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Tonal Assignment in English Loanwords in Mandarin Chinese

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by

Eleanor Rachel Glewwe

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ABSTRACT OF THE THESIS

Tonal Assignment in English Loanwords in Mandarin Chinese

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Eleanor Rachel Glewwe

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Professor Kie Zuraw, Chair

English words borrowed into Mandarin Chinese must be assigned tones. This thesis investigates which properties of the English form influence the tones English loanwords receive in Mandarin. The investigation is two-pronged, consisting of a corpus study of English borrowings in Mandarin and an online loanword adaption experiment with Mandarin speakers. The two approaches yield different results. The corpus study, which builds on earlier work by Wu (2006), points to English voicing as the primary determinant of tone in Mandarin: English sonorant and voiced obstruent onsets tend to trigger rising tone assignment while English voiceless obstruents tend to trigger high tone assignment. This is hypothesized to be due to the F0 perturbations caused by voiced and voiceless onsets. In the corpus study, English stress plays only a minor role in Mandarin tonal assignment. In contrast, stress is the most important determinant of tone in the loanword adaptation experiment. Stressed syllables are most often

adapted with high tone, with final stressed syllables also showing a strong preference for falling tone. The voicing effect found in the corpus is not found in the experiment. These results suggest that tonal adaptation depends on overall English intonation rather than small F0 perturbations. I discuss possible reasons for the two studies' conflicting results, as well as what they reveal about the broader picture of Mandarin tonal adaptation.

The thesis of Eleanor Rachel Glewwe is approved.

Bruce Hayes

Megha Sundara

Kie Zuraw, Committee Chair

University of California, Los Angeles

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Tonal Assignment in English Loanwords in Mandarin Chinese

1. Introduction

Loanword adaptation is the process whereby word forms from a source language are modified to conform to the phonotactics and other well-formedness requirements of the borrowing language. When a language with lexical tone borrows a word from a language without this feature, it must assign the word one or more tones. This is the case for the tone language Mandarin Chinese when it borrows words from English, which lacks tone. While previous studies have examined the segmental adaptation of English loanwords in Mandarin, relatively little work has been done on how these words are assigned tones. This paper sheds light on this question through a corpus study of English borrowings in Mandarin and an online loanword adaptation experiment with Mandarin speakers.

The corpus study and the experiment yield rather different results. Analysis of the loanword corpus points to English voicing as the primary determinant of tone in Mandarin: English sonorant and voiced obstruent onsets tend to trigger rising tone assignment while English voiceless obstruents tend to trigger high tone assignment. This is hypothesized to be due to the F₀ perturbations caused by voiced and voiceless onsets. English stressed syllables are more likely to be adapted with high tone, but the influence of stress is secondary to that of voicing. In contrast, stress emerges as the most important determinant of tone in the loanword adaptation experiment. Stressed syllables are most often adapted with high tone, with final stressed syllables also showing a strong preference for falling tone. This pattern suggests that tonal adaptation imitates English intonation. Meanwhile, the voicing effect found in the corpus is not present in the experiment. After presenting each study separately, I discuss what they may mean when taken together.

Section 2 gives an overview of previous research on tonal assignment in English loanwords in Chinese languages and describes the relevant phonological characteristics of English and Mandarin. Section 3 is dedicated to the corpus study and Section 4 to the experiment. Section 5 concludes the paper.

2. Background

Research on the tonal assignment of English loanwords in Mandarin is scant, but there is a body of literature reaching back to the 1970s on their tonal assignment in Cantonese. This section summarizes past findings for Cantonese and Mandarin. A common thread running through this line of research is the relationship between English stress and lexical tone in Chinese languages. There is evidence, especially in Cantonese, of mappings from English stress levels to Chinese tones, so I start by reviewing the properties of English stress. I also present the Mandarin tonal system and the consonant inventories of Mandarin and English.

2.1 English Stress

The phonetic correlates of English stress include duration, pitch, and amplitude (loudness). English stressed syllables tend to have longer duration, higher F₀, and greater amplitude than unstressed syllables (Cutler 2008). These correlates are also properties by which Chinese tones can be distinguished, so it is conceivable that a Chinese language may develop stress-to-tone correspondences.

English stress is also closely bound up with vowel quality. Vowels in unstressed syllables are reduced, so only a small number of English vowels are considered to occur in unstressed position. The presence of a vowel that is not a member of this small set indicates that a syllable bears stress. Following Dong (2012), I assume that English loanwords in Mandarin are borrowed from British English, so here and in the corpus study English transcriptions reflect British

pronunciation. The vowels that can occur in unstressed syllables are /ə/, /ɪ/, and, in word-final open syllables only, /i/ and /əʊ/ (I also allow an open syllable whose nucleus is /i/ to count as unstressed if it is the penult and the final syllable is unstressed and has the nucleus /ə/). Of these, /ə/ is the only vowel that exclusively occurs in unstressed position; the other vowels can also bear stress.

In the corpus study, I distinguish three levels of stress in English: primary, secondary, and unstressed. Every English word has a primary-stressed syllable, and longer words may also have one or more secondary-stressed syllables. For example, in the word *eucalyptus* [ju:.kə.'lɪp.təs], primary stress falls on the penult and the initial syllable bears secondary stress.

2.2 Cantonese

Hao (2009) provides a thorough review of tonal assignment rules for English words borrowed into Cantonese. While Hao cautions that there are exceptions related to word class and specific English consonants, it appears that, overall, tonal assignment in Cantonese follows stress-to-tone principles. Cantonese syllables corresponding to English syllables bearing stress (both primary and secondary) receive a high tone. Epenthetic syllables, which are inserted in the adapted form to preserve consonants from English clusters while complying with Cantonese phonotactics (e.g. the first syllable in [kej LL lim HH] from English *cream* (Hao 2009:46)), receive a low tone. Cantonese syllables corresponding to post-tonic unstressed syllables in English also receive a low tone, while those corresponding to pre-tonic unstressed syllables are assigned a mid tone. This asymmetry may stem from unstressed syllables being more salient in pre-tonic position than in post-tonic position. The tonal assignment of English loanwords in Cantonese thus seems to imitate English prosody. As we will see, this does not appear to be the case in Mandarin, at least in attested loanwords. Stress-to-tone principles will turn out to have

little influence in the corpus study of English-to-Mandarin loanwords, though they will emerge in the adaptation experiment.

2.3 Mandarin

2.3.1 The Tones of Mandarin

Mandarin has four lexical tones, which are exemplified in Table 1. The second column expresses the tones' pitch contours in citation form using numbers that represent five pitch levels (1 being the lowest and 5 being the highest). The third column shows how the four tones are written in Pinyin. Note that Pinyin tone diacritics differ from IPA notation. This paper marks Mandarin tone as in Pinyin.

