

A PHONOLOGICAL STUDY OF SECOND LANGUAGE ACQUISITION
OF MANDARIN CHINESE TONES

by
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ABSTRACT

HANG ZHANG: A Phonological Study of Second Language Acquisition
of Mandarin Chinese Tones

(Under the direction of Jennifer Smith)

This thesis examines disyllabic tonal productions produced by thirty English-speaking learners of Mandarin Chinese and tests for evidence of three phonological constraints, the Tonal Markedness Scale (*T2>>*T4>>*T1), Positional Faithfulness Constraints (tones at privileged positions have identical values), and the Obligatory Contour Principle (two identical whole tone sequences are prohibited) in the dataset. The tonal grammars of these speakers are accounted for within Optimality Theory, which describes a grammar as a set of universal, ranked constraints. It is shown that these three constraints are all relevant in the dataset. It is argued that these phonological effects result from universal markedness constraints that are present in these learners' grammars, but are masked in the learner's target language grammar by the effects of higher ranking constraints. These constraints emerge in the second language acquisition data and represent the situation of "the emergence of the unmarked" in second language phonology.

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CHAPTER 1

INTRODUCTION

1.1 The problem and hypothesis

Tone has been a recurrent theme in the study of phonology. The world's tone languages are often classified into two types: the terraced-level tone systems typical of African languages and the contour tone systems typical of Asian languages (Pike 1948). Mandarin Chinese (MC) is one of the most well-known Asian tonal languages, and the tone co-articulation in MC has been a controversial issue for a long time. The study of tone co-articulation in MC is usually examined in two domains: one is the domain of disyllabic tone sequences and the other is domains longer than two syllables. This thesis investigates the tone co-articulation of MC in disyllabic tone sequences by examining the interlanguage data produced by 30 English-speaking learners of MC and utilizes an Optimality Theory (OT) framework (Prince & Smolensky, 1993, McCarthy & Prince, 1993) to examine the interlanguage tonal grammars.

In Optimality Theory, languages differ in the rankings of those constraints, where ranking determines the strength of a particular constraint in a particular language. Lower ranked constraints may normally have no visible effects in a grammar, but they are still assumed to be present in the grammar. In the situation described as “the emergence of the unmarked” by McCarthy and Prince (1994), the effects of low-ranked markedness constraints

become visible. This thesis will argue that some markedness effects that are usually masked and hidden in the grammars of native MC speakers become visible in the data made by English-speaking learners, representing this kind of situation. In addition, language learners' modifications of underlying representations and learners' tendency to produce more unmarked tonal productions in interlanguage grammars can be taken as effects of universal constraints.

This study combining of tonal phonology and second language acquisition seeks to shed some light on the mechanisms of the tone implementation in connected speech in disyllabic tone sequences, and also to identify the phonological factors causing English-speaking learners to make tonal errors in the production of MC. In addition, we hope the understanding of the mechanism of producing tone coarticulation in the data of second language acquisition of MC can also help us better identify the phonological constraints playing roles in the historical development of sandhi phenomenon in Mandarin Chinese.

The primary goal of the study is to test whether (1) the Tonal Markedness Scale (TMS), (2) the Obligatory Contour Principle (OCP), and (3) Positional Faithfulness Constraints (PF) are relevant in the tonal productions made by the English-speaking learners. We hypothesize that these phonological constraints are all relevant in the dataset and the ranking of these constraints in the present data could be revealed by looking into the tonal grammars constructed by these constraints. In this way, the 'inactive' phonological constraints in the grammar of MC become active and visible in the data of second language acquisition.

The main findings we get from this study are the following: the Tonal Markedness Scale (TMS) (*T2>>*T4>>*T1) is relevant in the dataset. Some effects of Positional

Faithfulness (PF) Constraints are found in the dataset. In particular, the word-initial position is a privileged position for Tone 1 while the word-final position is privileged for Tone 4. The Obligatory Contour Principle (OCP) also works in the dataset, especially when the OCP refers to whole lexical tones. The related Markedness constraints were dominated or masked by some faithfulness constraints such as *Ident-Tones* in the native MC speakers' grammar or the learners' correct tonal productions, but they are moved to the upper part of the constraint rankings, that is, become visible, in most of the interlanguage grammars.

The next subsection presents some background information on the theoretical tool, Optimality Theory. Basic information concerning tones in Mandarin Chinese is presented in §1.3. §1.4 looks at the background information of acquisition of Mandarin Chinese by first language learners and second language learners respectively. §1.5 provides a brief overview of following chapters.

1.2 Optimality Theory

The analysis presented in this thesis makes use of the theoretical framework provided by Optimality Theory (OT). I assume no prior familiarity with OT. So, a brief introduction of a few basic and important concepts which are related to the analysis is provided in this section. Readers who are already comfortable with OT may skip directly to §1.3.

1.2.1. Some basic concepts of Optimality Theory

Optimality Theory or OT is a linguistic model proposed by the linguists Alan Prince and Paul Smolensky in 1993, and expanded by John J. McCarthy and Alan Prince in 1993 and 1995. It was first applied in the area of phonology. It shares its focus on the investigation of universal principles, linguistic typology and language acquisition.

OT shares with *The Sound Pattern of English*, henceforth SPE (Chomsky and Halle, 1968) the notion of an underlying form, or input, and both of them produce outputs. The difference is that SPE derives the outputs from inputs step by step, whereas OT simply selects the optimal output from many candidates.

The main idea of OT is that the outputs or the “surface” forms of the language arise from the resolution of conflicts between grammatical constraints. OT constraints are violable. These constraints are minimally violated in that the output form that wins out is the one that incurs the fewest serious violations, compared to all the other possible candidates. Thus, the grammar in OT is composed by a ranking of constraints that evaluate the well-formedness of possible outputs and creates the grammar of a language. Constraints are generally regarded as universal, but their ranking differs from language to language, accommodating cross-linguistic differences. Language acquisition can be roughly described as the process of adjusting the ranking of these constraints to match the language one is learning.

Two types of constraints are used in this process of evaluation, namely the Markedness constraints and the Faithfulness constraints. Markedness constraints require the structural well-formedness of the output. For example, level tones are more well-formed than contour tones. Faithfulness constraints require the output (surface form) to be identical, or faithful, to the input (the underlying, lexical form) in some particular way. For example, the disyllabic tone sequence output must maintain the same tonal characteristics as the underlying form. Since the constraints are violable, the constraints assign the violation mark * to each possible output by comparing the output to the input in the case of faithfulness constraints or by judging the form of the output in the case of markedness constraints. As a

result, the losing candidates violate a higher-ranking constraint than the winning candidate, the actual output.

This thesis takes the target forms of disyllabic tone sequences of Mandarin Chinese as the input, or underlying forms, and the tonal productions produced by the English-speaking learners of Mandarin Chinese as the outputs, or the surface forms. In this thesis, the Tonal Markedness Scale (TMS) and the Obligatory Contour Principle (OCP) are markedness constraints. TMS is a universal and phonetically grounded constraint scale and it is usually presented as *R >> *F >> *L (as cited in Hyman & VanBik, 2004), which indicate that rising tones are more disfavored by people than falling tones, which are more disfavored than level tones. Universally, tone behaviors are governed by the OCP which was first proposed by Leben (1973), stating that adjacent identical elements are prohibited. Positional Faithfulness (PF) Constraints are faithfulness constraints that refer to the notion of positional privilege in Optimality Theory. In the present study, we will look at two positions: one is the word-initial syllable and the other is the word-final syllable of the test disyllabic words, to see whether there are any positional effects in the Mandarin tonal productions made by English speakers.

1.2.2 OT and Second Language Acquisition

An interlanguage is a linguistic system that has been developed by a learner of a second language. One of the most interesting features of such a system is that it preserves some features of the learner's first or native language in speaking or writing the second language or target language and creating innovations. These innovations sometimes are systematic patterns which cannot be found in either the first language or the second language. Such patterns, which appear not to be obviously motivated by the input data, have often been

taken to “reveal universally preferred structures that emerge in the flux of grammar construction” (Broselow, 2004). Some previous works such as Broselow (2004) and O’Connor (2002), apply the framework of OT to the study of second language acquisition and utilize these universal principles of markedness to shape the grammar of their interlanguage data. This study utilized OT to model the grammar of tonal productions made by some English-speaking learners of MC tones.

The main idea of a grammar in OT is that a grammar consists not of a set of rules, but rather of a set of ranked constraints which are presumed to be universal. What a second language learner (i.e., the English speaking learners in this study) must induce from materials of the first language (i.e., MC in this study) is the ranking of these universal constraints. One claim regarding the end state grammar in OT is that it consists of a totally ranked hierarchy (Tesar and Smolensky, 1998). However, sometimes, some constraints in this grammar are ‘inactive’ because they are not necessary to play a role in determining the actual output, that is, the well-formed form for the end state (i.e., the correct productions) grammar in OT. These ‘inactive’ constraints are usually masked by some faithfulness constraints in the correct productions, or, the target language grammars (i.e., MC in this study), and we cannot identify these constraints by only examining this language. However, these ‘inactive’ constraints are assumed to be present in the grammar. In some cases, these hidden rankings have been uncovered through examination of loan-word phonology or of reduplication and truncation phenomena (Ito and Mester, 1995, McCarthy and Prince, 1995, among others). Study of second language acquisition is one of the means to reveal the hidden rankings because some of the originally ‘inactive’ constraints may rear their heads and become visible in the interlanguage grammars,

“thus revealing the ranking relative to other constraints” (O'Connor, 2002). The present study reveals the hidden rankings of the ‘inactive’ constraints of specific tone combinations of MC which cannot be determined by examining the phonology of MC. This study uncovers some tonal patterns that appear to be independent of both the native-language grammar and the target language grammar of these learners. These patterns frequently show a preference for less marked forms. Transformation of the input tonal forms “in the direction of less marked structures is generally described as an effect of universal principles of markedness, often conceived of as part of the innate endowment provided by Universal Grammar” (Epstein, Flynn & Martohardjono, 1966, as cited in Broselow, 2004). Following this idea of revealing the hidden rankings in second language data, we design two experiments for this study which will be introduced in detail in the next several chapters.

In the following §1.3 and §1.4, I will provide more background knowledge on the MC tones and the acquisition of Mandarin Chinese.

1.3 Tones in Mandarin Chinese

1.3.1 Lexical tones in Mandarin Chinese

Mandarin Chinese (MC) is a tone language, in that the pitch contour over a syllable can distinguish word meaning. That is, the tones are used to distinguish otherwise homophonous syllables. “Morphemes are almost exclusively monosyllabic in Mandarin Chinese” (Yip, 1999). Monosyllabic morphemes are phonologically constituted not only of consonants and vowels, but also of tones that are “manifested mainly in terms of the rate of vocal fold vibration during the vocalic portion of a syllable” (Xu, 1994). The tone each syllabic morpheme takes is entirely arbitrary.

On full syllables there are four tones which I refer to as Tone 1 (high level, [55]), Tone 2 (high rising [35]), Tone 3 (low dipping, [214] at phrase final position, [21] at non-final position), and Tone 4 (high falling [51]). The numbers represent relative pitch, 5 being the highest, 1 the lowest. Tone 1 is the only level tone and the other three are contour tones. The three pitch levels of Tone 3 form a complex contour according to the traditional description of Tone 3. In this thesis, we assume that Tone 3 is phonologically just a low level tone (Yip, 2002). The so-called fifth or neutral tone in standard Mandarin has no intrinsic pitch contour and necessarily occurs in unstressed syllables. Its pitch contour is determined by the tone of the preceding syllable or by sentence intonation. The neutral tone is not discussed in this thesis.

An example of a stressed syllable in all four tones is provided in Table 1-1.

Table 1-1: The four lexical tones of standard Mandarin Chinese

Pinyin Spelling	gloss	Wade-Giles name	Shape of tone	contour pitch value
mā	‘mother’	Tone 1	(high) level	55
má	‘hemp’	Tone 2	rising	35
mǎ	‘horse’	Tone 3	(low) dipping	214/21
mà	‘scold’	Tone 4	(high) falling	51

In this study, the Wade-Giles names are simplified to T1 for Tone 1, T2 for Tone 2, T3 for Tone 3, and T4 for Tone 4. Note that this table follows the traditional expressions of the four tones, especially Tone 3.

1.3.2 Tonal features and representation

In a large body of previous work on Chinese Linguistics, “tonal categories are consistently classified by two sets of descriptive terms: one denoting pitch height (high/low

or ‘yin’/‘yang’), the other pitch movement (rising, falling, dipping etc). This practice implies that tone consists of two independent orthogonal dimensions: register and pitch contour” (Chen, 2000). This thesis follows the model of tone proposed by Bao (1999), which is displayed in (1).

(1) Tonal representation I (Bao 1999)

TBU: tone bearing unit; T: tone root; r: register; c: contour; t: terminal tone segment



All these features including register and contour are borne by a syllable. This model suggests that a contour tone behaves like a single unit since the contour node dominates the terminal tone segments. In this model, register is a sister of contour but not a dominant. It predicts that register and contour could behave independently and they may undergo independent assimilatory spread. This prediction is verified by evidence from two Chinese dialects, namely Zhenhai and Chaozhou in Chen (2000).

In register feature analysis, a binary feature is referred to in Yip (1980) as [+/- upper]. This register feature “situates the beginning of the tone in either the upper or the lower part of the speaker’s register, since contours have only an initial tonal specification, and the phonetic contour is the result of drift away from that initial target. Level tones have two targets, firmly anchoring both ends and keeping the pitch stable” (Yip, 2001). This thesis will employ the binary feature, i.e., [+/- upper], henceforth [+/- U]. As far as contours, since we follow the model of Bao (1999), this thesis employs small ‘h’ and ‘l’ for high and low component tones in the terminal tone positions, where two terminal tone segments compose a

whole tone which is borne by a syllable. Following this claim, the four lexical tones can be represented as (2):

(2) Tonal representation II

tone	pitch value	register + component tones
Tone 1	55	[+U, hh]
Tone 2	35	[+U, lh]
Tone 3	21/214	[-U, ll/lh]
Tone 4	51	[+U, hl]

1.3.3 Tone sandhi in Mandarin Chinese

This section considers tone sandhi in MC. “Rich and highly developed as tonal systems have become in Chinese, they are surpassed in many instances by even more complex and intricate sandhi processes, which often drastically alter the phonetic shape of adjacent tones, when they come into contact with each other in connected speech. This tonal alternation in connected speech is what has been referred to as tone sandhi” (Chen 2000).

The conception of tonal coarticulation is different from that of tone sandhi. In connected speech, the underlying form of the lexical tones is possibly transformed in two ways. One is coarticulation. Coarticulation effects refer to the pitch level changes that are too subtle to be perceptible by the unaided ear. The second involves a few tone sandhi processes which result in categorical tone changes. That is, the coarticulation effects only involve some phonetic changes whereas the tone sandhi involves a phonemic change. Shen (1992) proposes various diagnostics to distinguish tonal coarticulation from tone sandhi, including “(a) only assimilation is considered coarticulation, but tone sandhi may be both assimilatory and dissimilatory; (b) tonal coarticulation obeys language-independent biomechanical constraints only, while tone sandhi may be subject to language-specific morphological

conditions; (c) tone sandhi may effect tonemic change, while tonal coarticulation involves only allotonic variations.”

Among the few existing tone sandhi processes in MC, the best known is T3 Sandhi, henceforth T3 Sandhi. The prototypical T3 sandhi rule is traditionally represented as a T3 changing to T2 before another T3. T3 Sandhi is illustrated by the following examples (3).

(3) Tone 3 Sandhi

- | | | |
|----|---------|---------------------------|
| a. | hao | “good” |
| | 214 | |
| | Hao jiu | “good wine” |
| | 214.214 | citation form |
| | 35.214 | sandhi form |
| b. | mai | “buy” |
| | 214 | |
| | Mai jiu | “to buy wine” |
| | 214.214 | citation form |
| | 35.214 | sandhi form |
| c. | mai | “to bury” |
| | 35 | |
| | Mai jiu | “to bury wine” |
| | 35.214 | citation form=sandhi form |

The rule turns a T3 on the first full syllable of a two-T3 sequence into a T2. However, T3 in other contexts does not experience this sandhi process, i.e., T3 loses the final rising part when it is followed by T1, T2 and T4, and keeps its original lexical tone value in word- or phrase-final positions.

In the range of two identical tone sequences, two T4 morphemes, *yi* and *bu*, have similar sandhi behavior to the T3 sandhi. When the T4 morphemes *yi* and *bu* are followed by another T4 morpheme, they change into rising tones, i.e. T2. The T4 sandhi only occurs on these two morphemes, but not on any other T4 morphemes. (4) is an example to illustrate *bu* sandhi.

(4) *bu* Sandhi

- | | | |
|----|-----------|---------------------------|
| a. | bu | “not” |
| | 51 | |
| | bu chang | “don’t sing” |
| | 51.51 | citation form |
| | 35.51 | sandhi form |
| b. | dui | “mutually/face to face” |
| | 51 | |
| | Dui.chang | “duet” |
| | 51.51 | citation form=sandhi form |

Since the T4 sandhi rule only applies to two specific T4 morphemes, i.e., *bu* and *yi*, the T4 morpheme *dui* in (4b) does not experience the sandhi process.

