0.94			
			47.58	189.18	0.88			
			47.59	187.75	0.80			
			47.60	185.59	0.68			

(22) Lists of pitch values and T values of Tone 4 when followed by Tone 2 in Standard Mandarin (Male)

sheng (jie) 'saintly'			*guai (ren)* 'strange person'			*gao (ting)* 'stop'		
Time (s)	**F0 (Hz)**	**T**	**Time (s)**	**F0 (Hz)**	**T**	**Time (s)**	**F0 (Hz)**	**T**
36.74	181.03	4.87	41.25	175.98	4.62	45.78	178.31	4.74
36.75	178.63	4.75	41.26	168.45	4.24	45.79	170.79	4.36
36.76	171.21	4.38	41.27	165.29	4.08	45.80	163.11	3.96
36.77	164.62	4.04	41.28	164.50	4.03	45.81	156.62	3.60
36.78	160.14	3.80	41.29	163.42	3.98	45.82	153.17	3.41
36.79	156.71	3.61	41.30	159.82	3.78	45.83	150.35	3.25
36.80	153.55	3.43	41.31	156.70	3.61	45.84	147.50	3.08
36.81	149.92	3.22	41.32	153.90	3.45	45.85	145.12	2.94
36.82	146.29	3.01	41.33	150.92	3.28	45.86	142.15	2.76
36.83	142.90	2.80	41.34	147.14	3.06	45.87	139.02	2.56
36.84	140.90	2.68	41.35	143.51	2.84	45.88	136.20	2.38
36.85	138.61	2.53	41.36	140.10	2.63	45.89	133.49	2.21
36.86	135.20	2.32	41.37	137.01	2.43	45.90	130.55	2.01
36.87	132.16	2.12	41.38	134.44	2.27	45.91	128.69	1.88
36.88	129.11	1.91	41.39	131.63	2.08	45.92	126.67	1.75
36.89	127.08	1.77	41.40	128.33	1.86	45.93	125.09	1.64
36.90	125.24	1.65	41.41	126.34	1.72	45.94	123.38	1.52
36.91	124.47	1.59	41.42	124.38	1.59	45.95	121.58	1.39
36.92	122.16	1.43	41.43	123.63	1.53	45.96	119.36	1.23
36.93	118.33	1.15	41.44	122.53	1.46	45.97	118.54	1.17
36.94	115.18	0.91	41.45	121.86	1.41	45.98	117.85	1.11
36.95	114.09	0.83	41.46	121.30	1.37	45.99	117.03	1.05
			41.47	120.35	1.30			
			41.48	118.96	1.20			
			41.49	117.22	1.07			

(23) Lists of pitch values and T values of Tone 4 when followed by Tone 3 in Standard Mandarin (Female)