Table 1: Mandarin Tones

Tone	Chao Digits	Example Word in Pinyin	Example Word Meaning
First (high)	55	mā	mother
Second (rising)	35	má	hemp
Third (falling-rising)	214	mǎ	horse
Fourth (falling)	51	mà	scold

Mandarin also has a fifth “neutral” tone which appears on some grammatical morphemes and the final syllables of some compounds and whose realization is context-dependent.

In addition to differing in pitch contour, the four Mandarin tones also vary in duration when pronounced in citation form. First and fourth tones are the shortest, second tone is longer than these two tones, and third tone is the longest of all (Whalen & Xu 1992).

The Mandarin tones do not occur with equal frequency in the lexicon. Table 2 gives the type frequency by word of the four tones based on a lexicon of 111,417 words. For instance, since the character 可 occurs in 66 words with the pronunciation *kě*, it contributes 66 types to the frequency of third tone in Mandarin. Word frequency in texts is not taken into account. By this

measure, fourth tone is the most frequent tone in Mandarin, followed by first tone, second tone, and finally third tone, which is borne by less than one fifth of the syllables in Mandarin words.

Table 2: Type Frequency by Word of Mandarin Tones
(From Tsai (2000))

Tone	Tone 1	Tone 2	Tone 3	Tone 4
Frequency	29,914 (26.9%)	27,501 (24.7%)	20,406 (18.3%)	33,527 (30.1%)

There exist tonotactic gaps in Mandarin, meaning that not all syllables occur with every tone. For instance, the syllable *dán* does not exist; there is no character with this pronunciation. Wu (2006) points out that some of these tonotactic gaps are systematic. In particular, syllables with unaspirated onsets (like *dan*) tend to lack second tone pronunciations. With a handful of historical exceptions (see Wu 2006), Mandarin does not fill tonotactic gaps in loanword adaptation, so the only syllables (including tone) that are available for rendering borrowings are those that are already attested in the native lexicon. This has consequences for both segmental adaptation (Miao 2005, Dong 2012) and tonal adaptation.

2.3.2 The Consonants of Mandarin and English

The consonant inventory of Mandarin is given in Figure 1, with Pinyin symbols in angle brackets after the IPA symbols. Throughout this paper, I use Pinyin to transcribe Mandarin. When two sounds appear in the same cell, the top one is unaspirated and the bottom one is aspirated. Aspiration is contrastive in Mandarin, and the stops and affricates come in complete aspirated and unaspirated series. Voicing, on the other hand, is not contrastive; all Mandarin obstruents are voiceless.

	Bilabial	Labio-dental	Dental	Post-alveolar	Alveolo-palatal	Palatal	Velar
Stop	p p ^h <p>		t <d> t ^h <t>				k <g> k ^h <k>
Fricative		f <f>	s <s>	ʃ <sh>	ç <x>		x <h>
Affricate			ts <z> ts ^h <c>	tʃ <zh> tʃ ^h <ch>	tɕ <j> tɕ ^h <q>		
Nasal	m <m>		n <n>				ŋ <ng>
Approximant	w <w>		l <l>	ɹ <r>		j <y>	

Figure 1: Mandarin Consonant Inventory (Adapted from Dong (2012:75))

The consonant inventory of English is given in Figure 2. When two sounds appear in the same cell, the left one is voiceless and the right one is voiced. Unlike in Mandarin, voicing in English is contrastive, and, with the exception of the glottal fricative, the stops, fricatives, and affricates have complete voiced and voiceless series. While English voiceless stops and affricates have aspirated and unaspirated allophones, aspiration is not contrastive in English, unlike in Mandarin.

	Bilabial	Labio-dental	Dental	Alveolar	Post-alveolar	Palatal	Velar	Glottal
Stop	p b		d t				k g	
Fricative		f v	θ ð	s z	ʃ ʒ			h
Affricate					tʃ dʒ			
Nasal	m		n				ŋ	
Approximant	w			l	r	j	(w)	

Figure 2: English Consonant Inventory (Adapted from Dong (2012:75))

While the segmental aspect of loanword adaption is not the focus of this paper, a few observations about these two consonant inventories are warranted. English and Mandarin have a number of sounds in common, making certain segmental adaptations straightforward (e.g. English /l/ to Mandarin /l/). Naturally, adaptation is still restricted by the phonotactic gaps of Mandarin. For instance, the Mandarin velar stops cannot occur before a high front vowel; there are no characters with pronunciations like *ki* or *gi*. Perhaps the most obvious broad difference

between the two languages' consonant inventories is that English contrasts fricatives in the same places of articulation (with voicing) while Mandarin does not. Thus while the English voiced and voiceless series can be mapped onto the Mandarin unaspirated and aspirated series for stops and affricates, as seems to be the general trend in loanword adaptation, the same cannot be done for English fricatives. This will turn out to be relevant for tonal adaptation as well as segmental adaptation.

2.3.3 Previous Work on Tonal Assignment in Mandarin

Given that tonal assignment in Cantonese follows stress-to-tone principles, one might wonder whether the same holds true in Mandarin. As far as I am aware, the only corpus study previously undertaken to investigate tonal assignment in English-to-Mandarin loanwords is Wu 2006. Wu argues that Mandarin does exhibit some stress-to-tone mapping, but factors beyond English stress are at work, and overall the picture is less clear and the evidence less convincing than for Cantonese.

The loanwords in Wu's corpus were "established loans that are still in use today in Taiwan" (2006:230). She did not include any proper names because of concerns about orthographic and semantic influence on their adaptation. The exact size of her corpus is unclear. In Appendix I, she lists the disyllabic loanwords in her corpus, which number around 100, but her corpus evidently included more items since she cites examples not found in Appendix I.

Wu found that English stressed syllables that constitute monosyllabic words were adapted with falling tone (e.g. English *show* becomes Mandarin *xiù*). The initial syllables of English trochees were assigned either high or rising tone (e.g. English *curry* → Mandarin *kālǐ*; English *modern* → Mandarin *módēng*). However, her Appendix I lists numerous loanwords in

which the syllable corresponding to the initial syllable of an English trochaic word receives neither high nor rising tone, so it is clear there are exceptions, possibly many.

Wu examines more closely the tonal adaptation of stressed initial syllables in disyllabic loanwords and concludes that the choice between high and rising tone for such syllables depends on properties of their Mandarin onset consonant. Syllables beginning with obstruents in their adapted form tended to bear first (high) tone, and syllables beginning with sonorants tended to bear second (rising) tone. This pattern is consistent with evidence that sonorants may have a depressive effect on F₀ (Hombert, Ohala, & Ewan 1979). Wu also identifies aspiration as playing a role: adapted syllables with aspirated onsets were more likely to have second tone while those with unaspirated onsets were more likely to have first tone. While the effect of aspiration on F₀ is disputed, Wu cites evidence that, in Mandarin, aspiration lowers F₀ at voicing onset across all four tones. This explains why loanword syllables with aspirated onsets received second tone more often than first. However, Wu's discussion of tonal assignment and aspiration is based on just 35 syllables, only 7 of which had aspirated onsets.