In summary, the sandhi rule that changes the initial tone into a T2 when it is followed by an identical tone (i.e., another T3 in T3 sandhi, and another T4 in T4 sandhi) only applies in all two-T3 sequences and in a more restricted fashion, with the T4 morphemes *yi* and *bu*, when followed by other T4 morphemes, but not at all with other identical tone sequences, i.e. T1+T1, T2+T2 and T4+T4.

The next subsection provides a previous account of T3 sandhi within the OT framework.

1.3.4. OCP and previous accounts for T3 sandhi

There is a vast literature on the T3 sandhi rule because its application is conditioned by prosodic and syntactic factors. Here I only discuss the accounts of T3 sandhi in the domain of disyllables. Many researchers, such as C. Cheng (1973) and Yip (1980, 2002), consider T3 Sandhi to be a case of dissimilation. Here I cite a representative account by Yip (2002), who takes Tone 3 to be underlyingly specified as L only, representing T3 Sandhi as a dissimilation process which is motivated by the Obligatory Contour Principle (OCP).

Yip (2002) assumes that a contour tone is composed of two level tones. For example, a rising tone is composed of a low component tone and a high component tone as proposed for the African tonal system. That is, the system has only two tones, H and L, since it is the “most parsimonious account” (Yip, 2002). As a result, the four tones are represented as H for T1, LH for T2, L for Tone 3 and HL for T4. The OCP referring to these component tones is OCP (general) and here it is labeled as OCP (constituent) for *constituent tones*. However, Yip (2002) refers to the dominating OCP constraint as OCP (whole tone) which means two identical whole contour tones are prohibited. The whole tone refers to an entire tone borne by a full syllable instead of the component tones within a contour tone. Under this analysis, the case of T3 Sandhi is identical to one of the Tianjin dialect changes, $L.L \rightarrow LH.L$, and the grammar of T3 sandhi can be illustrated by Tableau (1-1).

Tableau (1-1): Grammar of T3 Sandhi

/L.L/	FaithPrWdHd	OCP(Whole)	FAITH	OCP(Constituent)	*T
$\rightarrow LH.L$					***
H.L			*!		**
HL.L				*!	***
L.L		*!		*	**
L.HL	*!				

The candidate H.L changes the initial L tone to H tone, which obviously violates FAITH. Candidate HL.L does not violate OCP (whole tone) but will still be ruled out since it has two identical low constituent tones. Candidate L.L has two low tones, and actually it violates both OCP (whole tone) and OCP (constituent). As for why the initial tone of the winning output changes, but not the second one, Yip proposes that there is a highly ranked positional faithfulness constraint (FaithPrWdHead) resisting change on second syllables. Thus, the candidate L.HL (and other candidates who change the second tone) is ruled out. Note that I use L.HL as a representative of those candidates who change the second tone.

As a result, the grammar of T3 sandhi could be generally represented by the following constraint ranking: FaithPrWdHead, **OCP (whole tone) >> Faith**>> OCP (Constituent), *T. The ranking shows that an OCP (whole tone) markedness constraint, or, more specific to this case, OCP (L tone), outranks one or more faithfulness constraints. It implies that, for other two-identical-tone combinations (i.e. T1+T1, T2+T2, T4+T4) that keep their underlying tones as outputs in native speakers' productions of MC, the ranking of constraints would be that some Faithfulness constraints dominate Markedness constraints which might be OCP. That is, the effect of Markedness constraints such as OCP is visible in T3 sandhi, but is masked by the faithfulness constraints (FAITH in the above example, and Ident-tone in our discussion of the data of second language acquisition) in other two-identical-tone combinations, i.e., they are 'inactive' in the grammar of MC.

Remembering the discussion regarding the hidden ranking in OT in §1.2.2, these masked or 'inactive' markedness constraints in T1+T1, T2+T2 and T4+T4 sequences cannot be determined by examining MC, but can be determined by studying some second language acquisition data. Examining the tonal productions of subjects who have no tonal language background but have studied MC for several months will help us to make the inactive markedness constraints and the ranking visible. The study thus would determine if the constraint set also contains OCP constraints like Yip's analysis of Tone 3 Sandhi, and if these constraints are also subject to the high ranked positional faithfulness constraint. Based on the results of this study, we would predict the future development of the sandhi processes in the domain of two-identical tone sequences.

Another markedness constraint regarding tone acquisition, the Tonal Markedness Scale (TMS), is also predicted to be among to these 'inactive' constraints. The TMS will be

first introduced in the following section. In order to understand this markedness constraint better, the following section provides more background information regarding first and second language acquisition in MC.

1.4 The acquisition of Mandarin Chinese Tones

1.4.1 Tonal markedness scale

There is a universal, phonetically grounded markedness scale: *R >> *F >> *L (as cited in Hyman & VanBik, 2004) which indicates that rising tones are more disfavored by speakers than falling tones, which are more disfavored than level tones. Studies of First Language Acquisition (Li & Thompson, 1977, among others) reveal that Mandarin speaking children acquire T1 first, then T4, then T3 and T2. Note that the acquisition order of T3 and T2 is still a controversial issue. Some studies of Second Language Acquisition also show such a preference (Miracle, 1989). Thus, here we just focus on the three target tones and assume a Tonal Markedness Scale represented as *T2> *T4>*T1 which indicates that T2 is most disfavored by the English-speaking learners, then T4, then T1.

More details of first and second language acquisition of MC are offered below.

1.4.2 Acquisition of Mandarin Chinese as a first language

Until now, most research has focused on the exploration of adult speakers' tonal phonology. Very little is known about the acquisition of MC tones by children. With this in mind, this section summarizes our current understanding of the acquisition order and early productions.

Previous studies of first language acquisition reveal that MC tones are acquired very early, long before the inventory of segmental sounds is mastered.

The earliest studies on the acquisition of tonal inventories probably were made in the late 1970s. Li and Thompson (1977) looked at seventeen Mandarin-speaking children aged 1;6 to 3 years. They find that at the earliest one-word stage, high level tones (T1) are produced first, followed by high falling tones. Rising (T2) and dipping tones (T3) are later, and syllables with such tones are either avoided or changed to T1 or T4. When these last two tones are acquired, at first they are quite often confused, and this confusion continues on into the two- to three-word stage. Clumech (1980) studied two Mandarin-speaking children, and confirms this order of acquisition. The data (5) below are pooled over the age-range 1;10-2;10 for one child in Clumech's study, and show only citation or utterance-final words:

(5) Accuracy rate of Mandarin-speaking children (Clumech, 1980)

Tone	Accuracy (%)
High level (T1)	97.2
High falling (T4)	95.8
High rising (T2)	61.3
Low-dipping(T3)	73.9

Both Li and Thompson, on the one hand, and Clumech, on the other, agree that the children have more or less mastered the tones at a stage when segments are still quite far from adult forms. For example, one of Li and Thompson's later-stage subjects said [yaba day dəyi] for [labadʒaydzəli] 'the horn is here', but the tones were perfect [21 55 41 41 214].

Zhu & Dodd (2000) confirm the above findings, and describe the phonological acquisition of 129 monolingual Mandarin Chinese speaking children, aged 1;6 to 4;6 years. Children's errors suggested that MC-speaking children master four elements of MC syllables

in this order: (1) tones; (2) syllable-initial consonants; (3) vowels; and (4) syllable-final consonants. Zhu and Todd suggest that “the saliency of the components in the language system determines the order of acquisition” (Zhu & Todd, 2000).

Once a child starts to produce multi-word utterances the possibility of tonal alternations arises. Thus, the mastery of tone sandhi is also part of the task of tonal learning. Even less is known about this than about the acquisition of lexical contrasts. As Yue-Hashimoto (1980) reports, her subject used the Mandarin T3 Sandhi rule, which changes a low tone to a high rise before another low tone, productively from 2;3 years. That is, “the tone sandhi phenomena associated with the dipping tone (Tone 3) in MC are acquired with minor error once propositional utterances begin to be created” (Yue-Hashimoto, 1980). Li and Thompson report that the oldest children in their study, aged 3;0, did apply the T3 Sandhi rule, but still rather erratically and hesitantly. Unfortunately, their study did not continue past the age of 3;0, so we don’t know when this rule is finally solidly constructed.

1.4.3 Acquisition of Mandarin Chinese as a second language

Even less was known about the second language acquisition (SLA) of MC by adults than by children before 1990. Fortunately, more and more research on this aspect has appeared during recent years. The following is a summary of the studies on the acquisition of MC tones by English-speaking learners.

As we know, children acquire MC tones very early. However, study of second language acquisition reveals that English-speaking learners of MC have much more difficulty in tonal acquisition than in the acquisition of segmental inventories (Miracle, 1989, Wang, 2006, among others).

As reviewed in Sun (1998), most Western studies have focused on the experience of American classroom learners (G-T.Chen 1974; Q-H.Chen 1997; Elliot 1991; Lu 1992; McGinnis 1996; Miracle 1989; Shen 1989). Some are longitudinal studies (Kiriloff 1969; Leather 1990; Lu 1992; McGinnis 1996; as cited in Sun 1998) while some elicit data from a single performance (G-T.Chen 1974; Miracle 1989; Shen 1989; Zhao 1988) or from a battery of related tasks (Q-H.Chen 1997; Elliot 1991; Guo 1993, as cited in Sun 1998). There are very few reports on the acquisition of tone sandhi rules and stress patterns, either.

Concerning the acquisition order of the individual lexical tones, the authors of these studies have reported similar findings. In particular, L2 learners acquire the rising and/or dipping tones last (Q-H.Chen 1997; Elliot 1991; Guo 1993; Kiriloff 1969; Leather 1990; Miracle 1989). On the relative difficulty of the four tones, here are the acquisition orders reported in previous studies (as cited in Sun, 1998.)

Table 1-2: Acquisition orders of lexical tones (Sun, 1998):

Study	Mode	Order
Kiriloff (1969:p.66)	Perception	4<1<3<2
Elliot (1991:p.191)	Perception; Perception: self	4<3<1=2 4<3<1<2
Miracle (1989:p.52)	Production	1<4<3<2
Shen (1989:p.30)	Production	2<3<1<4
Leather (1990:p.83)	Production	1<4<2=3
Elliot (1991:p.191)	Production	1<4<2<3
Lu (1992)	Perception/production	Most difficult: Tone 2
Q-H.Chen (1997)	Perception/production	1<4<2<3
Sun (1998)	Production: Reading Translation	4<1≤3<2 1<2≤3<4

Two studies that are on SLA, but not on the SLA of Mandarin tone, Broselow, Hurtig, & Ringen (1987) and Suelser (1994), have found evidence suggesting that position within a polysyllabic word affects the perception and production of tone. Guo (1993) has reported that the accuracy of tone production decreases as the number of syllables in a word increases.

There are very few studies looking at the development of sandhi rules on two-identical tone sequences from the perspective of second language acquisition.

1.5 Summary and Overview

This thesis consists of four more chapters. Chapter 2 specifies the methodology employed in this study. In Chapter 3, I will present the results of the pre-test and the main experiment, respectively. From §3.3, the overall error distribution will be provided first, and then the three hypotheses regarding TMS, OCP, and PF will be tested and discussed thoroughly. In Chapter 4, I will closely examine the substitutions and analyze the grammars of the tonal productions in the framework of OT. Chapter 5 offers conclusions and proposals for future studies.

CHAPTER 2

METHODOLOGY

The bulk of this study consists of three statistical language studies, reported in chapter 3. The investigations seek to identify the phonological factors, namely the Tonal Markedness Scale, Positional Faithfulness Constraints, and the Obligatory Contour Principle, and the interactions among them, which are related to tonal production in American adult learners of Mandarin in disyllabic words. In order to complete the study, a pre-test and a main experiment were specifically designed. The purpose of the pre-test is to make sure that all participants are able to produce the individual lexical tones correctly and eligible for the main experiment, while the main experiment addresses the three core questions.

2.1 Subjects

Thirty American English speakers, nine females and twenty-one males, participated in this study. The first language of all participants is American English. The other native language of one bilingual participant is Italian, and of another three bilingual participants is German. The second or third language(s) of these participants are non-tonal languages, such as Spanish, French, Italian, German, Latin, Japanese, Portuguese, etc.

All subjects are undergraduate students in their second semester of Chinese language class (CHIN 102) in Spring 2007 at the University of North Carolina at Chapel Hill.

They had studied MC for about 5 months when the experiment was conducted and had learned the four MC lexical tones and all test morphemes, including the meaning, pronunciation and Chinese characters of the morphemes. The textbook they were using was the second edition of Integrated Chinese (Level 1 Part 1) by T. Yao et al (2005).

All the subjects participated in this study voluntarily.

2.2 Materials

The pre-test was used to test if the participants were able to pronounce the individual lexical tones correctly. 9 monosyllabic morphemes the participants have learned are selected for the pre-test. 3 of them are T1 morphemes, 3 of them are T2 morphemes and the other 3 are T4 morphemes (not *yi* and *bu*). The pinyin system of Romanization, tone marks, the Chinese characters and English translation of morphemes were presented to the participants in the reading lists. These 9 morphemes were randomly ordered in the lists. Table 2-1 lists the 9 test morphemes.

Table 2-1: Materials for pre-test

Item	Tone type	Pin Yin	Chinese Character	English translation
1	Tone 1	yīn	音	voice,music
2	Tone 1	yīng	英	English/hero
3	Tone 1	mēn	闷	stuffy
4	Tone 2	wén	文	written language
5	Tone 2	máng	忙	busy
6	Tone 2	mén	门	door
7	Tone 4	wàng	忘	to forget
8	Tone 4	wèn	问	to ask
9	Tone 4	màn	慢	slow

For the main experiment, 20 mono-syllables, which were composed into 18 bi-syllabic words as shown in Table 2-2, were used. The onsets of all test morphemes are sonorants (i.e., [m],[n],[r],[l],[w],[j]) and the rhymes either end in nasals(i.e.[m],[n],[ŋ]) or have no coda. These are all disyllabic words such that second syllables of the sequences cannot be pronounced with a neutral tone in spoken Mandarin, that is, the target forms of these test words should be identical to the underlying form in native speakers' productions. To avoid nonsense test words for the subjects, all morphemes in the test materials are chosen from chapters 1 to 12 of the text book *Integrated Chinese*. The subjects have learned all test morphemes in the classroom. However, some combinations of morphemes are new for the subjects such as 'ri yong' which means 'daily used' etc. These new combinations of morphemes are labeled with asterisks in the Table 2-2. The new combinations of morphemes are distributed evenly in the two sets and the two lists, as explained in Table 2-2 in the following section.

The test words were grouped into two sets. Set (A) contains three sequences of two identical tones (i.e., T1+1,T2+2 and T4+4), while Set (B) contains all 6 possible non-identical combinations of the three test tones T1,T2 and T4 (i.e., T1+T2,T2+T1, T1+T4, T4+T1, T2+T4 and T4+T2). In order to have the same size of samples between Set (A) and Set (B), the three sequences of tonal combinations of Set (A) were repeated one more time so that both Set (A) and Set (B) have 6 sequences of two-identical tonal combinations. Two versions of Set (A) and two version of Set (B) are proposed. Set (A-1) and Set (A-2) are parallel, that is, the test words in the two Set (A)s have the same tone combinations, but use different morphemes. Likewise, there are two Set (B)s, namely Set (B-1) and Set (B-2). Thus there are four groups of test words in total, namely Set (A-1), Set (A-2), Set (B-1), and

Set (B-2). Set (A-1) and Set (B-1) comprise List 1, and List 2 is composed by Set (A-2) and Set (B-2). List 3 is a repetition of List 1 but the test words were in different order from the List 1. List 4 is a repetition of List 2, but the test words were in different order from List 2.

Table 2-2: Test words in the main experiment

Tones	MC characters	Pinyin	IPA	Glossary
(Set A-1)				
T1+T1	* 闷音	men yin	[mən] [in]	smothered sound
T2+T2	明年	ming nian	[miŋ][niɛn]	next year
T4+T4	* 日用	ri yong	[ri][joŋ]	daily used
(Set A-2)				
T1+T1	* 英音	ying yin	[iŋ][in]	British English accent
T2+T2	* 名人	ming ren	[miŋ] [rən]	celebrity
T4+T4	问路	wen lu	[wən] [lu]	ask directions
(Set B-1)				
T1+T2	英文	ying wen	[iŋ][wən]	English language
T2+T1	* 忙音	mang yin	[maŋ][in]	busy voice
T1+T4	闷热	men re	[mən][rə]	stuffy and hot
T4+T1	* 练音	lian yin	[liɛn] [in]	practice pronunciation
T2+T4	牛肉	niu rou	[nju] [rou]	beef
T4+T2	外文	wai wen	[wæi] [wən]	foreign language
(Set B-2)				
T1+T2	* 英明	ying ming	[iŋ][miŋ]	wise
T2+T1	* 南音	nan yin	[næn][in]	southern accent
T1+T4	音乐	yin yue	[in] [yɛ]	music
T4+T1	录音	lu yin	[lu] [in]	tape recording
2+4:	鱼肉	yu rou	[y][rou]	fishes
4+2:	日文	ri wen	[ri] [wən]	Japanese language

These test words are embedded in sentences. Since the chosen words are all nouns or adjective words, they are used as modifiers to modify nouns in the sentences. In order to avoid the anticipatory and carry-over effects by neighbor tones (Yi Xu 1997), the tokens are embedded in sentences where the preceding and following morphemes are both neutral tone (labeled as Tone 0). In addition, these test words were placed in a sentence internal position. This restriction was made in an effort to reduce the possible interference of English sentence intonation.