sheng (li) 'holy ceremony'			*guai (jiao)* 'strange foot'			*gao (jing)* 'warn'		
Time (s)	**F0 (Hz)**	**T**	**Time (s)**	**F0 (Hz)**	**T**	**Time (s)**	**F0 (Hz)**	**T**
50.82	283.18	4.96	52.22	282.88	4.95	53.70	266.20	4.33
50.83	277.18	4.74	52.23	265.83	4.32	53.71	261.78	4.16
50.84	272.22	4.56	52.24	261.21	4.14	53.72	253.87	3.85
50.85	269.32	4.45	52.25	260.65	4.12	53.73	248.66	3.64
50.86	264.19	4.26	52.26	259.10	4.06	53.74	243.97	3.45
50.87	258.82	4.05	52.27	253.54	3.84	53.75	239.85	3.28
50.88	255.31	3.91	52.28	246.91	3.57	53.76	235.65	3.10
50.89	252.06	3.78	52.29	242.48	3.39	53.77	231.18	2.91
50.90	248.11	3.62	52.30	237.75	3.19	53.78	227.31	2.73
50.91	243.89	3.45	52.31	234.81	3.06	53.79	223.36	2.56
50.92	238.85	3.24	52.32	231.77	2.93	53.80	219.53	2.38
50.93	234.00	3.03	52.33	229.02	2.81	53.81	216.07	2.22
50.94	230.60	2.88	52.34	225.63	2.66	53.82	212.19	2.04
50.95	225.61	2.66	52.35	223.09	2.55	53.83	208.62	1.87
50.96	221.09	2.45	52.36	220.38	2.42	53.84	204.09	1.64
50.97	219.28	2.37	52.37	216.89	2.26	53.85	199.72	1.42
50.98	216.53	2.24	52.38	213.59	2.10	53.86	196.03	1.24
50.99	213.99	2.12	52.39	210.26	1.95	53.87	193.00	1.08
51.00	211.26	1.99	52.40	207.43	1.81	53.88	191.47	1.00
51.01	208.46	1.86	52.41	203.23	1.60	53.89	190.26	0.93
51.02	205.70	1.72	52.42	201.34	1.51	53.90	189.90	0.91
51.03	202.55	1.57	52.43	198.13	1.34	53.91	187.93	0.81
51.04	200.85	1.48	52.44	194.93	1.18	53.92	180.08	0.38
51.05	199.46	1.41	52.45	192.03	1.03	53.93	186.07	0.71
51.06	198.27	1.35	52.46	185.35	0.67	53.94	185.98	0.70
51.07	196.57	1.26	52.47	188.12	0.82			
51.08	194.84	1.17						
51.09	192.46	1.05						
51.10	190.96	0.97						
51.11	188.26	0.83						
51.12	184.82	0.64						
51.13	180.63	0.41						

(24) Lists of pitch values and T values of Tone 4 when followed by Tone 3 in Standard Mandarin (Male)

sheng (li) **'holy ceremony'**			***guai (jiao)*** **'strange foot'**			***gao (jing)*** **'warn'**		
Time (s)	**F0 (Hz)**	**T**	**Time (s)**	**F0 (Hz)**	**T**	**Time (s)**	**F0 (Hz)**	**T**
38.12	179.18	4.78	42.58	172.00	4.42	47.24	171.24	4.39
38.13	173.56	4.50	42.59	163.37	3.97	47.25	155.80	3.56
38.14	164.23	4.02	42.60	161.22	3.86	47.26	151.81	3.33
38.15	160.50	3.82	42.61	157.13	3.63	47.27	149.25	3.18
38.16	157.98	3.68	42.62	153.85	3.45	47.28	146.12	3.00
38.17	154.99	3.51	42.63	151.51	3.31	47.29	143.09	2.81
38.18	152.64	3.38	42.64	148.62	3.14	47.30	140.21	2.64
38.19	149.30	3.18	42.65	146.12	3.00	47.31	137.58	2.47
38.20	145.41	2.95	42.66	143.59	2.84	47.32	135.11	2.31
38.21	140.94	2.68	42.67	140.53	2.66	47.33	132.79	2.16
38.22	137.15	2.44	42.68	136.31	2.39	47.34	130.71	2.02
38.23	133.23	2.19	42.69	133.91	2.23	47.35	128.80	1.89
38.24	128.94	1.90	42.70	128.95	1.90	47.36	127.29	1.79
38.25	125.95	1.70	42.71	126.59	1.74	47.37	125.49	1.66
38.26	124.55	1.60	42.72	123.73	1.54	47.38	123.65	1.54
38.27	122.78	1.47	42.73	122.01	1.42	47.39	121.78	1.40
38.28	120.60	1.32	42.74	120.60	1.32	47.40	120.02	1.27
38.29	119.12	1.21	42.75	119.65	1.25	47.41	118.39	1.15
			42.76	116.97	1.05	47.42	117.82	1.11
			42.77	113.53	0.79	47.43	116.65	1.03
			42.78	108.10	0.36			