Wu claims that epenthetic syllables in Mandarin loanwords receive an L tone unless the English consonant the epenthetic syllable is inserted to preserve is /s/, in which case the syllable apparently takes high tone. It is not clear whether by "L tone" Wu means falling-rising tone or any tone whose contour contains an L tone, which would also include falling tone. The latter interpretation seems more likely because both falling-rising tone and falling tone are attested in the examples of epenthetic syllables she gives. In several of her examples, though, epenthetic syllables that did not begin with /s/ received high tone. These syllables surely had not been assigned an L tone. They appear to disprove or at least weaken Wu's claim about the tonal assignment of epenthetic syllables.

In sum, Wu's study provides some evidence that stress-to-tone principles are at work in Mandarin loanword adaptation, but they are not as uniform as the ones in Cantonese. While English stressed syllables are almost universally assigned a high tone in Cantonese, the tone they received in Mandarin depended on their position and on the sonority and aspiration of the Mandarin onset they were adapted with. In Cantonese, epenthetic syllables in loanwords are assigned a low tone, but they seemed to bear a variety of tones in Mandarin. English unstressed syllables receive either mid or low tone in Cantonese depending on whether they are pre-tonic or post-tonic, but Wu made no generalizations about the tones they took in Mandarin.

Figure 3 shows a decision tree summarizing Wu's claims about loanword tonal assignment in Mandarin. Note that it represents an idealized state of affairs and that it does not cover every type of English syllable.

Chang & Bradley (2012) followed up on Wu's corpus study with an experiment in which native Mandarin speakers were asked to adapt disyllabic English nonce words (both trochees and iambs) into Mandarin. Their stimuli were designed such that every English nonce word had an expected Mandarin segmental adaptation; they avoided using English syllable structures and segments that do not have straightforward Mandarin analogs. Consequently, the English stimuli and the Mandarin adaptations always matched in syllable structure (CV or CVN) and in the sonority and aspiration (but not necessarily the voicing) of their onsets. Thus when Chang & Bradley refer to, say, the effect of aspiration on tonal assignment, they do not need to distinguish between aspiration in English and aspiration in Mandarin.

Chang & Bradley analyzed the tonal adaptations of the stressed syllables from the English nonce words and found that fourth tone was the most frequently assigned tone overall. This was likely due to another aspect of the construction of their stimuli: the speaker who

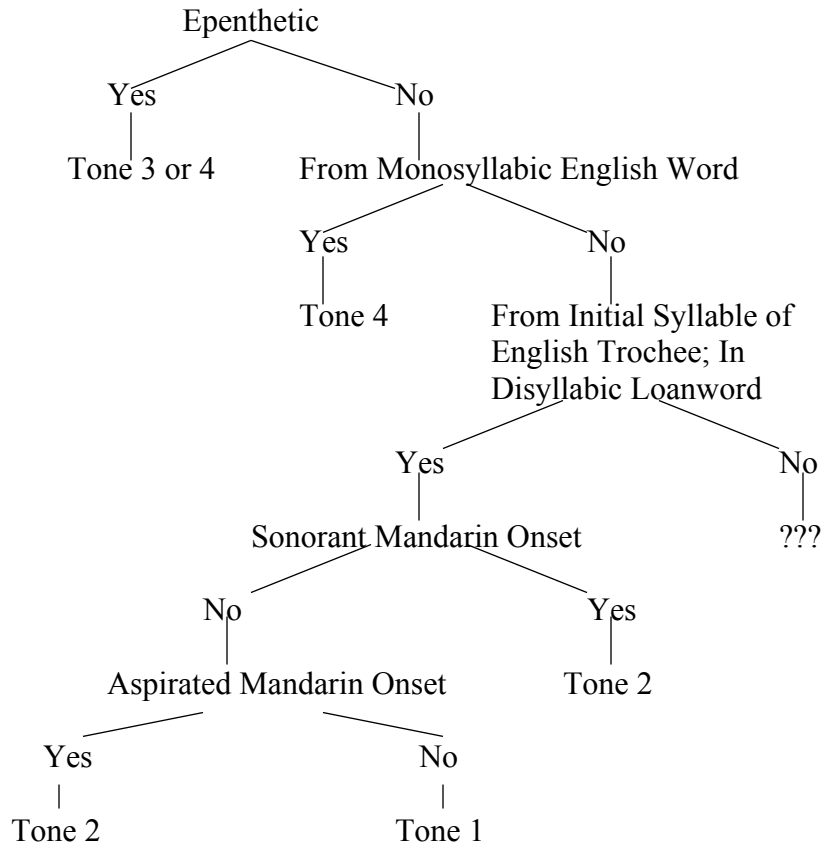


Figure 3: Decision Tree for English Loanword Tonal Assignment in Mandarin
(Based on Wu 2006)

recorded the English words was instructed to say them as if they were declarative statements in and of themselves, so the stressed syllables of the stimuli probably had falling pitch contours. Recall, though, that fourth tone is also the most frequent in the native Mandarin lexicon (see Table 2).

Chang & Bradley compared the tonal assignment of initial stressed syllables and final stressed syllables but found no major differences based on word position. Looking at just CV syllables, they observed that syllables with sonorant onsets were less likely to receive first tone than syllables with obstruent onsets and that syllables beginning with aspirated stops were more likely to receive second tone than syllables beginning with unaspirated stops. These results are

consistent with Wu's claims about the effects of sonority and aspiration on tonal assignment in loanwords.

3. A New Corpus Study

3.1 The Corpus

To further investigate the determinants of tone in English loanwords in Mandarin, I carried out a study of a larger corpus. The corpus consists of 3,660 syllables from 1,372 English loanwords in Mandarin. I assembled this corpus from several sources. The first was Dong's (2012) dissertation on segmental adaptation. Drawing from four different dictionaries, Dong compiled a corpus of 1,194 English borrowings that includes 292 place names and 577 first names. Dong's corpus accounts for about 85% of the syllables in my corpus. My second source was Wu 2006. Wu's much smaller corpus overlaps somewhat with Dong's, so it ultimately contributed only 58 syllables to my corpus. Finally, I searched the online Chinese dictionary MDBG for entries labeled "loanword." About 13% of the syllables in my final corpus come from loanwords taken from MDBG.