(6) Test sentence for main experiment:

Chinese character: 我觉得_____的东西很好.

Pinyin: Wo3 jue2de0 _____de0 dong1xi0 hen3 hao3.

Gloss: 'I feel _____things are very good.'

In each list of sentences, there are both 6 sentences of Set (A) and 6 sentences of Set (B). Therefore, there are 12 sentences in each list. Each participant read 4 lists, namely, List 1, List 2, List 3 and List 4. That is, each participant produced 48 sentences in the main experiment.

The sentences are in a randomized order in each list. They are transcribed in the Pinyin system of Romanization. The tonal diacritics were also used so that the students would not have to resort to guessing the proper tone of words which they may have forgotten. The Chinese characters of the sentences and the English translation are also provided to the participants in the reading lists. All of these measures were used to aid in the ease of the students' reading and to insure that they would not feel intimidated by the task.

2.3 Recording

In order to obtain natural performance of tones, the participants were not told that their performance of tones would be tested before the recording, but instead, that it would be their performance of pronunciation.

30 subjects' tonal productions are all recorded in the soundproof recording lab in Dey Hall 103 at University of North Carolina at Chapel Hill.

A microphone-headset from Radio Shack, and a Dell Pentium IV laptop computer with Windows XP were used to record the productions. For recording, listening to, viewing, and measuring the data, Version 4.3.31 of Praat was used.

On the procedures of the recording, after the subjects arrived at the lab, they were asked to sign a document of consent first. Then, subjects read the 9 monosyllabic morphemes with different tones for the pre-test. After that, subjects read the four lists of sentences. The recording was interrupted for half-a-minute to a minute between readings of the list. The pre-test productions and the four lists of the main experiment were saved separately in a personal computer. Upon completion of the recording session, the participants received a small gift as a token of appreciation.

2.4 Extraction of test tones

The test words were extracted from the sentences before the judgments by native speakers. The investigator extracted the monosyllables and saved them as separate sound files for the pre-test. According to the finding by Xu (1994) that “tonal identification of tones in running speech remained more accurate when the tones were presented with the original tonal context than without the original tonal context”, the bi-syllabic words from the main experiment were extracted from the test sentences as a whole instead of extracting

monosyllabic morphemes. Therefore, for each participant, 9 monosyllables and 48 bisyllables were extracted and all saved separately. 1710 sound files were extracted in total for this study.

2.5 Judgment

After the mono-syllabic morphemes and disyllabic words were extracted from the recorded sound files, all these utterances were presented individually to two native speakers, who listened to these sound files and judged whether these tonal productions are the same as the target tone productions (marked as ‘correct’), or not (marked as ‘incorrect’). For the incorrect productions, what kind of MC tonal productions the actual sound produced by subjects sounded like was also written down for statistical analysis. One of the native speakers is the principal investigator, who is a linguistics student and also a Chinese language teacher. The other native speaker is also an experienced Chinese language teacher. Both of these two native speakers have more than 10 years experience of teaching Chinese as a second language, that is, they both have more than 10 years of experience of judging non-native speakers’ tonal productions.

Two main parameters of judgment are “register” and “contour” of MC tones. As mentioned in §1.3.2, register denotes pitch height and pitch contour denotes pitch movement. We follow the binary feature of register by Yip (1980), so that the tonal register is either being upper [+U] or lower [-U]. We follow the traditional contour features of ‘rising’, ‘falling’ and ‘level’. Previous research reveals that tonal mis-production made by American learners of Mandarin result from errors in tonal contours, or the tonal mis-production primarily involves errors in tonal register (Chao 1980, Zhao 1987, Shen 1989, among others). The errors of contour and register in this experiment are labeled respectively, and a tone

would be counted as an error if either contour or register of the tone is wrong, that is, any mis-register or mis-contour will result in a wrong tone.

The two MC native speakers listened to every extracted utterance and judged whether the tone has the right contour and register. For each participant, 57 sound files were opened and 105 syllables were judged. As a result, 3150 syllables were judged by the two native speakers respectively in this study. After that, the principal investigator double checked the judgments. There is a small amount of data of inter-reader inconsistency, which will be reported in the first section of chapter 3.

2.6 Data presentation

There are 24 items for the main experiment produced by each participant. The summary of the all possible transcriptions of the judgments for one item is shown in the following Table 2-3. The scores for the dataset of List 1 is sampled with details, while the scores of other datasets of List 2, 3, and 4 (shown as L2, L3, L4, in the Table) are elided in this simplified table. This simplified table only records all the possible information for one item, that is, for one specific tonal production. This section will provide five actual examples in Table 2-4.

The results of the judgments were recorded in Excel. As Table 2-3 shows, the correct tones are scored as ‘0’, the wrong tones are scored as “1” and those inconsistent judgments are labeled with “*” in Excel. The following several columns record the details of the wrong tones. In the column of “Like”, for each wrong tone, the tone type which the target tones were heard as are recorded. For example, if the target tone is wrongly produced as a Tone 1, it is recorded as “T1” in the column of “Like”. One of the parameters of “Tone range” (i.e.,

High register or Low register) and “Tone shape” (i.e., level, rising, falling and other) are chosen according to the judgment of the native speakers.

Table 2-3: Possible transcriptions of the judgments for one item

			List 1 score	Like	Tone range		Tone Shape			
					H Reg	L reg	level	rising	falling	other
Consistent judgments	Correct tones		0							
	Wrong tones	In Tonal inventory	1	T1	1		1			
			1	T2	1			1		
			1	T3		1	1			
			1	T3”		1				Con-cave
			1	T4	1				1	
		Out of inventory	1	?33 middle			1			
			1	?31 Low-T4		?1			1	
			1	? 535... ..	?1					Con-cave
	Inconsistent judgments (*)		*1	*T1/T2 *33/T3	?1	... ?1.	?1 ?1	?1		
*0/1			*0/T1	?1 ...	?1					

In the following Table 2-4, five examples are excerpted from the actual Excel form. Example 1 represents a correct tonal item. Examples 2 and 3 are two typical “Wrong tones”. Example 2 has a “Like” tone which is within the Chinese tonal inventory but example 3 does not. Examples 4 and 5 show how we transcribe those “Inconsistent judgments”. Example 4 is a within-wrong-tone inconsistent case, while example 5 is a correct-or-wrong inconsistent case. I will provide more explanation regarding the inconsistent judgments in the next chapter.

Table 2-4: Five examples of judgments:

Example	Subject ID	Item	L1 score	Like	H reg	L reg	Level	Rising	Falling	Other
1	S-1	44-T4-P1	0		1				1	
2	S-6	22-T2-P2	1	T1	1		1			
3	S-11	42-T4-P1	1	?33 Mid- dle			1			
4	S-17	12-T2-P2	*1	?33/ T3		?1	?1			
5	S-11	22-T2-P1	*0/1	*T2/ T1	?1		?1	?1		

In this table, the Subject IDs are numbers from S-1 to S-30 which represent the IDs of thirty speakers. The sequence of number and letter in the column ‘Item’ is the unique identifier for each mono-syllabic tonal item produced by each subject. The first numbers are the codes for the tone combination types. Table 2-5 shows how these codes represent the tone combination types. The following letter and number such as “T1”, “T2” and “T4” are the target tone types for each item, and the last letter and number sequences such as “P1” and “P2” are the codes for the position of this mono-syllabic item in the context of the disyllabic words, “P1” representing the first position or the word-initial position of the disyllabic words, and “P2” representing the second position or word-final position of the disyllables.

In Table 2-5, the actual items used in all four lists are also listed. Remember that List 3 is a repetition of List 1 but the items in each list are in different orders, and List 2 and List 4 have the same situation. Readers can see §2.2 for more clarification.

Table 2-5: The tone combination type codes

Tone comb type codes	Tone combination types	Stimuli Set	Items in List 1 &List 3	Items in List 2 &List 4
11	T1+T1	A	Men yin	Ying yin
11	T1+T1	A	Men yin	Ying yin
22	T2+T2	A	Ming nian	Ming ren
22	T2+T2	A	Ming nian	Ming ren
44	T4+T4	A	Ri yong	Wen lu
44	T4+T4	A	Ri yong	Wen lu
12	T1+T2	B	Ying wen	Ying ming
21	T2+T1	B	Mang yin	Nan yin
14	T1+T4	B	Men re	Yin yue
41	T4+T1	B	Lian yin	Lu yin
24	T2+T4	B	Niu rou	Yu rou
42	T4+T2	B	Wai wen	Ri wen

2.7 Statistics

The study makes use of the SAS system for statistical analysis. Several procedures, such as the FREQ procedure, the GENMOD procedure, and the GEE model, are employed in the statistical analysis for the present study.

The significance criterion adopted for declaring a significant difference is $p < 0.05$ unless otherwise noted.

CHAPTER 3

RESULTS

3.1 Introduction

This chapter is the report of the results of the pre-test experiment and main experiment, as well as the statistical results. First mentioned is the inter-reader inconsistency in judgments which does not significantly influence the results of the two experiments due to its very small amount.

There are 50 inter-rater inconsistent items out of 2880 judgments in the main experiment, while no inconsistent cases were found among the 270 judgments in the pre-test experiment. Among the 50 inter-rater inconsistent items, 47 are inconsistency within ‘wrong tones’ which is 1.63% out of the total judgment. The inconsistency within ‘wrong tones’ means that two native speakers have the same judgment of ‘wrong tones’ for these tonal productions; however, they have a different description (i.e., the tone type, tone range or tone shapes) of what they’ve heard for these wrong tones. The other three inconsistent items are correct-or-wrong inconsistency, which is only 0.1% out of the total judgments. That is, the two native speakers have different judgments, correct or wrong, for these three items. Due to the low percentage of these inconsistent judgments, they have no effect on the statistical analysis.

The chapter is organized in the following manner: in §3.2. I examine the results of the pre-test including the error distributions and the substitutions, which suggests that all participants are able to produce the individual lexical tones correctly. Then, the overall error distributions in the main experiment and two types of errors are reported in §3.3. The following three sections, §3.4 to §3.6, offer statistical assessments of the relevance of the three phonological constraints, namely, the Tonal Markedness Scale (TMS), Positional Faithfulness (PF) constraints and the Obligatory Contour Principle (OCP), within the data sets. That is, the three central questions will be addressed in these three sections.

3.2 The Pre-Test

In the pre-test, all participants read aloud nine mono-syllabic morphemes, which include three T1 morphemes, three T2 morphemes and three T4 morphemes. According to the judgments of the two native speakers, the participants produced 7 wrong tones in total. These 7 wrong tones were produced by different participants. Table 3-1 shows the distribution of the errors and the substitutes for the target tones. The items are grouped in terms of target tones.

Table 3-1: Tone errors in Pre-test

item	Participant	Target tone	Segmental shape	Actual tones (judged by native speakers)	Actual Tone register	Actual tone shape
1	Subject 11	Tone 1	men	Tone 3	Low	level
2	Subject 24	Tone 1	men	Tone 2	High	rising
3	Subject 8	Tone 2	wen	Tone 3	Low	concave
4	Subject 14	Tone 4	wang	?31 low T4	Low	falling
5	Subject 16	Tone 4	wang	Tone 2	High	rising
6	Subject 23	Tone 4	man	Tone 2	High	rising
7	Subject 27	Tone 4	wang	Tone 2	High	rising

Amongst the 7 wrong tones, only one actual tonal production, item 4 in the above table, is out of the Chinese tone inventory, which is a low Tone 4, while the others are all categorized in Chinese tone types. (See 3.2.2 for further discussion of this classification of error types.)

7 participants' correct rates are 89% and the others are 100%; therefore, the mean correct rate for all subjects is 97.43%. Since both the individual correct rates and the mean correct rate for all subjects are higher than 85%, I assume that all participants are able to produce the individual T1, T2 and T4 correctly. Therefore, all of the participants are eligible for the main experiment.

3.3 Overall error distributions in the main experiment and two types of errors

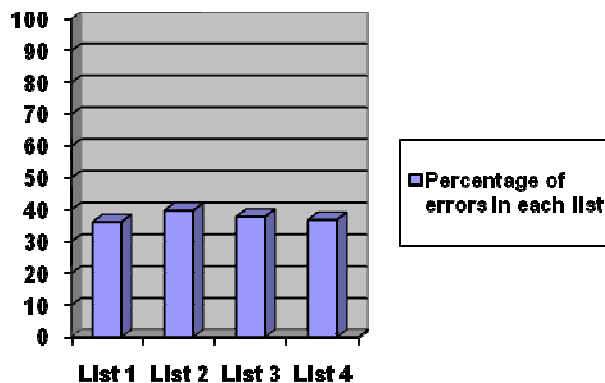
3.3.1. Total errors and the subtotals

There are 1067 wrong tones in total according to the judgments by the two Mandarin native speaking raters in the main experiment. The wrong tones are 37.7% out of 2830 total judgments (excluding the inconsistent judgments), while those 1763 correct tonal productions are 62.3% out of the total consistent judgments in the main experiment. The main analysis and discussion in this chapter will focus on these mis-productions, including the distribution and the phonological reasons why English native speakers make these mis-productions, etc. The error rates for each list are shown in Table 3-2 and Chart.3-1.

Table 3-2: The error rates across four lists in main experiment

Lists	Total consistent judgments	Error numbers in each list	Percentage of errors for each list
List 1	710	257	36.2%
List 2	704	280	38.9%
List 3	710	269	37.9%
List 4	706	261	36.9%

Chart 3-1: Tone errors across four lists



The error rates of the four lists in the main experiment are all lower than 40% but higher than 35%. Remembering that the List 3 is a repetition of List 1 and List 4 is a repetition of List 2, the second list has the highest error rate, whereas the first list has the lowest. The statistical analysis shows that there is no significant difference between the error rates across the four lists.

3.3.2 Errors in the Chinese tone inventory and those out of inventory

Amongst the 1067 mis-productions in the main experiment, there are two kinds of wrong tones in the data sets. As I mentioned in §3.2, one is those errors which could be categorized into Chinese tone types, that is, within the Chinese tone inventories. For example, the target T2 is produced wrongly as T4 (judged by the two native speakers) which is still one of Chinese tonal types. There are 910 within-inventory mis-productions, which is 85.3% out of 1067 total mis-productions. The other kind of mis-production are those “tonal” productions that cannot be categorized into any Chinese tone types, that is, out-of-Chinese tone inventory errors. For example, a target T2 is produced wrongly, and it sounds like a middle level tone which is not a Chinese lexical tone defined in Chapter 1. There are 157 out-

of-inventory mis-productions, which is 14.7% out of 1067 total mis-productions. As the numbers show that, the within-inventory mis-productions are about 5.8 times of as frequent as the out-of-inventory mis-productions.

According to the judgments of the two native speakers, there are mainly three categories of out-of-inventory tonal productions, and they are “middle tone”, “low T4” and “other”. These three kinds of out-of-inventory tonal productions are transcribed in the Chao’s five-letter system, 5 being the highest, 1 the lowest, where the numbers represent relative pitch. For example, if the mis-production sounds like a mid-level tone, it is marked as “33”. The distributions of the out-of-inventory mis-productions are shown in Table 3-3. Chart 3-2 shows the subtotals of out-of-inventory mis-productions and Chart 3-3 shows the breakdowns of the three types of out-of-inventory mis-productions. The percentages in the table and charts are the numbers of mis-productions out of total judgments in the main experiment.