(25) Lists of pitch values and T values of Tone 4 when followed by Tone 1 in Luoyang Dialect (Female)

sheng (du) 'holy capital'			*guai (sheng)* 'strange sound'			*gao (zhi)* 'inform'		
Time (s)	**F0 (Hz)**	**T**	**Time (s)**	**F0 (Hz)**	**T**	**Time (s)**	**F0 (Hz)**	**T**
25.26	211.80	3.65	28.38	225.49	4.22	31.65	217.37	3.89
25.27	206.01	3.39	28.39	219.87	3.99	31.66	210.84	3.61
25.28	199.69	3.11	28.40	213.52	3.72	31.67	200.35	3.14
25.29	194.14	2.85	28.41	207.65	3.47	31.68	194.73	2.88
25.30	190.42	2.67	28.42	202.76	3.25	31.69	188.00	2.55
25.31	187.26	2.52	28.43	197.61	3.01	31.70	181.10	2.21
25.32	184.68	2.39	28.44	188.68	2.59	31.71	174.09	1.85
25.33	180.97	2.20	28.45	184.93	2.40	31.72	169.30	1.59
25.34	176.41	1.97	28.46	181.37	2.22	31.73	165.54	1.38
25.35	174.35	1.86	28.47	178.17	2.06	31.74	163.18	1.25
25.36	172.25	1.75	28.48	174.46	1.87	31.75	160.11	1.08
25.37	171.53	1.71	28.49	170.61	1.66	31.76	157.14	0.91
25.38	171.06	1.68	28.50	168.53	1.55	31.77	157.20	0.91
25.39	169.88	1.62	28.51	166.24	1.42	31.78	160.77	1.11
25.40	170.47	1.65	28.52	165.95	1.41	31.79	163.44	1.27
25.41	171.47	1.71	28.53	166.88	1.46			
25.42	171.44	1.70	28.54	168.35	1.54			
25.43	169.34	1.59	28.55	168.35	1.54			
25.44	166.06	1.41						
25.45	161.64	1.16						
25.46	165.53	1.38						

(26) Lists of pitch values and T values of Tone 4 when followed by Tone 1 in Luoyang Dialect (Male)

sheng (du) 'holy capital'			*guai (sheng)* 'strange sound'			*gao (zhi)* 'inform'		
Time (s)	**F0 (Hz)**	**T**	**Time (s)**	**F0 (Hz)**	**T**	**Time (s)**	**F0 (Hz)**	**T**
36.77	122.19	4.02	41.39	116.41	3.56	45.80	114.81	3.43
36.78	119.72	3.82	41.40	117.04	3.61	45.81	112.23	3.21
36.79	113.58	3.33	41.41	110.72	3.08	45.82	108.74	2.91
36.80	109.04	2.94	41.42	107.77	2.83	45.83	105.54	2.63
36.81	105.20	2.60	41.43	101.13	2.22	45.84	102.01	2.31
36.82	103.63	2.46	41.44	99.10	2.03	45.85	100.44	2.16
36.83	103.18	2.41	41.45	98.29	1.95	45.86	98.40	1.96
36.84	102.77	2.38	41.46	95.24	1.65	45.87	96.36	1.77
36.85	102.18	2.32	41.47	94.25	1.56	45.88	95.21	1.65
36.86	101.19	2.23	41.48	93.13	1.44	45.89	94.41	1.57
36.87	100.58	2.17	41.49	92.08	1.33	45.90	93.36	1.47
36.88	100.27	2.14	41.50	90.98	1.22	45.91	92.56	1.38
36.89	100.28	2.14	41.51	90.21	1.14	45.92	91.49	1.27
36.90	100.02	2.12	41.52	88.44	0.95	45.93	91.63	1.29
36.91	99.44	2.06	41.53	86.96	0.79	45.94	91.34	1.26
36.92	100.01	2.12	41.54	86.80	0.77	45.95	92.43	1.37
36.93	100.49	2.16	41.55	86.94	0.79	45.96	93.41	1.47
36.94	101.05	2.22	41.56	86.78	0.77	45.97	93.73	1.50
36.95	100.62	2.18	41.57	86.18	0.71	45.98	95.44	1.67
36.96	98.34	1.96				45.99	96.00	1.73
36.97	91.99	1.32				46.00	93.14	1.44
						46.01	91.67	1.29
						46.02	92.17	1.34