My corpus was originally larger, comprising syllables from 1,551 loanwords. After the initial compilation, I removed loanwords for a number of reasons. First, I excluded loanwords whose adaptations into Mandarin were influenced by semantics. Dong's (2012) Appendix E identifies a subset of loanwords in her corpus whose adaptations are segmentally distorted for semantic reasons (e.g. Mandarin 声纳 *shēngnà* from English *sonar*; although there are Mandarin syllables more phonetically similar to the first syllable of *sonar*, 声 *shēng* means 'sound'). I removed the loanwords listed in Dong's Appendix E from my corpus, as well as additional loanwords that I deemed to have been adapted according to semantic considerations. Since Dong was concerned with segmental adaptation, she only excluded loanwords in which semantics

caused the adaptation to deviate segmentally from what it would otherwise have been. Because my interest is tonal adaptation, I excluded *any* loanword whose adaptation I considered to have been shaped by semantics. Even if such a word is adapted with the expected Mandarin segments, the choice of a particular character with a desired meaning entails the assignment of a particular tone, possibly obscuring the tone the syllable might otherwise have received had the adaptation been purely phonetic. For example, *bungee (jumping)* is adapted as 蹦极 *bèngjí*, where 蹦 means ‘jump’ and 极 means ‘extreme’. The choice of these particular characters to reflect the meaning of *bungee jumping* does not cause the Mandarin adaptation to deviate segmentally from what we would expect, but it imposes tones on the Mandarin form, potentially overriding a process of tonal assignment rooted in phonetics. Thus loanwords like 蹦极 *bèngjí* were eliminated from my corpus.

Since my goal was to investigate the tonal adaptation of English loanwords in Mandarin, I also removed loanwords that were borrowed from languages other than English. Dong’s corpus already excluded such loanwords, but the loanwords from MDBG were not labeled with their language of origin. When I suspected a loanword of having entered Mandarin from a language besides English, I looked it up in the *Hanyu Wailaici Cidian* (Liu et al. 1984), a dictionary of loanwords in Mandarin that lists language of origin. This process resulted in the removal of loanwords such as 芭蕾 *bālěi* ‘ballet’, borrowed from French, and 伏特加 *fùtèjiā* ‘vodka’, borrowed from Russian.

Some English loanwords used in Mandarin were first borrowed by Cantonese speakers and then presumably adopted into Mandarin by giving Chinese characters their Mandarin

pronunciations. I wanted to exclude such words because they reflect how tonal adaptation happens from English into Cantonese and not from English into Mandarin. Again, Dong's corpus is free of such loanwords, but I suspected certain loanwords collected from MDBG to have entered Mandarin via Cantonese rather than directly from English. These loanwords exhibited noticeable segmental differences between the Mandarin adapted form and the original English form, while the Cantonese form was closer to the English form. Unfortunately, the *Hanyu Wailaici Cidian* does not indicate whether English words were borrowed into Mandarin through another dialect. I was able to confirm that certain loanwords had been borrowed into Mandarin through Cantonese because they appeared in the literature on the adaptation of English loanwords in Cantonese (e.g. Mandarin: 士多啤梨 *shìduōpīlí*; Cantonese: [si: LL tɔ: HH pɛ: HH lej LH] (Hao 2009); English: *strawberry*). When I could not find definitive proof that an English loanword in Mandarin had arrived through Cantonese but I suspected it had because of the Cantonese form's greater segmental resemblance to the English, I also excluded it from my corpus. One such loanword was Mandarin 威化 *wēihuà*, which is borrowed from English *wafer* and whose Cantonese pronunciation is [wɛi HH fa: MM].

After converting my corpus of loanwords to a corpus of loanword syllables, I removed syllables that were subject to third tone sandhi. In Mandarin, when two underlyingly third tone syllables occur in a row, the first syllable is realized with second tone. For loanword syllables subject to this rule, it is impossible to tell whether it is their surface second tone or underlying third tone that reflects how tones are assigned to English loanwords in Mandarin. Thus I removed these syllables from my corpus. There were 60 such syllables; an example is the first syllable in 法老 *fǎlǎo*, borrowed from English *pharaoh*.

Lastly, there are ten syllables in my corpus that can only bear one tone in Mandarin. They are *ā*, *fó*, *hēi*, *lè*, *miù*, *rì*, *sè*, *sēn*, *tè*, and *téng*. Since the tones these syllables receive are fixed, it often does not make sense to include them in discussions of tonal assignment. Most of the analyses are based on a reduced corpus of 3,456 syllables from which these syllables are excluded. I make it explicit when these syllables are being counted. While there are also syllables in the corpus that can bear only two or three out of the four Mandarin tones, these are always retained in the analyses.

3.2. Testing Past Claims

In this section, I attempt to replicate previous claims about Mandarin tonal assignment in English loanwords using my larger corpus. Figure 4 closely reproduces the decision tree of Figure 3, which distilled Wu's (2006) predictions about tonal adaptation, and shows at each node how syllables of the given type were adapted in my corpus. The tree gives an idea of the extent to which the corpus results align with Wu's claims. For each node with reported results, the tone that Wu proposed would be preferred is in bold. Wu considered a narrower set of syllables than is included in my corpus. For instance, her corpus contained no proper names, and some of her generalizations apply only to initial syllables of English trochees. Unless otherwise indicated, the decision tree in Figure 4 shows results for all syllables in the corpus with the relevant property. Also, several of Wu's generalizations make reference to the onset of the loanword syllable in Mandarin (that is, in adapted form) while the results given in Figure 4 refer to the onset of the loanword syllable in English. Finally, unlike in Figure 3, not all the daughter nodes in Figure 4 cover mutually exclusive sets. While the first split isolates the set of epenthetic loanword syllables, terminal nodes of the other branch may represent sets of syllables that include both

epenthetic and non-epenthetic syllables. The default is for epenthetic syllables to be included; the decision tree indicates when they are not.

Wu claimed that epenthetic syllables in English loanwords received an L tone except when the epenthetic syllable began with /s/. This would make Mandarin's overall treatment of epenthetic syllables parallel to that of Cantonese, in which epenthetic syllables receive a low tone. A low or an L tone seems like a reasonable choice for epenthetic syllables because it is the least salient in terms of pitch. Since epenthetic syllables do not correspond to full syllables in the English form, it makes sense to assign them tones that minimize their obtrusiveness. The exceptional behavior that Wu reported for /s/-initial epenthetic syllables indicates that segmental identity plays a role in Mandarin that it does not play in the more straightforward Cantonese case. Wu hypothesizes that /s/-initial syllables may receive high tone because of the acoustic properties of /s/, specifically its intensity at high frequencies³.