Table 3-3: Distributions of the out-of-inventory mis-productions

Error types	Error numbers and percentages (out of 1067 total errors)			Errors in List 1 and percentages out of total errors	Errors in List 2 and percentages out of total errors	Errors in List 3 and percentages out of total errors	Errors in List 4 and percentages out of total errors
Out-of-inventory errors	157 (14.7%)	Subtotals and percentages for each list		37 (3.5%)	51 (4.8%)	32 (3.0%)	37 (3.5%)
		Three categories under out-of inventory errors	Middle-tones	23(2.2%)	23(2.2%)	20(1.9%)	21(2.0%)
			Low-Tone 4	10(0.9%)	23(2.2%)	9(0.8%)	13(1.2%)
			Others	4 (0.4%)	4 (0.4%)	3 (0.3%)	3 (0.3%)
Within-inventory errors	910 (85.3%)			220 (20.6%)	229 (21.5%)	237 (22.2%)	224 (21%)

Chart 3-2: Subtotals of out-of-inventory mis-productions

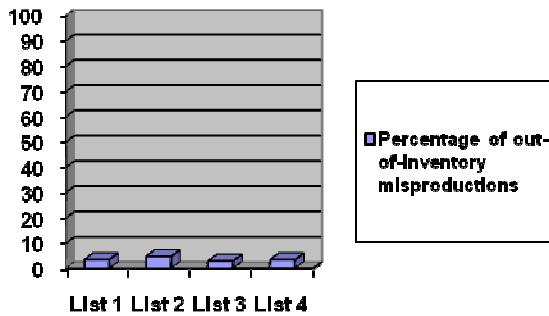
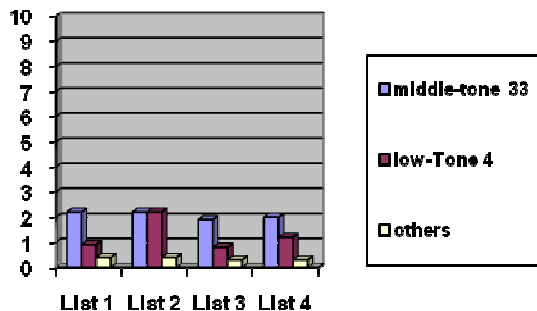


Chart 3-2 shows that there are very few out-of-inventory mis-productions in the main experiment and they are 3.5%, 4.8%, 3.0% and 3.5% in the four lists respectively. All of them are less than 5% of the total errors in the main experiment.

Chart 3-3 tells us the breakdowns (percentages) of three types of out-of-inventory mis-productions.

Chart 3-3: Three types of out-of-inventory mis-productions:



The “middle-tones” always have the highest percentages (2.2%,2.2%,1.9% and 2.0%), and the next is “low-Tone 4”(0.9%,2.2%,0.8% and 1.2%), and the lowest is the “others” (0.4%,0.4%,0.3% and 0.3%)which includes “high concave-535” etc. The out-of-inventory mis-productions had no noticeable effect on the statistical analysis because they were very few in number.

3.3.3 A discussion of the out-of-inventory errors

We generally cannot find these out-of-inventory errors in the grammatical utterances for native Mandarin speakers, but they occur in these non-native speakers' productions, although they are very few in numbers in the present study. If we put this issue in the framework of Optimality Theory, it seems that when the speakers produced out-of-inventory errors, the grammar for such output would be one in which those constraints eliminating within-inventory tone types are at a higher ranked position than those constraints eliminating out-of-inventory tone types. However, in most situations, the speakers produce within-inventory errors, which means that in OT the constraints which eliminate out-of-inventory tone types are at higher ranking positions than those eliminating the defined four tone types.

3.4 The Tonal Markedness Scale (TMS)

In this section, the related data and statistical results will be closely examined to determine whether the Tonal Markedness Scale (TMS) plays a role in the tonal productions made by English native speakers.

Tonal Markedness Scale (TMS) is a universal, phonetically grounded markedness scale, which is stated as *R>>*F>>*L (as cited in Hyman & VanBik 2004). The scale indicates that rising tones are more disfavored by tonal language speakers than falling tones, which are more disfavored than level tones. The study of First Language Acquisition (Li & Thompson 1977, among others) shows that Chinese Mandarin children usually acquire T1 and T4 earlier than T2 and T3, which fits with the universal TMS. This paper focus on the

three target tones of MC and assumes a Tonal Markedness Scale for this study represented as *T2>>*T4>>*T1.

I first look at the error distributions of Tone 1, Tone 2 and Tone 4 respectively in §3.4.1, and then move onto the statistical analysis and provide the statistical conclusion in §3.4.2.

3.4.1 Error distributions of T1, T2 and T4

In the whole dataset, as we know, there are 1067 errors in total. Amongst this number, there are 253 errors of Tone 1, 495 errors of Tone 2 and 319 errors of Tone 4. The percentages of the error rates in each list and each set are shown in Table 3-4.

Table 3-4: Tone errors of T1, T2, and T4

		Total errors in whole dataset (1067 errors)			Corresponding chart
Tone types		Tone 1	Tone 2	Tone 4	
Error numbers for each tone		253	495	319	Chart 3-4
Percentages out of 1067		23.7%	46.4%	29.9%	
Errors and the percentages in each list	List 1	64 (26.9%)	120(50.9%)	73(30.9%)	Chart 3-5
	List 2	62(26.4%)	125(53.8%)	93(39.2%)	
	List 3	70(29.4%)	120(50.6%)	79(33.6%)	
	List 4	57(24.4%)	130(55.1%)	74(31.4%)	
Errors and the percentages in each set	Set (A)	125(22.1%)	270(47.6%)	172(30.3%)	Chart 3-6
	Set (B)	143(26%)	244(44.4%)	163(29.6%)	

Chart 3-4 shows the total errors of T1, T2 and T4 in the main list. Chart 3-5 offers more details of the wrong tones of T1, T2 and T4 in each reading list in the main experiment. Chart 3-4 and 305 show that, whether in total number or in each list, T2 always has more errors than T 4 and T1. Interestingly, the ranking of errors of T1, T2 and T4 are the same in

Set (A) and Set (B) respectively. In Set (A), the error rates of T1, T2 and T4 are 22.1%, 47.6% and 30.3% out of the subtotal of Set (A) errors. In Set (B), the error rates of Tone1, 2 and 4 are 26%, 44.4% and 29.6% out of the subtotal of Set (B) errors. The error rates of T1, 2 and 4 in each list are shown in Chart 3-5 and in each set shown in Chart 3-6.

Chart 3-4: The total errors of Tone 1, 2 and 4 in the main experiment

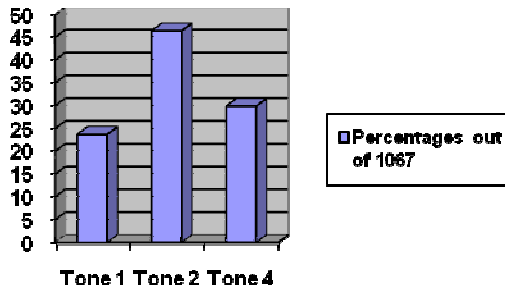


Chart 3-5: Errors and the percentages of Tone 1, 2 and 4 in each list

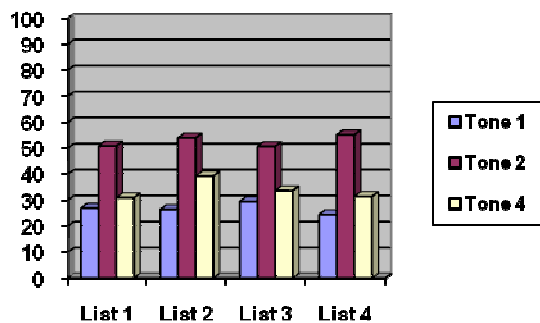
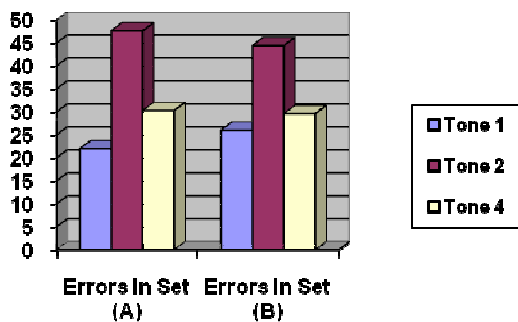


Chart 3-6: Errors and the percentages of Tone 1, 2 and 4 in each set



On all counts, we find that Tone2, in general, has the highest error rate, Tone 4 has the second highest error rate, and Tone 1 has the lowest error rate, in the whole dataset, each list, and each sub-set of data.

3.4.2 Statistical analysis

The GENMOD procedure of the SAS system is used to do the statistical analysis and get the following contrast estimate results.

According to the statistical analysis, in the whole dataset, the error rate of Tone 2 is significantly higher than that of Tone 4 ($p < .0001$). The error rate of Tone 2 is significantly higher than that of Tone 1 ($p < .0001$). And also, the error rate of Tone 4 is significantly higher than that of Tone 1 ($p = 0.0009$) where the 'p' value is still smaller than 0.05. Therefore, in the whole set, the error rate of Tone 2 is significantly higher than that of Tone 4, and Tone 4 is significantly higher than Tone 1. We can draw the conclusion that, statistically, the TMS (i.e., *Tone 2>>*Tone 4>>*Tone 1) works in the whole dataset.

The statistical analysis for the data set (A) and (B) confirms the conclusion we reached based on the study of the whole set. In data set (A), the error rate of T2 is significantly higher than Tone 4 ($p < .0001$), the error rate of Tone 4 is also significantly higher than T1 ($p = 0.0009$); that is $p < .05$. In data set (B), the error rate of T2 is significantly higher than T4 ($p < .0001$) and T1 ($p < .0001$) as well. However, there is no significant difference between the error rates of Tone 4 and T1 since $p = 0.1739$ where the 'p' value is bigger than 0.05. We still can conclude that the error rates of T2 are, in general, significantly higher than T4 and T1.

In addition, the examination of substitutions for each tone which I will discuss in Chapter 4 also verifies the conclusion that the tonal markedness Scale *Tone2 >>*Tone 4>>*Tone 1 is relevant in English native speaker's Mandarin productions. This tonal markedness scale will be used in the grammar analysis in §4.3.

3.5 About Positional Faithfulness Constraints

Positional Faithfulness (PF) Constraints, as I mentioned in the first chapter, are a family of faithfulness constraints. This kind of constraint is about the notion of positional privilege in Optimality Theory. This notion holds that only a small set of linguistic positions are privileged and they play a central role in the phonological systems of the world's languages. Privileged positions are those positions which have phonetic salience or some perceptual advantages in the processing system. Positional Faithfulness constraints are generally stated as in (7a) (McCarthy & Prince 1995, Beckman 1997) and the specific positional faithfulness constraint we will use in this study is as (7b) states:

- (7) a. The corresponding input and output representations at privileged positions should have identical values. (McCarthy & Prince 1995, Beckman 1997)
- b. Ident-Tone (Position)
The tones of the outputs and inputs should have identical values at corresponding positions. In particular, Ident-Tone (P1) requires that the tones of outputs and inputs at the corresponding word-initial positions have identical values; and Ident-Tone (P2) requires that the tones of outputs and inputs at the corresponding word-final positions have identical values.

If this kind of constraint is relevant in our present study of native English speakers' MC tonal productions, we can predict that the error rates of the tonal items would have some

error patterns strongly influenced by positional effects, either at the word-initial position (P1) of the di-syllabic test words, or at the word-final position (P2).

The “right-prominent” pattern characteristic of Mandarin and Min dialects, mentioned in Hoa (1983) and Duanmu (1993a, 1995) probably leads to the “regressive” dissimilation in OCP (Chen 2000). “Right-prominent” generally refers to the effects of tonal stability of the tones at the right part of a sequence of tones, usually at the word- or phrase-final positions. For example, when OCP affects a disyllabic word and results in a tonal change in the sequence, it is usually the tone at the left position making the change. This kind of effect is found in the data of some Chinese dialects. However, in our study of English speakers’ Mandarin tonal productions, some interesting patterns are found: positional effects appear in the dataset and that they are contingent upon the tone types. The positional effects are examined in the whole dataset and in Set (A) respectively in §3.5.1 and §3.5.2. The conclusion and a discussion will be offered in §3.5.3.

3.5.1 The positional effects in the whole dataset and the statistical analysis

In the whole dataset, as we know, there are 1067 errors in total. Amongst this number, there are 253 errors of Tone 1, 495 errors of Tone 2 and 319 errors of Tone 4. The numbers are also shown in Chart 5 in section 3.4.1.

Among the 253 errors of T1 in the whole dataset, there are 103 errors in P1, which is 21.59% out of all T1s in the same positions, and 150 errors in the P2, which is 32.05% out of all T1s in P2.

Among the 495 errors of T2 in the whole dataset, there are 231 errors in P1 which is 48.71% out of the total T2 at P1, and 264 errors in P2 which is 56.53% out of all T2 in P2.

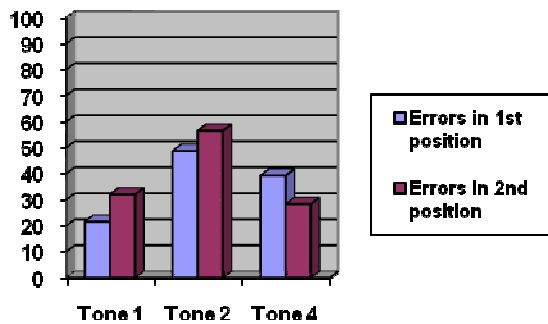
Among the 319 errors of T4 in the whole data set, there are 186 errors in the P1 which is 39.24% out of the total T4s at this position, and 133 errors in P2 which is 28.3% out of total T4s at P2.

Table 3-5: Errors in P1 and P2 in whole dataset

	Total errors in whole dataset	Errors in the first position (P1)	Percentages (P1)	Errors in the second position (P2)	Percentages (P2)	Statistical results
Tone 1	253	103	21.59%	150	32.05%	P1<P2 (p<.001)
Tone 2	495	231	48.71%	264	56.53%	P1<P2 (p<.05)
Tone 4	319	186	39.24%	133	28.3%	P1>P2 (p<.001)

Chart 3-7 demonstrates the error percentages of the three tones in different positions.

Chart 3-7:



The FREQ procedure is used to analyze the positional effects for these three tone types in the whole dataset. In the whole dataset, for T1, the error rate in P1 is significantly lower than that in P2 according to Fisher's Exact Test ($p=3.126E-04$ or 0.0003126, $p<.001$). It means that T1 at word-initial position is more resistant to change than at word-final position. For T2, like T1, the error rate in P1 is significantly lower than that in P2 ($p=0.0187$, $p<.05$). Different from T1 and T2, the error rate of T4 at P1 is significantly higher

than that at P2 according to the Fisher's Exact Test ($p=4.422\text{E-}04$ or 0.0004422 , $p<.001$). It means that the T4s at word-final position is more likely to be resistant to change than at the word-initial positions.

3.5.2. The positional effects in Set (A) and the statistical analysis

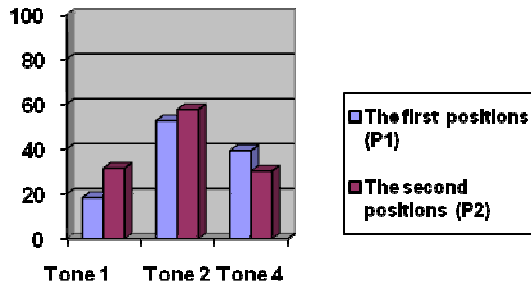
In Set (A) there are 117 Tone1 errors, 259 Tone 2 errors, and 164 Tone 4 errors.

Table 3-6 shows the error rates of Tone 1, Tone 2 and Tone 4 in dataset (A). The examination of PF in Set (A) will help us to determine if there is any interaction of PF and OCP in this study.

Table 3-6: Error rates of T1, T2, and T4 at P1 and P2 in dataset (A)

Tones	The first positions (P1)			The second positions (P2)			Statistical result
	Error numbers	Total number of this tone	Percentage	Error numbers	Total number of this tone	Percentage	
Tone 1	44	240	18.33%	73	232	31.47%	$P1 < P2$ ($p=0.0013, p<.05$)
Tone 2	123	234	52.56%	136	235	57.58%	$P1 ? P2$ ($p=0.2658, p>.05$)
Tone 4	93	237	39.24%	71	235	30.21%	$P1 > P2$ ($p=0.0427, p<.05$)

Chart 3-8: Error rates of T1, T2 and T4 at P1 and P2 in Set (A)



Note that the total numbers of each tone in this chart do not include the 50 inconsistent judgments. Thus the total numbers for each tone vary here. The percentages are calculated from each error number out of the total number of each tone at the specific positions.

The above table and chart show that, for T1, the error rate at P1 is significantly lower than that at P2. For T4, the error rate at P1 is significantly higher than that at P2. The results of T1 and T4 are exactly the same as the contrasts in the whole dataset in §3.5.1. We cannot tell if the error rates of Tone 2 at the two positions have significant difference in Set (A).

We can conclude that, T1 is more likely to be resistant to change at the first position than at the second position of disyllabic words in both set (A) and the whole dataset. T4s, however, are more likely to be resistant to change at the second position than at the first position in both Set (A) and the whole dataset. As for T2, it has the same situation as T1 in the whole dataset, but there is no positional effect found in the dataset (A). In other words, the present study finds that native English speakers, who do not have any tone language background, prefer to maintain the high level tone at the beginning of the utterance, but maintain the high falling tones at the end of disyllabic utterances.

Two related positional faithfulness constraints based on the finding in this section are: Ident-T1-P1 and Ident-T4-P2. These two constraints will be formally defined and discussed in the next chapter.

3.5.3 Discussion

According to the findings we get from the data in the present study, there is no obvious “right-prominence” pattern characteristic of native English speakers’ tonal productions. Interestingly, the positional effects seem to be contingent upon the tone types. In

short, the word-initial syllables are preferred bearers of level tones while word-final syllables are preferred bearers of contour tones, especially the Tone 4 in this study.