(27) Lists of pitch values and T values of Tone 4 when followed by Tone 2 in Luoyang Dialect (Female)

sheng (jie) 'saintly'			*guai (ren)* 'strange person'			*gao (ting)* 'stop'		
Time (s)	**F0 (Hz)**	**T**	**Time (s)**	**F0 (Hz)**	**T**	**Time (s)**	**F0 (Hz)**	**T**
26.28	222.83	4.11	29.39	213.84	3.74	32.65	220.38	4.01
26.29	207.30	3.45	29.40	211.09	3.62	32.66	214.03	3.74
26.30	195.12	2.89	29.41	208.54	3.50	32.67	208.63	3.51
26.31	187.33	2.52	29.42	205.05	3.35	32.68	204.64	3.33
26.32	182.11	2.26	29.43	200.92	3.16	32.69	199.13	3.08
26.33	174.58	1.87	29.44	196.03	2.94	32.70	195.04	2.89
26.34	171.09	1.69	29.45	190.65	2.68	32.71	188.38	2.57
26.35	167.98	1.52	29.46	185.77	2.44	32.72	180.76	2.19
26.36	164.36	1.32	29.47	181.27	2.22	32.73	175.87	1.94
26.37	162.65	1.22	29.48	178.01	2.05	32.74	173.69	1.82
26.38	161.83	1.17	29.49	175.32	1.91	32.75	171.62	1.71
26.39	163.46	1.27	29.50	172.32	1.75	32.76	168.52	1.55
26.40	164.53	1.33	29.51	170.04	1.63	32.77	165.96	1.41
26.41	165.11	1.36	29.52	169.16	1.58			
26.42	166.15	1.42	29.53	167.29	1.48			
26.43	165.88	1.40	29.54	166.45	1.43			
26.44	163.31	1.26	29.55	165.95	1.41			
26.45	161.14	1.14	29.56	165.65	1.39			
			29.57	167.69	1.50			

(28) Lists of pitch values and T values of Tone 4 when followed by Tone 2 in Luoyang Dialect (Male)

sheng (jie) 'saintly'			*guai (ren)* 'strange person'			*gao (ting)* 'stop'		
Time (s)	**F0 (Hz)**	**T**	**Time (s)**	**F0 (Hz)**	**T**	**Time (s)**	**F0 (Hz)**	**T**
38.25	113.32	3.30	42.84	121.47	3.96	47.42	124.19	4.17
38.26	107.66	2.82	42.85	121.52	3.97	47.43	120.37	3.88
38.27	101.90	2.30	42.86	118.04	3.69	47.44	116.75	3.59
38.28	100.29	2.14	42.87	106.86	2.75	47.45	104.02	2.49
38.29	99.27	2.05	42.88	103.93	2.48	47.46	101.31	2.24
38.30	97.68	1.89	42.89	101.48	2.26	47.47	99.06	2.03
38.31	97.44	1.87	42.90	99.69	2.09	47.48	97.16	1.84
38.32	96.90	1.82	42.91	97.94	1.92	47.49	95.78	1.71
38.33	97.96	1.92	42.92	96.09	1.74	47.50	95.00	1.63
38.34	97.58	1.88	42.93	94.38	1.57	47.51	93.79	1.51
38.35	97.98	1.92	42.94	93.71	1.50	47.52	92.96	1.42
38.36	98.04	1.93	42.95	93.52	1.48	47.53	92.83	1.41
38.37	98.10	1.94	42.96	92.85	1.41	47.54	92.26	1.35
38.38	97.86	1.91	42.97	92.00	1.33	47.55	90.94	1.22
38.39	97.81	1.91	42.98	90.91	1.21	47.56	91.57	1.28
38.40	97.99	1.92	42.99	90.09	1.13	47.57	93.66	1.50
38.41	98.19	1.94	43.00	89.82	1.10	47.58	86.43	0.73
38.42	97.46	1.87	43.01	89.01	1.01	47.59	88.13	0.92
38.43	96.90	1.82	43.02	89.05	1.02	47.60	88.01	0.91
38.44	97.81	1.91	43.03	89.76	1.09	47.61	86.11	0.70
38.45	98.75	2.00	43.04	88.79	0.99			
38.46	98.88	2.01	43.05	90.92	1.21			
38.47	98.47	1.97	43.06	90.96	1.22			
			43.07	91.94	1.32			
			43.08	93.45	1.47			
			43.09	93.69	1.50			