While Wu's exceptional rule for /s/ already complicates the picture for Mandarin epenthetic syllables, I noted in Section 2.3.3 that her own examples suggest that her generalization is still too sweeping. As shown in Figure 4, the epenthetic syllables in my corpus also show more variation in the tones they receive than Wu's generalization predicts. If we interpret Wu's claim that epenthetic syllables receive an L tone to mean that they receive either third or fourth tone, still only 46.4% of the epenthetic syllables in my corpus bear one of these tones. Of course, Wu also stated that /s/-initial epenthetic syllables take first tone, and indeed, of the 251 epenthetic syllables in Figure 4 that have first tone, 195 are instances of the syllable *sī*.

³ It is unclear whether Wu means these epenthetic syllables receive high tone because they are /s/-initial in Mandarin or because they are /s/-initial in English. If the former, she predicts all /s/-initial epenthetic syllables to bear high tone (which, in her examples, they do). If the latter, she predicts all epenthetic syllables whose onsets correspond to *English* /s/ to receive high tone (one of her examples is an exception to this) and /s/-initial epenthetic syllables that adapt other English sounds, such as /z/ or /θ/, to receive an L tone, in accordance with her general rule (none of her examples can be used to test this prediction).

Even if these syllables are excluded, though, a non-negligible proportion of the epenthetic syllables exhibit first or second tone. It appears that Mandarin, unlike Cantonese, does not have a single “least salient” tone it assigns to all epenthetic syllables. The tones of epenthetic loanword syllables will be further explored in Section 3.6. For now, it appears that Wu’s generalization is not quite right.

Another of Wu’s (2006) claims was that monosyllabic English words are adapted with fourth tone in Mandarin. This generalization is not borne out in my corpus. As seen in Figure 4, English monosyllabic words borrowed into Mandarin receive all four tones, and the most frequently assigned tone is second, not fourth. Of course, Wu’s corpus contained no proper names, which constitute the majority of my corpus. If I narrow the set of non-epenthetic loanword syllables under consideration to those that are adaptations of monosyllabic common nouns⁴, these do receive fourth tone most frequently (30.8% of the time), but it still cannot be said that English monosyllabic words borrowed into Mandarin are assigned fourth tone in general or even a majority of the time.

Wu found that English initial stressed syllables whose Mandarin adaptations began with sonorants were less likely to receive first tone and more likely to receive second tone than those whose Mandarin adaptations began with obstruents. My corpus reveals the same pattern across all syllables, though unlike Wu I consider the sonority of the English segment to which the onset of the Mandarin adapted syllable corresponds (the results are almost identical when the sonority of the Mandarin onset is considered instead, since English sonorants and obstruents are almost always mapped to Mandarin sonorants and obstruents, respectively). Looking at Figure 4, loanword syllables (including epenthetic syllables) whose onsets in Mandarin correspond to

⁴ While nearly all the English words in my corpus that are not proper names are common nouns, there are a handful of words that belong to other classes (e.g. verb, adjective). When I refer to common nouns, I am referring to all the non-proper names in my corpus, including the occasional verb or adjective.

obstruents in English most often get first tone while loanword syllables whose onsets correspond to sonorants in English most often get second tone and rarely get first tone.

I was unable to replicate Wu’s finding about the effect of onset aspiration on tonal assignment. Wu claimed that loanword syllables from English initial stressed syllables were more likely to receive second tone if their onset in Mandarin was aspirated than if it was unaspirated. Figure 4 shows the tonal assignment of loanword syllables whose onsets correspond to English stops or affricates according to the English segment’s aspiration, since the higher split by sonority was made by English sonority. We see that syllables whose onsets correspond to aspirated English sounds receive second tone much less often than syllables whose onsets correspond to unaspirated English sounds. The former syllables most often receive first tone while the latter syllables have a strong preference for second tone. This pattern runs counter to Wu’s generalization, but the comparison may not be valid since Wu and I classified syllables by aspiration in different languages. Table 3 shows the tones loanword syllables were assigned according to their onsets’ aspiration in Mandarin:

Table 3: Tones of Loanword Syllables by Onset’s Aspiration in Mandarin

Mandarin Onset’s Aspiration in Mandarin	Tone 1	Tone 2	Tone 3	Tone 4
Aspirated (N = 490)	90 (18.4%)	83 (16.9%)	135 (27.6%)	182 (37.1%)
Unaspirated (N = 764)	230 (30.1%)	296 (38.7%)	69 (9.0%)	169 (22.1%)

Even when Mandarin aspiration is considered, syllables with aspirated onsets are much less likely to bear second tone than syllables with unaspirated onsets, which is precisely the opposite of what Wu claimed. Syllables with unaspirated onsets are expected to prefer first tone, but in fact they prefer second tone.

Wu also considered a more specific type of syllable than I did in Figure 4. To better imitate the composition of her data, I excluded syllables from proper names and looked only at loanword syllables corresponding to initial primary-stressed syllables in English. Table 4 gives the tones assigned to these syllables according to the aspiration of their onsets in Mandarin:

Table 4: Tones of Loanword Syllables from Initial Stressed Common Syllables by Onset’s Aspiration in Mandarin

Mandarin Onset’s Aspiration in Mandarin	Tone 1	Tone 2	Tone 3	Tone 4
Aspirated (N = 77)	22 (28.6%)	12 (15.6%)	25 (32.5%)	18 (23.4%)
Unaspirated (N = 92)	43 (46.7%)	22 (23.9%)	13 (14.1%)	14 (15.2%)

Though the difference is less extreme, the syllables in my corpus that resemble those Wu was considering are less likely, not more likely, to receive second tone when their Mandarin onsets are aspirated. Tables 3 and 4, together with Figure 4, show that aspiration, whether in the source form or the adapted form, is associated with markedly reduced assignment of second tone.

To recapitulate, analysis of my corpus confirms Wu and Chang & Bradley’s findings on the effect of sonority on tonal assignment in loanword syllables but contradicts their findings on the effect of aspiration.

3.3 Voicing

In this section, I investigate the role of voicing in the tonal assignment of non-epenthetic loanword syllables. Voicing is underexplored in the previous literature on tones in English loanwords in Mandarin. Wu’s (2006) generalizations all referred to properties of the loanword in Mandarin, and thus she discussed aspiration, which is distinctive in Mandarin, much more than voicing, which is not. In Chang & Bradley’s (2012) experiment, there was a one-to-one mapping between English and Mandarin segments, and the authors only investigated the tonal effects of

properties shared by the English stimuli and their Mandarin adaptations. Since voiced obstruents only exist in English, the English and Mandarin segments could not match perfectly for voicing, and so Chang & Bradley did not examine the effect of voicing in English obstruents on tonal assignment in Mandarin.