3.5.3.1 About the interference from English intonation

A question probably would arise whether the ‘preferred’ tone combination, i.e., T1+T4, may stem from the nature of intonation in English. Some observations, which I will discuss as follows, support this point of view. However I will argue that this is not all due to the interference from English intonation, but probably some other factors cause this preferred tone pattern.

As White (1981) found, first, the mechanisms of stress in English and MC are extremely different and many observed English-speaking learner’s errors can be directly attributed to this. Stress in English is associated with pitch height; because of this, the English speaker will hear or produce the Mandarin high tones, such as T1 and T4 which begin at a high pitch level, as stress. As White (1981) claimed, this is one of the reasons why English speakers prefer producing T1 and T4 whenever the situation indicates the use of stress. Secondly, White (1981) found that “the basic intonational contour, the simple, declarative sentence, usually begins on a low, unstressed syllable, builds to the nuclear (or stressed) syllable, and then glides off” in English. This pattern may account for the low-tone initial syllable and gliding final syllable, which sounds very like T4, heard when English

However, the two observations above are probably not good reasons for the preference for T1+T4 combination in this study. For the first observation, it might seem likely that the speakers in the present study take the test words as stressed since the disyllabic test words are the only item distinguishing all test sentences and then they produce the two

high-pitched tones T1 and T4. There are two reasons why this is probably not the case. One reason is, if this was the case, there would be other possible tonal combinations of these two high pitched tones such as T1+T4, T1+T1 and T4+T4, which also could be used to express the stress. However, the only preferred tonal combination is just T1+T4, but not other tone combinations. The second reason is that, the potential for these two high-pitched tones to express 'stress' is probably not the only reason for the English speakers to produce T1 and T4. According to the Tonal Markedness Scale we discussed in the previous section, T1 and T4 are less marked than other tones, such as the rising T2 (see the general TMS definition in Hyman & VanBik 2004). Thus, there seems be other factors affecting the choice of T1+T4 by the English speakers.

For the second observation, although our test sentences are all declarative sentences, it's not a good reason why English speakers like T1+T4 sequence, because the intonation domain in English does not well match the domain of the tone sequences in Mandarin. The declarative intonation covers the whole English sentence; however, the T1+T4 sequence in this study are two tones occurring on two full syllables which are embedded in the middle of MC sentences. In addition, even if the intonation pattern of English and tone combination pattern occur in similar domains, this could not explain the fact that the preceding syllable in the preferred tone sequences is T1 but not T2, since usually the declarative English sentence begins with initial low pitch level, and it would rise up approaching the high pitch level of the falling tone.

In summary, interference from English intonation probably influences the Mandarin productions of English speakers in the domain of sentences to some degree, but it seems that the preferred tone patterns of the disyllabic tone sequences of T1+T4 in this study cannot be

entirely accounted for by the influence of English intonation. There are some other factors, such as other general phonological reasons or constraints, causing the preferred tone sequence pattern. These phonological constraints are probably the TMS, which suggests that T1 and T4 are much easier to produce than other tones, and PF constraints which require the language learners to be faithful to the underlying tone, in particular, to keep T1 in the word-initial positions and T4 in the word-initial positions. I also will mention another positional markedness constraint *T4-Initial which probably is another factor accounting for the preferred tone pattern in §4.2 in next chapter.

This situation also shows that, English-speaking learners' choice of the preferred tonal combination is independent from the speakers' native language. These rules cannot be imported from the target-language grammar either, because that MC has no regular, productive rule of positional faithfulness. We will continue to discuss the source of interlanguage grammars in the next chapter.

3.5.3.2 About positional licensing of contour tones

About the positional faithfulness constraints, J Zhang (2004) has claimed that “phrase-final syllables and syllables in shorter words are preferred bearers of contour tones, even though they are usually not privileged for other phonological contrasts. Word-initial syllables, which have been shown to selectively license many other phonological contrasts (Steriade 1993,1995; Beckman 1997), do not show up on the list of privileged contour tone bearer” because “the positional licensing behavior of contour tones is ... sensitive to the phonetic properties that are crucial to contour tones per se, namely duration and sonority.” The findings in the present study regarding the distribution of T4 is compatible with the

claims of contour tone distributions by J Zhang (2004), and the present study provides further findings on the distribution of the high level tone in the English speakers' productions of MC. It seems that while the English speakers are more likely to keep contour tones at the phrase-final syllables, they prefer to keep level tones at the phrase-initial syllables.

3.6 About Obligatory Contour Principle (OCP)

As I mentioned in Chapter 1, the Obligatory Contour Principle (OCP) is a 'family' of markedness constraints. The general definition of OCP is first proposed by Leben (1973) as stated in (8a). There may be different OCP constraints for different features such as high tones, whole tones, etc. In this section, I assume the dominating OCP constraint in this study is OCP (whole tone) (Yip, 2002). This constraint is stated in (8b). The whole tone refers to an entire tone borne by a full syllable instead of the component tones, as mentioned in Chapter 1, within a contour tone.

- (8) a. Obligatory Contour Principle: Adjacent identical elements are prohibited.
- b. OCP (whole tone): Two identical whole tones at adjacent syllables are prohibited.

In this section, two error-driven studies of OCP will be offered. I will first examine whether the OCP (whole tone) is relevant based on the contrast of the error rates of each test tone in Set (A) and Set (B) and offer the statistical analysis. After that, I will examine the data from a different perspective and also offer the statistical analysis based on the new examination. A summary will be given in the last part of this section.

3.6.1 The contrast of error rates in Set (A) and Set (B) and the statistical analysis

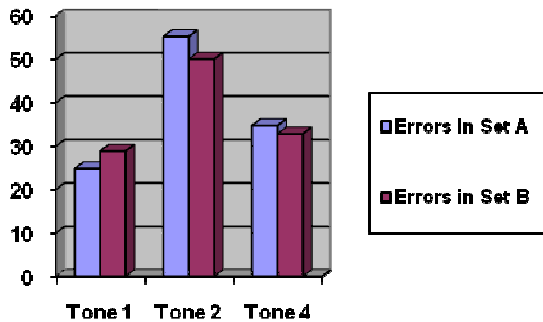
As we know, the test words in Set (A) are disyllables where the two syllables have the same tone types, such as T1-T1, T2-T2, and T4-T4. The two syllables in each disyllabic word of Set (B) are different in tone type, such as T1-T2, T2-T4, etc. If we want to test whether the speakers dislike two identical tones in a row, i.e., the Set (A) items, a very convenient way is to determine whether the error rate of Set (A) is significantly higher than that of Set (B). This is our first method to test OCP in this study. If the error rate of Set (A) is significantly higher than that of Set (B), it means English speakers do not like two-identical-tone sequences, but prefer those two-non-identical tone sequences, i.e., the Set (B) items.

There are 540 errors in Set (A) and 527 errors in Set (B). Table 3-7 offers the error numbers and error rates for each tone in Set (A) and (B) respectively.

Table 3-7: Error numbers and error rates for each tone in Set (A) and (B)

Tones	Set	Error numbers	Total number of tone in this Set	Percentage
Tone 1	A	117	472	24.8%
	B	136	473	28.8%
Tone 2	A	259	469	55.2%
	B	236	472	50%
Tone 4	A	164	472	34.7%
	B	155	472	32.8%

Chart 3-9: Error rates of each tone in Set (A) and Set (B)



Note that the total numbers of each tone in specific sets in this chart do not include the 50 inconsistent judgments. Thus the total numbers for each tone vary here. The percentages are calculated from each error number out of the total number of each tone in the specific sets.

The GENMOD Procedure of SAS system is used in statistical analysis for this part.

For T1, there is no significant difference between the error rates of Set (A) and Set (B) ($p=0.0999$, $p>.05$). For T2, there is no significant difference between the error rates of Set (A) and Set (B) either ($p=0.1522$, $p>.05$). And likewise, for T4, we do not find any significant difference between the error rates for Set A and B ($p=0.6388$, $p>.05$).

The statistical results based on the contrast of error rates of Set (A) and (B) are incompatible with the hypothesis. Closely examining the testing above, we would find this result is not reliable. A new study of OCP and the argument for the new result is provided in the following section 3.6.2.

3.6.2 A new perspective and discussion

Closely examining data sets (A) and (B), it is found that the error numbers actually are not the only factor affecting the results of OCP testing. Substitution in the domain of disyllabic words also plays a very important role in determining whether OCP is relevant in the dataset.

The errors of the tonal productions simply tell us only that the speakers did not produce each individual tone correctly, but it cannot tell us if English speakers really dislike two adjacent identical tones. The study should not only focus on the errors in the domain of individual tones, but in the domain of the two tone combinations. The reason is that the

speakers can have the same number of errors in Set (A) and Set (B), but they may have made totally different numbers of “identical tone sequences” and “non-identical tone sequences” in their actual incorrect tonal productions. For example, suppose a speaker makes two errors for the two syllables in Set (A), so that, for a target word with the tone combination T2+T2, the speaker wrongly produced T4+T4 sequence instead. This speaker does make 2 individual tone errors in Set (A), but it does not mean that the speaker dislike two adjacent identical tones because the speaker actually produced T4+T4. The real reason for such a substitution may be that this speaker likes T4 but not T2. The same situation would take place in Set (B). The errors occurring in Set (B) may be identical tone pairs and also non-identical tone pairs. From this point of view, the error types in the domain of disyllabic utterance need to be closely re-examined.

Here I use the ‘identical tone combination’(ITC) to refer to those di-syllabic words that bear two identical tones on the syllables, such as T1+ T1, T2+T2, T3+T3, and T4+T4 in speakers’ actual productions (i.e., within errors). The ‘non-identical tone combinations’ (NITC) refer to those di-syllabic words that bear two different tones on the syllables, such as T1+T2, T3+T4, etc, in the mis-productions made by these speakers.

The close examination of error types will provide more information about the errors and the number of ITC and NITC. Since Set (A) and Set (B) have the exact same size of sample, we can test whether the OCP is relevant in our data by comparing the number of NITC found in the actual tonal productions of Set (A) and the number of ITC found in the actual tonal productions of Set (B). If the former is significantly bigger than the latter, it is very likely that speakers dislike two adjacent identical tones, and vice versa.

I first analyze the error types in the domain of the disyllable combinations. For Set (A), there are three error types:

Type 1 is: one of the target tones in the di-syllabic word is produced wrongly, and it leads to a NITC in the actual tonal production. For example, a T1+T1 combination is produced as T2+T1. In this case, one error is counted, and also one NITC.

Type 2 is: two tones of this test word are both produced wrongly, and it leads to a NITC. For example, a T1+T1 sequence is produced as T2+T4. In this case, there are two errors, but only one NITC.

Type 3 is: two tones of the test words are both produced wrongly, but it leads to another ITC. For example, a T1+T1 combination is produced into T4+T4. In this case, there are two errors, but there is no NITC.

For Set (B), there are four error types:

Type 1 is: one of the target tones in the disyllabic word is changed, and it still maintains its NITC status. For example, a T1+T2 sequence changes into T1+T4. In this case, one error is counted, but there is no count of ITC.

Type 2 is: one of the target tones in the test word is changed, but it changes into an ITC. For example, a T1+T2 combination changes into T1+T1, or T2+T2. In this case, one error is counted and one ITC is counted.

Type 3 is: two tones of the word are both changed, but the production is still a NITC. For example, T1+T2 combination is changed into T3+T1. In this case, there are two errors, but there is no ITC.

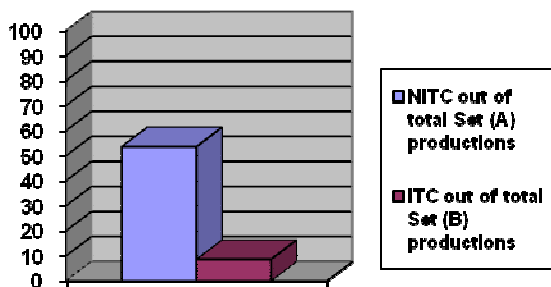
Type 4 is: two tones of the word are both produced wrongly, and the combination changes into an ITC. For example, T1+T2 combination is changed into T4+T4. In this case, two errors are counted, but there is only one ITC.

For Set (A) the Type 1 and Type 2 cases are added up for the total number of NITC, while for Set (B) the Type 2 and Type 4 are counted for the total number of ITC. It is found that there are 386 NITC in Set (A) but only 62 ITC in Set (B). Table 3-8 and Chart 3-10 show the distribution of NITC and ITC in Set (A) and (B). Note that each count of NITC and ITC is actually a two-tone sequence.

Table 3-8 Distribution of NITC and ITC in Set (A) and (B):

Set	Total tone productions	Total errors in each set	The numbers of tonal items in INTC and NTC	Percentages of INTC and NTC out of total tone productions	Percentages of INTC and NTC out of total errors
Set (A)	720	545	(NITC) 386 (193 pairs)	53.6% (386/720)	70.8% (386/545)
Set (B)	720	527	(ITC) 62 (31 pairs)	8.6% (62/720)	11.8% (62/527)

Chart 3-10: NITC out of Set (A) productions and the ITC out of Set (B) productions.



The FREQ Procedure, GENMOD Procedure and GEE Model are used in the statistical analysis. It is found that the number of NITC in the actual productions of Set (A) is significantly higher than the number of ITC in the actual productions of set (B) ($p < .001$).

Based on the study of NITC and the ITC within the errors of this study above, the English native speakers seem to dislike two-identical-tone sequences. According to the statistical analysis, the OCP (whole-tone) is relevant in the present dataset. We thus will use this constraint in our grammar analysis in Chapter 4.

3.7 Summary

This chapter mainly addressed the three core questions for present study. The thesis first gives a brief discussion of the inconsistent judgments since some of the statistical analyses exclude them in this chapter. After that, the thesis focuses on the pre-test in § 3.2 and offers a discussion on the two types of errors in the main experiment in §3.3. §3.1 to §3.3 actually clear the way for the discussion of the three core questions in next three sections. From § 3.4 to §3.6, the various numbers or subtotals of errors related to TMS, PF and OCP are reported. Then, the thesis provides the statistical analysis and draws conclusions about whether these constraints are relevant in our present study. The conclusions are, the TMS (*T2>>*T4>>*T1) definitely plays a role in the dataset; PF is also relevant but it has different effects contingent on tone types such that word-initial position is a privileged position for T1 while word-final position is privileged for T4; and also, OCP is also relevant in our dataset based on the argument from a new perspective since there are more ‘non-identical-tone-combinations’ in the productions of Set (A) than the ‘identical-tone-combinations’ in the outputs of Set (B).

CHAPTER 4

SUBSTITUTIONS AND GRAMMAR ANALYSIS

In Chapter 3 we look at the error distributions and then test the three phonological constraints based on the study of various error numbers and statistical analysis. In this chapter, we will go a step further to examine the error patterns, particularly, the substitutions for the test tones. After we identify the most frequent substitutions for the tones, we will analyze them in the framework of Optimality Theory and then discuss the tonal grammars of these English speaking learners based on our findings in Chapter 3 that all these three phonological constraints are relevant in the dataset. That is, the OT part will show how these phonological constraints and even more constraints construct the tonal grammars of our subjects.

In this chapter, we will first look at the individual error patterns and substitutions for T1, T2 and T4 respectively in §4.1. Then we will move on to the substitutions in the bigger domain, disyllabic words, in §4.2. The analysis of the tone grammar of English speaking learners is offered in §4.3. §4.4 is a summary of Chapter 4.

4.1 Error patterns and substitutions for individual tones

In order to have an overall look at the substitutions, the total numbers of occurrences in Table 4-1, 4-2 and 4-3 refer to actual occurrences of the productions, including all

inconsistent judgments and out-of-inventory mis-productions. The substitutions also count those inconsistent judgments and out-of-inventory mis-productions. For “Item codes” in the Table 4-1, 4-2 and 4-3, still, the first two numbers like “11” are the tone types of the two syllables in test words, “11” representing “T1-T1”; the following is the target tone type for this monosyllabic tonal item and the “P1” and “P2” represent the position of this tonal item, with ‘P1’ representing the word-initial position and ‘P2’ representing the word-final position. Please see Table 2-5 in §2.6 of Chapter 2 for more clarification of the item codes. The last rows of the three tables show the total number of mis-productions of this tone, and also, the ranking of the substitutes for this tone.

4.1.1 Error pattern and substitutions of Tone 1

Table 4-1 shows the substitutions of all Tone1s occurring in 6 different positions.

Table 4-1 Substitutions of T1.