(29) Lists of pitch values and T values of Tone 4 when followed by Tone 3 in Luoyang Dialect (Female)

sheng (li) **'holy ceremony'**			***guai (jiao)*** **'strange foot'**			***gao (jing)*** **'warn'**		
Time (s)	**F0 (Hz)**	**T**	**Time (s)**	**F0 (Hz)**	**T**	**Time (s)**	**F0 (Hz)**	**T**
27.35	224.42	4.18	30.45	210.30	3.58	33.69	218.69	3.94
27.36	214.11	3.75	30.46	206.82	3.43	33.70	213.61	3.73
27.37	204.62	3.33	30.47	202.60	3.24	33.71	206.89	3.43
27.38	193.34	2.81	30.48	198.98	3.07	33.72	200.91	3.16
27.39	186.06	2.46	30.49	178.90	2.10	33.73	169.37	1.59
27.40	181.51	2.23	30.50	175.74	1.93	33.74	168.89	1.57
27.41	177.80	2.04	30.51	173.64	1.82	33.75	168.27	1.53
27.42	176.29	1.96	30.52	172.12	1.74	33.76	167.81	1.51
27.43	176.36	1.96	30.53	171.33	1.70	33.77	167.04	1.47
27.44	174.81	1.88	30.54	167.84	1.51	33.78	165.44	1.38
27.45	173.26	1.80	30.55	168.28	1.53			
27.46	172.02	1.74	30.56	169.86	1.62			
27.47	169.93	1.62	30.57	170.35	1.65			
27.48	167.54	1.49	30.58	168.41	1.54			
27.49	164.99	1.35	30.59	164.62	1.33			
			30.60	161.98	1.18			
			30.61	164.22	1.31			

(30) Lists of pitch values and T values of Tone 4 when followed by Tone 3 in Luoyang Dialect (Male)

sheng (li) 'holy ceremony'			*guai (jiao)* 'strange foot'			*gao (jing)* 'warn'		
Time (s)	**F0 (Hz)**	**T**	**Time (s)**	**F0 (Hz)**	**T**	**Time (s)**	**F0 (Hz)**	**T**
39.83	118.47	3.73	44.21	116.46	3.56	48.84	118.40	3.72
39.84	115.13	3.45	44.22	114.51	3.40	48.85	115.68	3.50
39.85	110.07	3.03	44.23	111.44	3.15	48.86	113.69	3.33
39.86	108.31	2.87	44.24	108.40	2.88	48.87	101.91	2.30
39.87	107.60	2.81	44.25	96.96	1.82	48.88	91.13	1.24
39.88	107.30	2.79	44.26	96.00	1.73	48.89	90.30	1.15
39.89	106.07	2.68	44.27	95.11	1.64	48.90	89.35	1.05
39.90	105.24	2.60	44.28	93.82	1.51	48.91	88.59	0.97
39.91	95.70	1.70	44.29	93.48	1.48	48.92	88.13	0.92
39.92	96.19	1.75	44.30	91.30	1.25	48.93	88.60	0.97
39.93	96.71	1.80	44.31	91.14	1.24	48.94	89.04	1.02
39.94	96.94	1.82	44.32	88.24	0.93	48.95	88.81	0.99
39.95	97.19	1.85	44.33	90.36	1.16	48.96	89.68	1.08
39.96	97.23	1.85	44.34	90.10	1.13	48.97	91.03	1.23
39.97	96.92	1.82	44.35	90.21	1.14	48.98	92.01	1.33
39.98	97.06	1.83	44.36	87.49	0.85	48.99	92.83	1.41
39.99	96.62	1.79	44.37	87.60	0.86	49.00	95.85	1.71
40.00	95.97	1.73	44.38	87.30	0.83	49.01	90.91	1.21
40.01	95.38	1.67	44.39	85.30	0.61			
40.02	95.69	1.70						
40.03	96.04	1.73						
40.04	96.93	1.82						
40.05	97.95	1.92						
40.06	98.99	2.02						