Wu did briefly mention voicing with regard to the adaptation of English stop-initial syllables. In her corpus, English syllables with voiced stop onsets were adapted into Mandarin either with unaspirated stop onsets, as is expected, since English phonemically voiced stops are also unaspirated, or with aspirated stop onsets *and* rising tone. She accounted for the latter cases as follows: the lowering effect of voiced stops in English leads to the assignment of rising tone, and this in turn entails adaptation with an aspirated stop because of the lowering effect of aspiration in Mandarin. Wu observed that the two adaptation strategies for voiced stop-initial English syllables were used equally often. That is, English voiced stops were only adapted with Mandarin unaspirated stops half the time, which seems surprising.

Wu's claims about the tonal adaptation of English syllables beginning with voiced stops are partially corroborated by my own corpus. To try to replicate her findings, I consider the 459 non-epenthetic loanword syllables in my corpus whose onsets correspond to voiced stops or affricates in English. Wu discovered that only half of English voiced stop onsets were adapted with unaspirated stops in Mandarin, but in my corpus, 429 out of 459 Mandarin onsets from English voiced stops or affricates (93%) are unaspirated. The vast majority of the time, the expected segmental adaptation prevails: English voiced stops and affricates become Mandarin unaspirated stops and affricates. What about tonal assignment? The following table shows the distribution of tones in non-epenthetic loanword syllables whose onsets derive from English voiced stops or affricates, broken down by aspiration in Mandarin:

Table 5: Tones of Non-Epenthetic Loanword Syllables from English Voiced Stops and Affricates by Mandarin Aspiration (N = 459)

Aspiration in Mandarin	Tone 1	Tone 2	Tone 3	Tone 4
Aspirated (N = 29)	0	28 (96.6%)	0	1 (3.4%)
Unaspirated (N = 429)	144 (33.6%)	168 (39.2%)	46 (10.7%)	71 (16.6%)
Neither⁵ (N = 1)	0	1 (100%)	0	0

Wu found that when English voiced stops were adapted with Mandarin aspirated stops, the Mandarin syllables bore second tone, and my corpus confirms this. All but one of the 29 syllables in which an English voiced stop or affricate is adapted into Mandarin with an aspirated onset take second tone. I verified that this was not because second tone is the only tone available: for all but 6 of these 29 syllables, all four tones are available, and for all of them, at least first and second tones are available. At the same time, the one syllable with an aspirated onset in Mandarin that receives fourth tone instead of second does not do so because second tone is unavailable: the syllable is *tài*, adapting /dei/ from *Judaism*, and *tái* is a possible syllable of Mandarin.

The most common loanword syllable among these 29 cases is *qiáo* (11 cases), used mostly to adapt proper names beginning with /dʒ/ such as *Joanna*, *Georgia*, and *Jonathan*. The Mandarin unaspirated counterpart of this syllable is *jiào*. There are only two characters with the Mandarin pronunciation *jiào* while there are about a dozen with the pronunciation *qiáo* (MDBG 2014). If the lowering effect of English voicing triggers the choice of Mandarin second tone before segmental adaptation has taken place, it makes sense for *qiáo* to be chosen over *jiào* for frequency reasons. I have been assuming, however, that segmental adaption takes precedence

⁵ I.e. the loanword syllable's onset is not a stop or an affricate and therefore has no value for aspiration. The one syllable in Table 12 that is adapted with a Mandarin onset that has no value for aspiration is /dʒu/, again from *Judaism*, which is rendered with Mandarin *yóu*, with a sonorant onset.

over tonal assignment. Wu (2006) cites evidence that segmental similarity is more salient than pitch contour similarity, which would lead us to expect segmental adaptation to constrain the choice of tone and not the other way around. For now, I continue to assume that segmental adaptation takes precedence over tonal assignment.

Table 5 shows that loanword syllables with unaspirated onsets that adapt English voiced stops and affricates take all four tones. There is an overall preference for second tone, which is assigned to these syllables 39.2% of the time. If one takes tonal availability into account, this preference is even more striking: when second tone is available, which it is in only 326 out of 429 syllables, it is chosen 51.5% of the time. It seems there is quite a strong tendency for second tone to be assigned when English voiced stops and affricates are adapted with Mandarin unaspirated onsets. This is in contrast with Wu's finding that Mandarin aspirated onsets, regardless of the English phoneme they correspond to, tend to appear with second tone in loanwords while unaspirated onsets tend to appear with first tone. Given that English voiced (and hence unaspirated) stops and affricates are usually adapted with Mandarin unaspirated sounds (in 596 out of 631 syllables, or 94.4%, including epenthetic syllables) and that Mandarin unaspirated onsets usually come from English voiced (unaspirated) stops and affricates (596 out of 763 syllables, or 78.1%), it is unsurprising that my finding here is consistent with the facts I reported in my examination of aspiration, namely, that Mandarin syllables whose onsets correspond to unaspirated segments in English receive second tone most frequently (see Figure 4).

To sum up, the preference for second tone in loanword syllables whose onsets correspond to English voiced stops and affricates is robust when the Mandarin onset is unaspirated and almost absolute when the Mandarin onset is aspirated. Setting Mandarin aspiration aside, it is possible to say that voicedness in English stops and affricates is associated with a

disproportionate incidence of second tone in adapted syllables. This suggests that voicing in English may be a useful predictor of tonal assignment in Mandarin.

To test this hypothesis, I show in Table 6 the tones assigned to loanword syllables whose onsets derive from English obstruents, broken down by voicing.

Table 6: Tones of Non-Epenthetic Loanword Syllables from English Obstruents by English Voicing (N = 1385)

Voicing in English	Tone 1	Tone 2	Tone 3	Tone 4
Voiced (N = 561)	177 (31.6%)	250 (44.6%)	54 (9.6%)	226 (14.3%)
Voiceless (N = 824)	346 (42.0%)	88 (10.7%)	164 (19.9%)	226 (27.4%)

A chi-squared test confirms that the large differences between the tone distributions of the voiced and voiceless rows in Table 6 are quite significant (χ -squared = 179.8687, $p < 2.2e-16$).

Loanword syllables whose onsets correspond to English voiced obstruents are most likely, by a wide margin, to receive second tone while syllables whose onsets correspond to English voiceless obstruents are most likely to receive first tone, again by a wide margin. Loanword syllables whose onsets derive from voiced obstruents are less likely to have first tone than syllables whose onsets derive from voiceless obstruents. Similarly, adapted syllables whose onsets derive from voiceless obstruents are much less likely to have second tone than syllables whose onsets derive from voiced obstruents.

These patterns may be accounted for by the lowering effect of voicing on F0 (Hombert, Ohala, & Ewan 1979). Because of this effect, loanword syllables whose onsets come from voiced obstruents prefer to take second tone. The relatively high incidence of first tone in these syllables may be due to the fact that, as Wu observed, Mandarin syllables with unaspirated onsets, which are the expected adaptation of English voiced stops and affricates, tend to have

gaps in second tone. The fact that second tone still emerges as the preferred tone for these syllables, despite a Mandarin-internal bias that might lead speakers to prefer high tone over rising tone for syllables with unaspirated onsets, seems to testify to the strength of the second tone preference.