Item Codes	Set	Total number of occurrences	Number of mis-productions		Three highest-frequency substitutions (Percentages out of error numbers for each item)						Numbers of substitution types
			number	% out of total occurrences	1 st Tone type and its counts	%	2 nd Tone type and its counts	%	3 rd Tone type and its counts	%	
11-T1-P1	A	240	44	18.3%	T3 (20)	45.5%	T2 (10)	22.7%	?33 (7)	15.9%	5
11-T1-P2	A	240	81	33.8%	T4 (57)	70.4%	T3 (10)	12.3%	*T1/T4 (3)	3.7%	11
12-T1-P1	B	120	28	23.3%	T4 (12)	42.9%	T3 (7)	25%	T2 (4)	14.3%	6
21-T1-P2	B	120	40	33.3%	T4 (26)	65%	?33 (6)	15%	T3 (3)	7.5%	7
14-T1-P1	B	120	34	28.3%	T3 (15)	44.1%	T4 (10)	29.4%	T2 (6)	17.6%	6
41-T1-P2	B	120	41	34.2%	T4 (20)	48.8%	T3 (7)	17.1%	?31 (4)	12.2%	9
Tone 1	A & B	960	268	27.9%	T4(131)> T3(62)>T2(23)> ?33(21)>?31(4) The ranking is based on the subtotals of all substitutes						

Here are several findings we can get from Tone 1 mis-productions.

First, T4 is the most frequent substitute for T1 in positions of 11-T1-P2, 12-T1-P1, 21-T1-P2 and 41-T1-P2. The ranking of substitutes shows that T4 is dramatically more frequent than other substitutions. However, it is interesting that T4 does not appear in the list of three highest frequent substitutes at position 11-T1-P1, although it serves as the most frequent substitute for position 12-T1-P1. It seems that speakers really dislike having T4 at the word-initial position when it is followed by another T1, but speakers prefer having T4 at the word-initial position when it is followed by T2. We will look at the substitutions of the T1-T1 and T1-T2 sequences in the domain of di-syllables in section 4.2 to verify this finding.

Secondly, 11-T1-P1 and 14-T1-P1 have T3 as the highest frequent substitute. Actually Tone 3 serves as substitute for T1 much more frequently than T2. As the ranking of substitutes shows, T3 serves as a substitute for T1 for 63 times but T2 only 23 times. Furthermore, both 11-T1-P1 and 14-T1-P1 are located at the word-initial positions.

Thirdly, the middle level tone is a comparative high frequent substitute for T1. It keeps the contour shape correctly but is wrong in register. English native speakers seem to pay more attention to the contour shapes than the registers.

Fourthly, 11-T1-P2 and 41-T1-P2 have the most types of substitutions, and both of these two items are at the second position of disyllabic words.

4.1.2 Error pattern and substitutions of Tone 2

This section focuses on the error pattern and substitutions of Tone 2. Table 4-2 shows the substitutions of Tone 2 in Set (A) and Set (B).

Table 4-2 Substitutions of T2:

Item Codes	Set	Total number of occurrences	Number of mis-productions		Three highest-frequency substitutions (Percentages out of error numbers for each item)						Numbers of substitution types
			number	% out of total occurrences	1 st Tone type and its counts	%	2 nd Tone type and its counts	%	3 rd Tone type and its counts	%	
22-T2-P1	A	240	129	53.8%	T3 (47)	36.4%	T1 (44)	34.1%	T4 (22)	17.1%	8
22-T2-P2	A	240	141	58.8%	T4 (59)	41.8%	T1 (44)	31.2%	?31 _{low} T4 (13)	9.2%	11
12-T2-P2	B	120	60	50%	T4 (59)	48.3%	T1 (10)	16.7%	T3 (6)	10%	10
21-T2-P1	B	120	55	45.8%	T3 (20)	36.4%	T1 (18)	32.7%	T4 (8)	14.5%	5
24-T2-P1	B	120	53	44.2%	T1 (18)	34%	T3 (16)	30.2%	T4 (14)	26.4%	5
42-T2-P2	B	120	76	63.3%	T1 (23)	30.3%	T4 (20)	26.3%	T3 (14)	18.4%	12
Tone 2	A & B	960	514	53.4%	T1(157)>T4(152)>T3(115) > ?31(29)=?33(29) The ranking is based on the subtotals of all substitutes						

We can get the following findings from Tone 2 mis-productions.

First, T1, T4 and T3 all serve as the most frequent substitute for Tone 2 twice. Most speakers substitute T2 with T1 when the target T2 occurs at the position of 24-T2-P1 and 42-T2-P2. Most speakers substitute T2 with T4 when the target T2 occurs at the position of 22-T2-P2 and 12-T2-P2, which are both located at the second syllables of the test words. Most speakers substitute Tone 2 with Tone 3 when the target T2 occurs at 22-T2-P1 and 21-T2-P1, which are both located at the first syllable of the test words. This is compatible with the occurrence of Tone 3 when it substitutes for Tone 1 in Section 4.1.1.

Second, different from Table 4-1, both “low-T4” and the “middle tone” serve as the fourth frequent substitute for Tone 2.

Third, the items 22-T2-P2, 12-T2-P2 and 42-T2-P2 have much more substitution types than other items and these three items all happen to be located at the second position of the disyllabic test words.

4.1.3. Error pattern and substitutions of Tone 4

This section focuses on the error pattern and substitutions of Tone 4. Table 4-3 shows the substitutions of Tone 4:

Table 4-3: Substitutions of T4

Item Codes	Set	Total number of occurrences	Number of mis-productions		Three highest-frequency substitutions (Percentages out of error numbers for each item)						Numbers of substitution types
			number	% out of total occurrences	1 st Tone type and its counts	%	2 nd Tone type and its counts	%	3 rd Tone type and its counts	%	
44-T4-P1	A	240	96	40%	T1 (57)	59.4%	T3 (23)	24%	T2 (7)	7.3%	10
44-T4-P2	A	240	76	31.7%	T1 (39)	51.3%	T3 (13)	17.1%	?33 (9)	11.8%	10
14-T4-P2	B	120	38	31.7%	?31 low T4 (10)	26.3%	?33 (9)	23.7%	T3 (8)	21.1%	7
41-T4-P1	B	120	48	40%	T3 (17)	35.4%	T1 (13)	27.1%	?31lowT4 (3)	6.3%	8
24-T4-P2	B	120	29	24.2%	T1 (10)	34.5%	T3 (7)	24.1%	?33 (4)	13.8%	7
42-T4-P1	B	120	48	40%	T3 and T1 (15)	31.3%			T2 (12)	25%	8
Tone 2	A & B	960	335	34.9%	T1(138)>T3(83)>T2(30) >?33(26) > ?31lowT4(23) The ranking is based on the subtotals of all substitutes						

We can get the following findings from the Table 4-3.

First, both T1 and T3 serve as the most frequent substitutes three times in Table 4-3. It is obvious that T1 is the most frequent substitute for T4, and the next is T3 according to the ranking of substitutes.

Second, T3, as in both Table 4-1 and 4-2, substitutes T4 most frequently in word-initial position, such as 41-T4-P1, 42-T4-P1 and 44-T4-P1.

Third, as for the error patterns of T1, T2 serves as the substitute for T4 much less frequently than T1 and T3.

Fourth, as in Table 4-2, the middle tone and “Low-T4” also serve as substitutes for T4 frequently. It’s noticeable that “Low-T4” is the most frequent substitute for the item 14-T4-P2. Speakers seem to keep the correct contour shape but wrong register when they try to produce the target T4.

Fifth, the items in Set (A) have the biggest number of substitution types.

4.1.4 Summary

Based on the findings above, we have further findings from the error pattern and substitution of these three tones:

First, error patterns and substitutions of each tone verify our findings regarding TMS and PF in Chapter 3. Comparing the numbers of substitutes for each tone, T1 is the most frequent substitute whose frequency of occurrence reaches 295 in total, and T4 is the second most frequent substitute whose frequency of occurrence is 283. T2 is the least frequent substitute for errors whose frequency of occurrence is 53 in total. This ranking perfectly corresponds to the findings we got from the error rate contrasts in §3.4, showing that the

Tonal Markedness Scale (i.e., *T2>>*T4>>*T1) works in the English speakers' MC tonal productions.

Second, T3 is very noticeable when it serves as substitute for all test tones since its total frequency of occurrence is as many as 260, which is much more than T2. It seems that T3 is a more 'unmarked' tone type than T2 since it's more frequently used as a substitute when errors occur. If we make a further proposal and put this finding in the Tonal Markedness Scale, the scale could be proposed as *T2>>*T3>>*T4>>*T1.

Previous research on first language acquisition only reveal that the Mandarin high-level and falling tones (i.e., T1 and T4) are acquired before the rising and dipping tones (i.e., T2 and T3) and the rising and dipping tones are substituted for each other throughout the tone acquisition process (Li & Thompson, 1977). Yue-Hashimoto (1980) claimed that for her subject, it was more difficult to acquire T2 than T3, but the claim is derived based only on the study of one subject. As for other studies on second language acquisition (see Table 1-3 in Chapter 1), only Miracle (1989) and Sun (1998) claim that T3 is easier for English speaking learners in the mode of productions than Tone 2 since students make more mistakes with T2 than T3. However, Sun (1981) has another claim with the acquisition order of T2 and T3 switched which seems to be incompatible with her first claim. Miracle (1989) actually does not derive an acquisition order of tones, but just lists the error numbers of tones. In addition, the numbers of occurrences of the four tones in his experiment are not the same; it seems that the error rates of T3 and T4 are almost the same, and he actually did not point out a contrast between the error rates of T3 and T2. The finding about the T3 and T2 in the present study has a very clear contrast between the substitution frequency ranking of T3 and T4, and also of T3 and T2. This finding might shed some light on the study of first language

acquisition of T3 and T2 since we found that for English native speakers, T3 is more ‘unmarked’ than T2, and they might acquire T3 prior to T2.

In addition, T3 substitutes for the test tones mostly in the word-initial positions. It seems that English native speakers prefer to have a low tone at the beginning of the words as compared to the end of the words.

Third, middle-tone and Low-T4 also substitute the test tones very frequently. The Middle-Tone substitutes for T1 21 times, T2 29 times and T4 26 times. The Low-T4 substitutes for T1 4 times, T2 29 times and T4 23 times. It seems that Middle-Tone is a very popular substitute probably because it’s very easy for speakers to produce a tone in the middle zone of their f0 range. Another probable reason for the Middle-tone serving as substitute for Tone1 and the Low-T4 serving as substitute for T4 is that English native speakers pay more attention to the tone shapes than to the tone registers, and the high pitch of T1 and the starting point of T4 is not comfortable for English native speakers, so they adjust the pitch values and make it lower. This is compatible with the finding of Chen (1974) that the relative pitch range of Chinese is wider than that of English. In an oscillograph study, it was determined that “the pitch range of Chinese speakers was 1.5 times wider than the pitch range of English speakers” (Chen 1974). Both word-level and sentence-level pitch were tested. Based on this finding, it is not strange that English speakers prefer producing middle level pitch sounds, like the ‘33 middle tone’ and ‘low- T4’ in our study.

4.2 The error patterns and substitutions for disyllabic tone combinations

This section looks at the error patterns and substitutions in the domain of disyllabic tone combinations. After the numbers and the rankings of substitutions are presented in

§4.2.1, these patterns will be analyzed in the framework of Optimality Theory to look at the tone grammars of the subjects with no tonal language background and only 5 months experience studying MC.

Table 4-4 shows the three most frequent tone productions for disyllabic tone sequences, including the correct productions. The numbers of substitution types are also provided in the table.

Table 4-4 Most frequent tone productions for disyllabic tone combinations

Set	Target tone combinations	Numbers of target tone combinations	Productions						
			Most frequent production	%	The second most frequent production	%	The third most frequent production	%	Numbers of substitution types
Set (A)	T1+T1	240	T1+T1 (128)	53.3 %	T1+T4 (53)	22.1%	T3+T1(16)	6.7%	23
	T2+T2	240	T2+T2 (73)	30.4 %	T1+T4 (21) T3+T1 (21)	8.8% 8.8%	T4+T4(17)	7.1%	36
	T4+T4	240	T4+T4 (105)	43.8 %	T1+T4 (36)	15%	T4+T1(31)	12.9 %	31
Set (B)	T1+T2	120	T1+T2 (53)	44.2 %	T1+T4 (24)	20%	T1+T1(4) T1+T3(4) T4+T2(4)	3.3% 3.3% 3.3%	25
	T2+T1	120	T2+T1 (48)	40%	T3+T1 (18)	15%	T2+T4(10)	8.3%	21
	T1+T4	120	T1+T4 (63)	52.5 %	T3+T4 (10)	8.3%	T4+T4(8)	6.7%	20
	T4+T1	120	T4+T1 (57)	47.5 %	T3+T1 (13)	10.8%	T4+T4(11)	9.2%	25
	T2+T4	120	T2+T4 (53)	44.2 %	T1+T4 (15)	12.5%	T3+T4(11) T4+T4(11)	9.2% 9.2%	20
	T4+T2	120	T4+T2 (38)	31.7 %	T4+T1 (14)	11.7%	T4+T4(10)	8.3%	28

Observing the second most frequent productions (since the first most frequent productions are always the true tone combinations), or the most frequent substitutes, we can get the following findings.

First, there is no T2 serving as a substitute for the target tones. T1 serves as the substitute 5 times, T3 4 times, and T4 1 time at the word-initial position in the substitutions; T1 serves as the substitution at the word-final position 4 times, and T4 6 times in the substitutions.

Second, the most frequent substitute tonal combinations are ‘T1+T4 and ‘T3+T1’ in the column of most frequent substitutes. ‘T1+T4’ serves as the most frequent substitute 4 times (for T1+T1, T2+T2, T4+T4, and T1+T2); ‘T3+T1’ serves as the most frequent substitute 3 times (for T2+T2, T2+T1, T4+T1); T3+T4 one time (for T1+T4), and ‘T4+T1’ one time (for T4+T2). These substitute tone combinations tell us again that T3s are preferred to be at the word-initial position, and they are preferred to be followed by tones with high f0 starting points (i.e., T1 and T4). This finding motivates two particular constraints for our analysis within OT in next section. One is a positional markedness constraint that requires “no T3 at word-final positions” (*T3-Final), and the other is “Identical registers cannot occur on adjacent syllables” (OCP-register). I will formally define these two constraints in §4.3.1.

Third, there are some faithfulness effects we can identify from the table: many of the most frequent substitutes keep T1 at the word-initial position and keep T4 at the word-final position from the underlying forms. For example, for the target T1+T1, T4+T4, T1+T2, T1+T4 and T2+T4 combinations, all T1s at word-initial position and T4s at word-final position are kept unchanged. Based on the finding here and our discussion about the distribution of level tones and contour tones in §3.5.3 of Chapter 3, we propose two

positional faithfulness constraints, *Id-T1-Initial* and *Id-T4-Final*. We will formally define the two constraints and use them in the grammar analysis within OT in §4.3.

Fourth, rather than the effects of positional faithfulness we found above, an asymmetric phenomenon about T4 as substitute instead presents an effect of a positional markedness constraint. In the most frequent substitutions, it is clear that T4 is never found to substitute any non-T4 tone targets at word-initial position but substitutes several non-T4 tones at word-final position, as in T1+T1, T2+T2, T1+T2, T4+T1, etc. This is not about faithfulness effects since the underlying tones are not T4s, but about positional markedness effects. Based on this finding, we speculate a specific positional markedness constraint for this study which is **T4-Initial* which means ‘no T4 at the word-initial position’. We would find that this constraint is crucial in the tableau of 4-2 where the T1+T4 substitutes T2+T2.

Fifth, there is no two-identical-tone combination that serves as the most frequent substitute. It seems that OCP(whole tone) is relevant in the domain of most frequent substitutes. However, we still can find some two-identical-tone combinations in the column of ‘the third most frequent productions’ and they are ‘T4-T4’ and ‘T1+T1’.

Sixth, remember that we found that T4 serves as the substitute for individual T1 in the position of 11-T1-P1 and 12-T1-P1 along with the very different pattern that speakers really dislike T4 substituting T1 when it is followed by another T1 (i.e., at the position of 11-T1-P1) but prefer substituting T1 with T4 when it is followed by T2 (i.e., at the position of 12-T1-P1). Now looking at the asymmetry in the domain of disyllable sequences (Table 4-4), we can find that the asymmetry is not obvious since there are only 4 substitutes (3%) of ‘T4+T2’ for the target T1+T2 sequence. It seems that the T4 is the most frequent substitute for

individual T1 in the position of 12-T1-P1, but it does not mean it really likes being followed by T2 instead of T1 in the disyllabic sequences.

4.3 Error pattern analysis in OT

In this section, I will examine the error patterns, especially the most frequent substitute tonal combinations, in the framework of Optimality Theory. I will discuss the relevant constraints in §4.3.1 first, and then determine the grammars of the most frequent substitutes for the test tone combinations of Set (A) in §4.3.2 and those of Set (B) in §4.3.3. In §4.3.4 I will briefly discuss the grammar of the correct productions, i.e., the most frequent productions. With the grammars of most frequent substitutes and the correct productions at hand, I will compare these grammars and have a discussion in §4.3.5.

It should be noted that the actual interlanguage grammar is more complicated. For each subject, he or she probably employs different kinds of grammars since the subject may produce correct productions for some target tones, and also mis-productions which either serve as the most frequent substitutions or less frequent substitutions, as we've seen in Table 4-4. The grammars we discuss in this section only use the related constraints to model the grammar of the most frequent substitutions. By analyzing the grammar of the most frequent substitutions, we can reveal the originally inactive constraints since they would control the substitute productions, especially the most frequent substitutions. However, we will provide a discussion of a fuller picture of interlanguage grammar in §4.3.5.