The fact that F0 is higher after a voiceless obstruent onset than a voiced one may explain the preference for first tone in loanword syllables linked to English voiceless obstruents. After first tone, fourth tone is the most frequent tone these syllables receive, and like first tone, fourth tone begins high. That so few of these syllables bear second tone even though aspirated onsets in Mandarin, with which most English voiceless stops and affricates are adapted, seem to have some association with second tone further suggests that voicing is a stronger determinant of tonal assignment than aspiration.

The tonal preferences based on voicing in English are more robust than those based on sonority and aspiration. In fact, the apparent effects of sonority and aspiration on tonal assignment may in fact be effects of voicing. In the case of sonority, we saw that loanword syllables whose onsets derived from English obstruents preferred first tone (see Figure 4). However, 61.2% of those English obstruents are voiceless, so it is likely that the association between English obstruents and first tone actually reflects an association between *voiceless* English obstruents and first tone.

Similarly, the apparent effects of English aspiration seen in the bottom-most terminal nodes of Figure 4 seem to be masking the true determinant of tone: voicing. Figure 4 shows that loanword syllables whose onsets correspond to aspirated sounds in English greatly prefer first tone to second tone. The distribution of tones is similar to that of the voiceless obstruents in Table 6, and the reason is clear: all aspirated English sounds are voiceless obstruents. The tonal

assignment of loanword syllables whose onsets derive from aspirated English consonants can be accounted for by the English consonants' voicelessness. Figure 4 also shows that loanword syllables whose onsets come from unaspirated English consonants prefer second tone to first tone, though not as strongly as syllables whose onsets come from voiced English obstruents do (see Table 6). As it turns out, 65.5% of the unaspirated English segments in Figure 4 are voiced, so the preference for second tone just reflects a watered down version of voiced English obstruents' association with second tone. In the end, it is English voicing, not sonority or aspiration, that proves to be the most successful predictor of tonal assignment in loanwords.

3.4 Stress

In this section, I revisit the question of stress-to-tone principles in the Mandarin adaptation of English words. Wu claimed that initial stressed syllables in disyllabic words take first or second tone when adapted into Mandarin, depending on sonority and aspiration, but her corpus contained many exceptions to this generalization. Here, I examine whether the stress of an English syllable influences the tone it receives in Mandarin without regard to factors like sonority, aspiration, and voicing. I exclude epenthetic loanword syllables since they have no English correspondents and therefore no value for stress in English. Table 7 breaks down the distribution of tones in loanword syllables by English stress:

Table 7: Tones of Non-Epenthetic Loanword Syllables by English Stress (N = 2692)

Stress in English	Tone 1	Tone 2	Tone 3	Tone 4
Primary (N = 1298)	401 (30.9%)	346 (26.7%)	213 (16.4%)	338 (26.0%)
Secondary (N = 255)	78 (30.6%)	55 (21.6%)	51 (20.0%)	71 (27.8%)
Unstressed (N = 1139)	278 (24.4%)	354 (31.1%)	171 (15.0%)	336 (29.5%)

A chi-squared test shows that there are overall differences in the tone distributions among the different levels of stress (χ -squared = 24.0637, $p = 0.0005$). Primary-stressed and secondary-

stressed syllables receive first and fourth tone about the same percentage of the time, while secondary-stressed syllables receive second tone somewhat less often and third tone somewhat more often than primary-stressed syllables. As it turns out, the tone distributions of the primary- and secondary-stressed syllables do not differ significantly from each other (χ -squared = 4.0221, $p = 0.2591$). The tone distribution of the unstressed syllables does look different from those of the two types of stressed syllables. Most notably, unstressed syllables receive first tone less often and second tone more often than both kinds of stressed syllables. Indeed, chi-squared tests of the first and third rows and second and third rows of Table 7 reveal significant differences (χ -squared = 16.6695, $p = 0.0008$ and χ -squared = 12.9904, $p = 0.0047$, respectively).

The results of these tests suggest that primary- and secondary-stressed syllables pattern similarly to each other and differently from unstressed syllables. Stressed syllables prefer first tone overall, recalling the Cantonese adaptation strategy whereby all English stressed syllables receive a high level tone. This preference for adaptation with first tone may reflect an attempt to reproduce the high pitch correlated with English stress. Compared to stressed syllables, unstressed syllables are less likely to be assigned first tone, a decrease that appears to be made up for mostly by an increase in second tone assignment. Mandarin may use a tone that starts at a mid pitch instead one that begins high to reflect the lower average pitch of English unstressed syllables. At the same time, unstressed syllables are also slightly more likely than stressed syllables to be adapted with fourth tone, which is unexpected if the choice of tone is governed by imitation of English pitch. However, as with epenthetic syllables, duration is another factor to consider. Since longer duration is also a correlate of English stress, Mandarin may prefer to adapt unstressed syllables with the tones that have the shortest duration, namely, first and fourth. First tone already appears to be associated with stressed syllables for pitch reasons, however, so

that leaves fourth tone, which, while it starts high, ends low. This could explain the modest increase in fourth tone assignment for unstressed syllables compared to stressed syllables.

Interestingly, the importance of stress as a determinant of tone differs between proper name adaptation and common noun adaptation. Proper non-epenthetic loanword syllables (N = 1853) exhibit the same patterns seen for all non-epenthetic loanword syllables in Table 7. This is not unexpected, since 68.8% of the syllables in Table 7 are from proper names. Among common non-epenthetic loanword syllables (N = 839), however, there are no significant differences between the tones received by primary-stressed, secondary-stressed, and unstressed syllables. All three types receive first tone most often in Mandarin. Unstressed syllables do receive second and fourth tone slightly more often than stressed syllables, showing trends in the same direction as those seen for the full set of syllables, but the differences are not significant for common syllables.

It is possible that stress is a significant determiner of tone only in proper loanword syllables. Proper name adaptation is often guided by Chinese institutions like the China National Committee for Terms in Sciences and Technologies and the Proper Names and Translation Service of the Xinhua News Agency (Dong 2012:95-96). These institutions may impose prescriptive adaptation strategies that have an original basis in phonetic similarity. If the adaptations of common nouns tend not to be regulated by institutions but are instead carried out more organically by ordinary speakers, it would seem that ordinary speakers do not assign tones with much regard to phonetic similarity, at least as far as English stress is concerned. It would be interesting if it turns out that official approaches to tonal assignment in English loanwords are more faithful to the source form than unregulated approaches.

Next, I examine whether the tonal assignment of English unstressed syllables depends on their position relative to the primary-stressed syllable of their word. Table 8 shows the tone distributions of pre-tonic, post-tonic, and neither pre- nor post-tonic unstressed syllables.