This thesis assumes that the Mandarin native speakers' grammatical tonal productions are the underlying forms, and the most frequent substitutes are the surface forms. All four tones within the Chinese tone inventory appear in the column of most frequent substitutes, so

we also assume all the combinations of T1, T2, T3 and T4 are the candidates. Since no Middle-tone and Low Tone4s are found in the pool of most frequent substitutes, the two out-of-inventory ‘tones’ are excluded from our analysis in this chapter.

In the following analysis, we will see that while the correct productions have faithfulness constraints at the top of the ranking, that some lower ranked constraints, such as OCP, become visible (i.e., move to the top of the ranking) when faithfulness constraints must be violated in the incorrect productions and these faithfulness constraints then will be ranked lower.

4.3.1 Constraints

According to our discussion and conclusions in Chapter 3 that the TMS, PF and OCP are all relevant in our study, we will integrate these three constraints in the process of determining our subjects’ tonal grammars. In addition to these three main constraints, we also need to use some other constraints that we have mentioned in the previous sections.

Markedness Constraints we will use in the analysis below are:

(9) Markedness constraints

a.OCP-(whole tone) (Yip, 2002):

Identical whole tones cannot occur on adjacent syllables/morphemes.

A pattern with the same whole tone at the two positions, such as Tone1+Tone1 [+U, hh][+U, hh], violates this constraint.

b.OCP-register:

Identical registers cannot occur on adjacent syllables/morphemes. So, a tonal pattern with the same register feature at the two positions, such as Tone1+Tone 4[+U,hh][+U,h] violates this constraint because they have the same register value [+U].

c. Tonal Markedness Scale (cf., Hyman & VanBik, 2004): *T2>>*T4>>*T3>>*T1

Tone 2 is more disfavored than Tone 4 than Tone 3 than Tone1.

Tone 2:(+U, lh) σ . No high rising contours. Give a ‘*’ to any occurrence of T2.

- *Tone 4: $*(+U, hl) \sigma$. No high falling contours. Give a '*' to any occurrence of T4.
- *Tone 3: $*(-U, ll) \sigma$. No low tones. Give a '*' to any occurrence of T3.
- *Tone 1: $*(+U, hh) \sigma$, No high level tones. Give a '*' to any occurrence of T1.

d. *Tone4-Initial (*T4-I):

No high falling contours at the word-initial positions. Give a '*' to any T4 at word-initial position.

e. *Tone3-Final (*T3-F):

No low tone at the word-final positions. Give a '*' to any T3 at word-final position.

(9d) and (9e) are positional markedness constraints, justified in section 4.2.

Faithfulness constraints we will use in the analysis in OT are:

(10) Faithfulness constraints

a. Ident-tones (Id-T):

A whole tones in the output and its correspondent in the input must have identical values. Give a '*' to any output tone which is not faithful to the correspondent input tone.

b. Ident-T1-Initial (Id-T1-I):

Tone 1 in the word-initial position in the output and its correspondent in the input must have identical values. Give a '*' to any output Tone which is not faithful to the input Tone1 at word-initial position.

c. Ident-T4 –Final (Id-T4-F):

Tone 4 in the word-final position in the output and its correspondent in the input must have identical values. Give a '*' to any output tone which is not faithful to the input Tone4 at word-final position.

4.3.2 The grammar of the most frequent substitutes for items of Set (A)

Table 4-4 shows that the most frequent substitute for a T1+T1 sequence is T1+T4.

The most frequent substitutes for a T2+T2 sequence are T1+T4 and T3+T1. And, the most frequent substitute for T4+T4 is still T1+T4. We found the productions share two grammars

at this point. I will analyze the sub-grammars for each substitute first, and provide a summary at the end of this section.

4.3.2.1 For the target T1+T1

Most English speaking subjects substitute T1+T1 sequence with T1+T4 sequence.

Tableau 4-1 shows how T1+T4 sequence defeats other candidates.

Tableau 4-1: T1+T4 substitutes T1+T1

T1+T1	OCP- (whole tone)	*T4- I	*Tone 2	Id-T1- I	*T3	*T4	*T1	OCP- reg	Id- Tones
→ T1+T4						*	*	*	*
T1+T1	*!						**	*	
T2+T2	*!		**	*				*	**
T4+T4	*!	*		*		**		*	**
T1+T2			*!				*	*	*
T2+T1			*!	*			*	*	*
T4+T1		*!		*		*	*	*	*
T2+T4			*!	*		*		*	**
T4+T2		*!		*		*		*	**
T1+T3					*!		*		*
T3+T1				*!	*		*		*
T2+T3			*!	*	*				**
T3+T2			*!	*	*				**
T3+T4				*!	*	*			**
T4+T3		*!		*	*	*			**f

The ranking of constraints in Tableau 4-1 is:

OCP-(whole tone), *T4-I, *T2, *T3, Id-T1-I >> *T4, *T1, OCP-reg, Id-Tones

4.3.2.2 For the target T2+T2

Most English speaking subjects substitute T2+T2 with T1+T4. Tableau 4-2 shows how

T1+T4 defeats other candidates when the underlying form is T2+T2:

Tableau 4-2 :T1+T4 substitutes T2+T2:

T2+T2	OCP (whole tone)	*T4- I	*T 2	*T3	*T4	*T1	OCP-reg	Id-Tones
→ T1+T4					*	*	*	**
T1+T1	*!					**	*	**
T2+T2	*!		**				*	
T4+T4	*!	*			**		*	**
T1+T2			*!			*	*	*
T2+T1			*!			*	*	*
T4+T1		*!			*	*	*	**
T2+T4			*!		*		*	*
T4+T2		*!	*		*		*	*
T1+T3				*!		*		**
T2+T3			*!	*				*
T3+T2			*!	*				*
T3+T4				*!	*			**
T4+T3		*!		*	*			**
T3+T1				*!				**

For Tableau 4-2, the ranking of constraints is: OCP-(whole tone), *T4-I, *T2, *T3 >> *T4, *T1, OCP-reg, Id-Tones. In this tableau we can see that the positional markedness constraint *T4-I is crucial in ruling out the candidate T4+T1.

The T3+T1 sequence has the same number of substitutes for T2+T2. Tableau 4-3 shows how T3+T1 defeats other candidates when the underlying form is also T2+T2.

Tableau 4-3: T3+T1 substitutes T2+T2

T2+T2	OCP- (whole tone)	*T4-I	*T3-F	*Tone 2	OCP- reg	*T3	*T4	*T1	Id- Tones
→ T3+T1						*		*	**
T1+T1	*!				*			**	
T2+T2	*!			**	*				**
T4+T4	*!	*			*		**		**
T1+T2				*!	*			*	*
T2+T1				*!	*			*	*
T4+T1		*!			*		*	*	**
T2+T4				*!	*		*		*
T4+T2		*!			*		*		*
T1+T3			*!			*		*	**
T2+T3			*!	*		*			*
T3+T2				*!		*			*
T3+T4						*	*!		**
T4+T3		*!	*			*	*		**
T1+T4					*!			*	**

The ranking of constraints in Tableau 4-3 is:

OCP(whole tone), *T4-I, *T3-F, *T2, OCP-reg >> *T3>> *T4, *T1, Id-Tones

Thus, based on the results of the constraint rankings of Tableau 4-2 and Tableau 4-3, there are two rankings for most frequent substitutes of T2+T2 sequence. They are “OCP-(whole tone), *T4-I, *T2, *T3>> *T4, *T1, OCP-reg, Id-Tones”, and “OCP (whole tone), *T4-I, *T3-F, *T2, OCP-reg >> *T3>> *T4, *T1, Id-Tones”. The only difference between the two rankings are the positions of *T3 and OCP-reg such that for the substitute T1+T4, *T3 dominates OCP-reg, and for the substitute T3+T1 OCP-reg dominates *T3.

4.3.2.3 For the target T4+T4

Most English speaking subjects substitute T4-T4 sequence with T1+T4. Tableau 4-4 shows how the T1+T4 sequence defeats other candidates when the underlying form is T4+T4.

Tableau 4-4: T1+T4 substitutes T4+T4

T4+T4	OCP- (whole tone)	*T4- I	*T2	Id-T4-F	*T3	*T4	*T1	OCP- reg	Id- Tones
→ T1+T4						*	*	*	*
T1+T1	*!			*			**	*	**
T2+T2	*!		**	*				*	** *
T4+T4	*!	*				**		*	
T1+T2			*!	*			*	*	**
T2+T1			*!	*			*	*	**
T4+T1		*!		*		*	*	*	*
T2+T4			*!			*		*	*
T4+T2		*!		*		*		*	*
T1+T3				*!	*		*		** *
T3+T1				*!	*		*		** *
T2+T3			*!	*	*				** *
T3+T2			*!	*	*				** *
T3+T4					*!	*			*
T4+T3		*!		*	*	*			*

The ranking of constraints in Tableau 4-4 is: OCP-(whole tone), *T4-I, *T2, Id-T4-F, *T3>> *T4, *T1, OCP-reg, Id-Tones.

4.3.2.4 Summary of two grammars for Set (A)

Here I excerpt the rankings of each Tableau as:

Tableau 4-1 is: OCP-(whole tone), *T4-I, *T2, *T3, Id-T1-I >> *T4, *T1, OCP-reg, Id-Tones

Tableau T4-2 is: OCP-(whole tone), *T4-I, *T2, *T3 >> *T4, *T1, OCP-reg, Id-Tones

Tableau 4-3 is: OCP(whole tone), *T4-I, *T3-F, *T2, OCP-reg >> *T3 >> *T4, *T1, Id-Tones

Tableau 4-4 is:

OCP-(whole tone), *T4-I, *T2, Id-T4-F, *T3 >> *T4, *T1, OCP-reg, Id-Tones.

It seems that, although the sub-grammars in Tableau 4-1, 4-2 and 4-4 vary a little bit, they still can share one grammar. The ‘total’ grammar of the most frequent substitute for above three tableaus is: OCP-(whole tone), *T4-I, *T3-F, Id-T1-I, Id-T4-F, *T2 >> *T3 >> *T4, *T1, OCP-reg, Id-Tones.

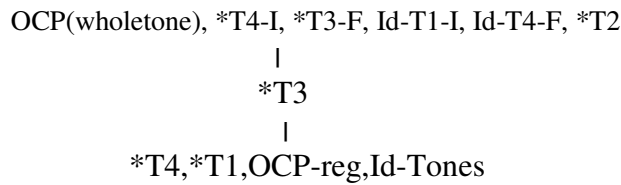
The substitute T3+T1 for target T2+T2 is a little different from other grammars, it is:

OCP(whole tone), *T3-F, *T2, OCP-reg >> *T3 >> *T4, *T1, Id-Tones.

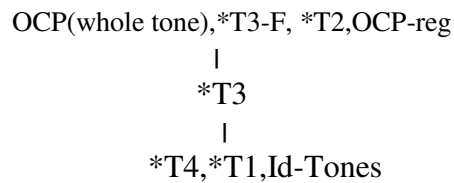
Comparing the two grammars we get using Hasse diagrams:

(11) Grammar 1 of Set (A):

(Accounts for T1+T4 serving as the substitute for T1+T1, T2+T2, T4+T4)



(12) Grammar 2 of Set (A): (Accounts for T3+T1 serving as the substitute for T2+T2)



In the rankings of constraints for the grammar of most substitutes for Set (A), we can find that OCP-(whole tone) constraints, the Positional markedness constraints (i.e., *T4-I, *T3-F) and two positional faithfulness constraints (i.e., Id-T1-I, Id-T4 -F) are always at the top of the ranking. What's more, the TMS is also very obvious and the constraints in this scale crucially rule out those candidates that were not eliminated by the other markedness and faithfulness constraints. The Faithfulness constraint 'Id-Tones' is at the bottom of the rankings. To generalize the two grammars, we can find that the following partial grammar is shared by the two rankings: OCP (whole tone), *T4-I, *T3-F, Id-T1-I, Id-T4-F, *T2 >> *T3 >> *T4, *T1, OCP-reg, Id-Tones

4.3.3 The grammars of the most frequent substitutes for items of Set (B)

There seem to be two grammars shared by the most frequent substitutes for items of Set (B) too. The first type of grammar (Grammar 1) is shared by the sub-grammars of the substitutes of T1+T2, T2+T4 and T4+T2; the other type of grammar (Grammar 2) is shared by the sub-grammars of the substitutes of T2+T1, T1+T4, T4+T1.

4.3.3.1 Grammar 1 in Set (B)

Grammar 1 is based on the sub-grammars of the most frequent substitutes (T1+T4, T1+T4 and T4+T1) for the items of T1+T2, T2+T4 and T4+T2 in Set (B). I will use tableaux to display these rankings of constraints in this section, and offer a summary at the end.

Tableau 4-5 shows how the most frequent substitute T1+T4 defeats other candidates when the underlying form is T1+T2. Tableau 4-6 shows how the most frequent substitute T1-T4 defeats other candidates when the underlying form is T2+T4. Tableau 4-7 shows how the most frequent substitute T4+T1 defeats other candidates when the underlying form is T4+T2.

Tableau 4-5: T1+T4 substitutes T1+T2

T1+T2	OCP(whole tone)	*T2	Id-T1-I	*T3	OCP-reg	*T4	*T1
→ T1+T4					*	*	*
T1+T1	*!				*		**
T2+T2	*!	**	*		*		
T4+T4	*!		*		*	**	
T1+T2		*!			*		*
T2+T1		*!	*		*		*
T4+T1			*!		*	*	*
T2+T4		*!	*		*	*	
T4+T2		*!	*		*	*	
T1+T3				*!			*
T3+T1			*!	*			*
T2+T3		*!	*	*			
T3+T2		*!	*	*			
T3+T4			*!	*		*	
T4+T3			*!	*		*	

Tableau 4-6: T1+T4 substitutes T2+T4:

T2+T4	OCP(whole tone)	*T2	Id-T4-F	*T3	OCP-reg	*T4	*T1
→ T1+T4					*	*	*
T1+T1	*!		*		*		**
T2+T2	*!	**	*		*		
T4+T4	*!				*	**	
T1+T2		*!	*		*		*
T2+T1		*!	*		*		*
T4+T1			*!		*	*	*
T2+T4		*!			*	*	
T4+T2		*!	*		*	*	
T1+T3			*!	*			*
T3+T1			*!	*			
T2+T3		*!	*	*			
T3+T2		*!	*	*			
T3+T4				*!		*	
T4+T3			*!	*		*	

Tableau 4-7: T4+T1 substitutes T4+T2

T4+T2	OCP(whole tone)	*T2	*T3	Id-Tones	OCP-reg	*T4	*T1	*T4-I
→ T4+T1				*	*	*	*	*
T1+T1	*!			**	*		**	
T2+T2	*!	**		*	*			
T4+T4	*!			*	*	**		*
T1+T2		*!		*	*		*	
T2+T1		*!		**	*		*	
T1+T4				**!	*	*	*	
T2+T4		*!		**	*	*		
T4+T2		*!			*	*		*
T1+T3			*!	**			*	
T3+T1			*!	**			*	
T2+T3		*!	*	**				
T3+T2		*!	*	*				
T3+T4			*!	**		*		
T4+T3			*!	*				*

Examining the above three rankings:

Tableau 4-5 is: OCP (whole tone), *T2, Id-T1-I, *T3>> OCP-reg, *T4, *T1

Tableau 4-6 is: OCP (whole tone), *T2, Id-T4 -F, *T3>> OCP-reg, *T4, *T1

Tableau 4-7 is: OCP (whole tone), *T2, *T3>> Id-Tones>> OCP-reg, *T4, *T1, *T4-I.

Although they have somewhat different relevant constraints used in the rankings, they are still compatible with each other. That is, the positional faithfulness constraints (Id-T1-I and Id-T4-F) are not applied in Tableau 4-7; Id-tones could be also inserted in the first two rankings but won't cause problems. Thus, we can have a common grammar (Grammar 1) shared by the sub-grammars of these three substitutes and Grammar 1 is:

OCP(whole tone), Id-T1-I, Id-T4-F, *T2, *T3>> Id-Tones>> OCP-reg, *T4, *T1, *T4-L.

4.3.3.2 Grammar 2 in Set (B)

Grammar 2 is based on the sub-grammars of the most frequent substitutes (T3+T1, T3+T4 and T3+T1) for the items of T2+T1, T1+T4 and T4+T1 in Set (B). I will use tableaux to display these rankings of constraints in this section, and offer a summary at the end.

Tableau 4-8 shows how the most frequent substitute, T3+T1, defeats other candidates when the underlying form is T2+T1. Tableau 4-9 shows how the most frequent substitute, T3+T4, defeats other candidates when the underlying form is T1+T4. Tableau 4-10 shows how the most frequent substitute, T3+T1, defeats other candidates when the underlying form is T4+T1.

Tableau 4-8: T3+T1 substitutes T2+T1

T2+T1	OCP(whole tone)	*T2	*T3-F	OCP-reg	Id-Tones	*T3	*T4	*T1
→T3+T1					*	*	*	*
T1+T1	*!			*	*			**
T2+T2	*!	**		*	*			
T4+T4	*!			*	**		**	
T1+T2		*!		*	**			*
T2+T1		*!		*				*
T1+T4				*!	**		*	*
T4+T1				*!	*		*	*
T2+T4		*!		*	*		*	
T4+T2		*!		*	**		*	
T1+T3			*!		**	*		*
T2+T3		*!	*		*	*		
T3+T2		*!			**	*		
T3+T4					**!	*	*	
T4+T3			*!		**	*	*	

Tableau 4-9: T3+T4 substitutes T1+T4.

T1+T4	OCP(whole tone)	*T2	Id-T4-F	OCP-reg	Id-Tones	*T3	*T4	Id-T1-I
→T3+T4					*	*	*	*
T1+T1	*!		*	*	*			
T2+T2	*!	**	*	*	**			*
T4+T4	*!			*	*		**	*
T1+T2		*!	*	*	*			
T2+T1		*!	*	*	**			*
T1+T4				*!			*	
T4+T1			*!	*	**		*	*
T2+T4		*!		*	*		*	*
T4+T2		*!	*	*	**		*	*
T1+T3			*!		*	*		
T3+T1			*!		**	*		*
T2+T3		*!	*		**	*		*
T3+T2		*!	*		**	*		*
T4+T3			*!		**	*	*	*

Tableau 4-10: T3+T1 substitutes T4+T1

T4+T1	OCP(whole tone)	*T2	OCP-reg	*T3-F	Id-Tones	*T3	*T1
→T3+T1					*	*	*
T1+T1	*!		*		*		**
T2+T2	*!	**	*		**		
T4+T4	*!		*		*		
T1+T2		*!	*		**		*
T2+T1		*!	*		*		*
T1+T4			*!		**		*
T4+T1			*!				*
T2+T4		*!	*		**		
T4+T2		*!	*		*		
T1+T3				*!	**	*	*
T2+T3		*!		*	**	*	
T3+T2		*!			**	*	
T3+T4					**!	*	
T4+T3				*!	*	*	

Based on the above three rankings:

Tableau 4-8 is: OCP (whole tone), *T2, *T3-F, OCP-reg >> Id-T>> *T3, *T4, *T1

Tableau 4-9 is: OCP (whole tone), *T2, Id-T4-F, OCP-reg>> Id-T, *T3, *T4, Id-T1-I

Tableau 4-10 is: OCP (whole tone), *T2, *T3-F, OCP-reg >> Id-T>>*T3, *T4, *T1

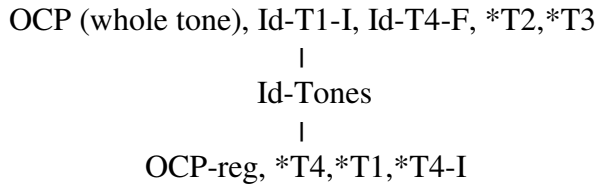
The three rankings can be merged into one ranking (Grammar 2) as follows:

OCP(whole tone), *T2, Id-T4-F,*T3-F, OCP-reg>> Id-T>> *T3, *T4, *T1, Id-T1-I

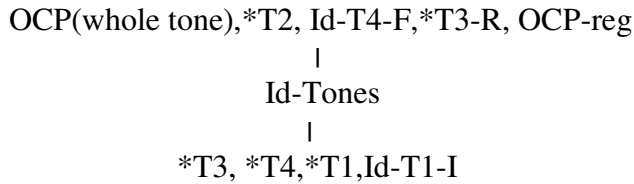
4.3.3.3 Summary of the grammars in Set (B)

Comparing Grammar 1 and Grammar 2 of Set (B) using Hasse diagrams:

- (13) Grammar 1: (Accounts for T1+T4 serving as the substitute for T1+T2 and T2+T4; and T4+1 serving as the substitute for T4+T2)



- (14) Grammar 2: (Accounts for T3+T1 serving as the substitute for T2+T1 and T4+T1; and T3+T4 serving as the substitute for T1+T4)



We found that three markedness constraints have different positions in the two rankings. In Grammar 1, OCP-reg and *T4-I are at the bottom of the ranking which means that the winning tone sequences themselves have worse performance (i.e., violates these constraints) than other candidates; and *T3 is at the top of the ranking which means that there is no T3 in any winning tone sequences in Grammar 1. Different from Grammar 1, in the

ranking of Grammar 2, *T4-I and OCP-reg are at the top while *T3 is at the bottom of the ranking, which means that the winning tone sequences don't have any T4 at the word-initial position, and the two tones of winning disyllabic words have different register values.

Furthermore, the winning tone sequences sharing Grammar 2 all have T3s at the word-initial position since, although the '*T3' is at the bottom of the ranking, another constraint '*T3-F' is at the top of ranking.

Besides these differences, the Grammar 1 and Grammar 2 of Set (B) share a lot of characteristics. Both of them have the markedness constraints of OCP (whole tone), *T2 and a positional faithfulness constraint Id-T4-F at the top of the rankings. The Tonal Markedness constraint scale keeps the same order no matter if '*T3' is at the top or at the bottom of the two rankings. To generalize the two grammars and get a ranking shared by the two grammars: OCP (whole tone), Id-T4-F, *T2, *T3-F >> Id-Tones >> OCP-reg, *T4, *T1, *T4-L, Id-T1-I.

4.3.4 The grammar of the correct productions

In this section, I provide a brief discussion of the grammar of correct productions, i.e., the most frequent productions of our English-speaking subjects, which is part of the full picture of speakers' tonal grammars.

For the correct productions of Set (A), all tones are kept in the outputs, that is, follow the faithfulness constraint 'Ident-Tones', although they obviously violate the markedness constraint OCP(whole tones), *T2, *T4, and *T1'. Thus, the grammar for the three items in Set (A) is: Id-Tones >> OCP (whole tone), *T2, *T4, *T1.

For the items of Set (B), the same, all tone sequences are perfectly kept in the outputs. That is, they follow the faithfulness constraint 'Ident-Tones'. However, they violate some

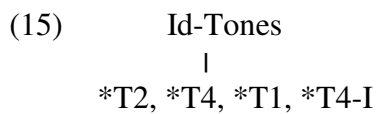
other markedness constraints like *T2, *T4, *T1, and some positional constraints such as *T4-I, etc. Thus, the grammar for the six items in Set (B) is: Id-Tones>> *T2, *T4, *T1, *T4-I.

The above two rankings are compatible with each other although some constraints are only applied in one grammar but not the other. To generalize the two rankings based on their consistent part, the grammar shared by both the correct productions of Set (A) and Set (B) is: Id-Tones>> OCP(whole tone), *T2, *T4, *T1, *T4-I.

4.3.5 Discussion

4.3.5.1 The emergence of markedness constraints

As we discussed above, we have the generalized grammar of correct productions and (15) is the Hasse diagram for it:



We also get a generalized grammar for the most frequent substitutions for Set (A) as: OCP (whole tone), *T4-I, *T3-F, Id-T1-I, Id-T4-F, *T2 >> *T3 >> *T4, *T1, OCP-reg, Id-Tones; and the generalized grammar for the most frequent substitutions for Set (B) is: OCP (whole tone), Id-T4-F, *T2, *T3-F >> Id-Tones >> OCP-reg, *T4, *T1, *T4-I, Id-T1-I. Now we can generalize the two grammars of Set (A) and Set (B) based on the consistent part of them and get an even more generalized grammar for the most frequent substitutions which is the Hasse diagram (16):

substitutions, some markedness constraints, such as OCP(whole tone), *T3-F, *T2, and also the tonal scale *T2>>*T3>>*T4>>*T1, become visible. Knowing about these constraints helps us determine the preferred tone patterns, predict the English-speaking learners' tonal mistakes, and explain the reasons why English-speaking learners make the tonal errors we listed in the previous sections.

The above analysis of the grammars by native speakers and the substitutions also help us determine that these emerging constraints are part of the Universal Grammar of tones. Note that, as we explained in Chapter 3 that, *T3-F is a present study specific constraint, therefore it is not claimed to be part of the universal grammar. The emerging of these markedness constraints is not obviously motivated by either the learners' native language (i.e., English intonation, as we discussed in Chapter 3) or the target language grammars (i.e., native Mandarin speakers' grammars) since there are no such regular, productive rules changing disyllabic tone production in MC. These patterns reveal a preference for less marked structures (i.e., the most frequent substitutions). These less marked structures, that is, the lower ranked constraints may normally have no visible effects in the native speakers' grammars, but they are still assumed to be present in the grammar. The situation focused on the circumstances in which the effects of low-ranked markedness constraints become visible is described as "the emergence of the unmarked" by McCarthy and Prince (1994). In the present study, we found that the markedness effects that are often visible in second-language acquisition of Mandarin tones also represent this kind of situation. "The changing of the rankings in the substitutions of tone combination in the direction of less marked structures is generally described as an effect of universal principles of markedness, often conceived of as part of the innate endowment provided by Universal Grammar (Epstein, Flynn &

Martohardjono,1996)” (Broselow, 1998) . It is Universal Grammar that gives the language learners constraints, such as OCP (whole tone), that are not motivated by either the target language or the native language.

4.3.5.2 A fuller picture of the interlanguage grammar

In the previous sections, we actually have presented a comparatively idealized picture of interlanguage grammar. In above grammar discussion, these grammars seem to predict that speakers will always choose two non-identical tone sequences, and non-T2 tones in the substitutions. We should note that actually, the grammar of interlanguage is much more complicated than our discussion. The fact is, some subjects produce some tones correctly, and also employ some grammars of substitutions, that is, produce some mis-productions from time to time. Furthermore, “because the movement from the native- language grammar to a grammar that more closely approximates that of target-language speakers involves re-ranking of constraints, we would expect the ranking of these constraints to be in flux.” However, “Initially, the ranking of these constraints will be as in the native language, as the learner becomes more proficient, an interlanguage grammar will develop in which the rankings of constraints more closely approximate the target-language ranking” (Broselow 1998). In our study, concerning this kind of movement, the tonal productions show some less marked forms of tonal productions as we discussed in above sections, and this indicates that these speakers have developed an interlanguage grammar that differs from both the native-language and the target-language grammars.

Some other works provide us with other ideas of modeling intra-speaker variation. The idea of Anttila and Cho (2004) states that a total ordering compatible with the grammar’s

partial ordering is selected each time the grammar is employed. The model of Grammar lattice proposed in their paper provides a potential solution for describing language variation and language change. The Gradual Learning Algorithm (Boersma and Hayes, 2001) is a constraint-ranking algorithm for learning optimality-theoretic grammars. It is claimed that this model is in some respects a development of Tesar and Smolensky's proposal (Tesar and Smolensky, 1993) in that it directly perturbs constraint rankings in response to language data. The new aspect of the Gradual Learning Algorithm is the type of optimality-theoretic grammar it presupposes: rather than a set of discrete rankings, it assumes a continuous scale of constraint strictness (Boersma and Hayes, 2001). We could try and applying these two ideas in explaining our intra-speaker variation a future study.

4.4 Summary of Chapter 4

Chapter 4 mainly looks at the substitutes for the test tones, both the substitutes for the individual tones and those for the two-tone-sequences. For the latter, we not only determine the most frequent substitutes for the tone sequences, but also analyze the related tone grammars shared by our English-speaking subjects. From these grammars, we find that, compared to the native speakers' tone grammars, some phonological constraints rear their heads and become visible. This process helps us determine the phonological reason why English-speaking subjects make tonal mistakes. In addition, these constraints are valuable because they are observed in the tonal grammars of the speakers who have no tonal language background in the past, and we propose that these emerging lower-ranked markedness constraints are part of the Universal Grammar.

CHAPTER 5

CONCLUSION AND FUTURE DIRECTIONS

5.1 Conclusion

First, the experiments and statistical analysis reported in this thesis addressed the three questions we asked at the beginning of this paper: whether OCP, PF, and TMS apply in English-speaking learners' tonal productions, and how they interact in their tonal grammars. We found that, TMS (*T2>>*T4>>*T1) works in our corpus as determined by the statistical analysis based on the error rates of the test tone types. Also, the data of the substitutions of the test tones verify this result. The PF has different effects according to different tone types, such that English speaking learners prefer changing T1 at the word-final position and changing T4 at the word-initial position. It is not clear whether the PF works on the T2 pairs. As for the OCP, based on our analysis of the two types of substitutions of two-tone-sequences (i.e., two-identical-tone-combinations and non-identical-tone-combinations) we found that OCP (whole tone) also works in our corpus.

Second, based on our findings regarding these three constraints, the grammars of the most frequent substitutes were determined in the framework of Optimality Theory and the rankings show how these three constraints interact in English-speaking learners' grammars. We found that, different from the grammar of correct productions where the Faithfulness constraint 'Ident-Tones' dominates many markedness constraints, the grammar of the

substitutes clearly makes those masked markedness constraints visible. The generalized grammar of the most frequent substitutions shared by the English speaking learners is:

- (16) OCP(wholetone), *T3-F, Id-T4-F, *T2
 |
 OCP(reg), *T3, Id-Tones
 |
 *T4, *T1

The changing rankings in the grammars of substitutions from the grammars of correct productions (which is the same as the Mandarin native speakers' grammar) and the emergence of the markedness constraints in substitutions' rankings represent the situation of "the emergence of the unmarked". These language learners' modification of underlying representations and learners' tendency to favor less marked structures in interlanguage grammars can be seen simply as effects of universal constraints. This explains how the English speaking learners of Mandarin create their own grammars which are not motivated by either the native- or target-language grammars.

Third, the grammars of substitutes in our study also conform perfectly to Yip (2002)'s analysis on the issue of Tianjin Tone sandhi and Mandarin Tone3 sandhi where Yip claims that the grammar of Tianjin Tone sandhi and Tone3 sandhi is "FaithPrWdHead, OCP>> Faith>> *T"(Yip, 2002).

The PF constraint Id-T4-F perfectly reflects the existing T4 sandhi rule in the tonal grammar of Mandarin native speakers. As I mentioned in Chapter 1, in the grammar of Mandarin native speakers, certain morphemes (such as *yi* and *bu*) change their T4s when they occur at the word-initial positions in T4 pairs.

Now we have a picture of comparison of the underlying forms of tone pairs, the existing tonal grammars of Mandarin native speakers, and our English-speaking learners' tonal grammars on tone pairs:

Table 5-1: Three forms of the MC tone pairs

Underlying forms	T1+T1	T2+T2	T3+T3	T4+T4
Mandarin speakers	T1+T1	T2+T2	T2+T 3	<i>yi, bu:</i> T2+T4
				Others: T4+T4
English-speaking learners	T1+ changed (to T4?)	?	N/A	Changed+T4 (to T1?)
	has similar grammars with Mandarin speakers' T3 sandhi			

It seems that changing the contour tones at word-initial positions instead of word-final positions (in both T4 pairs made by Mandarin speakers and English-speaking learners) conforms to the claim about the distribution of contours in J. Zhang (2004). We found for level tones, changing the level tones at the word-final positions is more preferred by these non-tonal language speaking subjects. More research is need to verify if this is part of Universal Grammar. OCP is, as we know, widespread in African languages, but we cannot see it in Mandarin native speakers' tonal grammar except for that of T3 sandhi. We found the OCP is relevant in our corpus made by the English-speaking learners. It seems that OCP actually works in both Asian languages and African languages, although it is masked by some faithfulness constraint in existing grammars of Mandarin speakers.

5.2 Future Studies

We leave some problems open for future studies.

Examining Table 5-1, if we take the current grammar of the native Mandarin speakers (the second row) as only one stage of the many historical development stages of Mandarin tone grammars, we could propose that, if there is some changes involving tone pairs in the future and the changes are influenced by Universal Grammar, the grammar of English learners is probably the image of the future Mandarin tone grammar. A future longitudinal study is needed to test this proposal.

Another finding we get from our study is the status of T3 in acquisition ordering. According to the present study, it seems that T3 is more ‘unmarked’ than T2 based on the very clear contrast between these two tones. It would shed some light on the research on T2 and T3 since much previous research holds that T2 and T3 are very similar and they are very difficult to distinguish by both children (Li & Thompson 1976 among others) and adults (Moore & Jongman 1997 among others). It’s probably because the default form of T3 is just a low level tone, instead of a low falling and rising (or, dipping tone). Yip (2002) and Xu (1997) actually assume that the tonal representation of T3 is just ‘L’ but they give no theoretical discussion. I support their proposal and would do more research on the case of T3.

We also found in the present study that the Middle-Tone and Low-T4 serve as substitutes often and a discussion of the reasons why English-speaking learners like these out-of-inventory ‘tones’ is offered in the section 4.1.4 of Chapter 4. However, since they are not the most frequent substitutes for the disyllabic tone sequences, they are excluded from the analysis in the frame work of OT. I also leave the study of Middle-Tone and Low-T4 open for future research.

About modeling grammars for the intra-speaker variation in Optimality Theory, we mentioned two other ideas in Chapter 4, and we also leave the application of these ideas in explaining the interlanguage tonal grammar for the future.

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