Table 8: Tones of Non-Epenthetic Loanword Syllables from English Unstressed Syllables by English Word Position

Syllable Type	Tone 1	Tone 2	Tone 3	Tone 4
All Unstressed Syllables (N = 1139)	278 (24.4%)	354 (31.1%)	171 (15.0%)	336 (29.5%)
Pre-tonic (N = 119)	42 (35.3%)	23 (19.3%)	21 (17.6%)	33 (27.7%)
Post-tonic (N = 844)	196 (23.2%)	291 (34.5%)	127 (15.0%)	230 (27.3%)
Neither (N = 176)	40 (22.7%)	40 (22.7%)	23 (13.1%)	73 (41.5%)

A chi-squared test demonstrates that there are significant differences in the tone distributions of pre-tonic, post-tonic, and other unstressed syllables (χ -squared = 29.9692, $p = 3.984e-05$). Pre-tonic unstressed syllables exhibit a fairly robust preference for first tone while post-tonic unstressed syllables exhibit a similarly strong preference for second tone. Interestingly, this pattern in some ways mirrors the one reported by Hao (2009) for Cantonese, whereby English pre-tonic unstressed syllables are adapted with a mid tone and post-tonic unstressed syllables with a low tone. The Mandarin pattern could reflect the same positional difference in salience to which Hao attributed the Cantonese pattern. The pre-tonic syllables tend to get Mandarin high tone, like stressed syllables, because they occupy the relatively prominent position immediately preceding the high pitch of the stressed syllable in English. The post-tonic syllables tend to get rising tone, which begins at a mid pitch, because their unstressed position is less prominent. While it might seem odd to assign a tone with a rising contour to a syllable that *follows* the English tonic, the other Mandarin tone that begins at a non-high pitch also ends higher than it begins. Moreover, third tone may be avoided when adapting unstressed syllables because it has the longest duration of the four Mandarin tones. Third tone may also occur the

least in loanword syllables overall because it is the least frequent tone in the native Mandarin lexicon and because there is no similar pitch contour at the syllable-level in English.

Unstressed syllables that are not adjacent to the tonic have a strong preference for fourth tone. Perhaps this is because it has short duration and is not first tone, which is associated with stressed syllables and now also with pre-tonic unstressed syllables. It is worth noting that the overall preference for second tone exhibited by the full set of unstressed syllables emerges due to the second tone preference of post-tonic unstressed syllables, which constitute the bulk of the unstressed syllables in the corpus.

To summarize, my corpus offers evidence that English stress influences tonal assignment in Mandarin. In the next two sections, though, different analytic techniques applied to the corpus data cast doubt on the importance of stress in tonal adaptation.

3.5 Exploring the Determinants of Tonal Assignment with a Decision Tree

Thus far, my search for the properties that influence tonal assignment in English loanwords in Mandarin has been based on the previous literature and my own intuitions. In this section, I employ another means of uncovering which factors significantly affect Mandarin tonal adaptation. I used the `ctree()` function from the R package `party` (Hothorn, Hornik, & Zeileis 2006) to generate a binary-branching decision tree built through recursive partitioning. Ideally, this decision tree will confirm some of the generalizations I have put forth in earlier sections. It may also reveal other determinants of tone I did not find myself or show that certain determinants only have an effect in a subset of the corpus. I limited the input data of the decision tree to non-epenthetic loanword syllables because, as will be discussed in the next section, the choice of epenthetic syllables in loanwords is largely inflexible. The predictors supplied to the

`ctree()` function are listed in Table 9. The variables `EngPretonicCorresp`, `PreTonicCorresp`, `PostTonicCorresp`, and `TotalEngSyll` did not emerge as significant predictors in the decision tree.

Table 9: Decision Tree Predictors

Predictor	Description	Values
<code>EngSegOnsetSon</code>	Sonority of the English segment to which the loanword syllable's onset corresponds	Sonorant Obstruent
<code>EngSegOnsetAsp</code>	Aspiration of the English segment to which the loanword syllable's onset corresponds	Aspirated Unaspirated Null
<code>EngSegOnsetVoice</code>	Phonemic voicing of the English segment to which the loanword syllable's onset corresponds	Voiced Voiceless Null
<code>Stress</code>	Stress level of the English syllable	Primary Secondary Unstressed
<code>EngPretonicCorresp</code>	Whether the loanword syllable corresponds to an English pre-tonic unstressed syllable or not	Yes/No
<code>EngPosttonicCorresp</code>	Whether the loanword syllable corresponds to an English post-tonic unstressed syllable or not	Yes/No
<code>PreTonicCorresp</code>	Whether the loanword syllable is immediately before the loanword syllable that corresponds to a primary-stressed English syllable	Yes/No
<code>PostTonicCorresp</code>	Whether the loanword syllable is immediately after the loanword syllable that corresponds to a primary-stressed English syllable	Yes/No
<code>EngPosition</code>	Position in the word occupied by the English syllable the loanword syllable corresponds to, counting from the beginning of the word	1, 2, 3, 4, 5
<code>TotalEngSyll</code>	Total number of syllables in the English word the loanword syllable adapts	1, 2, 3, 4, 5
<code>ProperNoun</code>	Whether the loanword syllable adapts a proper name or not	Yes/No

The tree is too large to show in a single figure, so I split it into two parts. Consequently, its root node is not visible. The variable that triggers the first split in the decision tree is `EngSegOnsetVoice`, or the phonemic voicing of the English segment to which the loanword syllable's onset corresponds. This variable can take on the values `Voiceless`, `Voiced`, or `Null`, where `Null` is applied to loanword syllables corresponding to onsetless English syllables. The

split by EngSegOnsetVoice separates syllables with the value Voiced from those with the values Voiceless or Null. The subtree descending from the Voiced branch is shown in Figure 5 and the subtree descending from the Voiceless/Null branch is shown in Figure 6.

I first discuss the Voiced branch of the decision tree. This branch includes loanword syllables whose onsets correspond to sonorants as well as to voiced obstruents. I showed earlier that both sonorants and voiced obstruents in English are associated with more frequent assignment of second tone. In the decision tree in Figure 5, the graphs at three out of four terminal nodes show second tone as the most frequently assigned tone. This is as expected, given my previous analysis of the corpus.

The first split enacted for the syllables with onsets from English voiced segments is by EngSegOnsetSon (the counterpart of EngSegOnsetVoice for sonority). The loanword syllables whose onsets derive from English sonorants (Node 2) undergo no further splits. For these syllables, second tone assignment is most common, followed by fourth tone assignment, just as in the decision tree in Figure 4 (though Figure 4 included epenthetic loanword syllables, which this decision tree does not). Thus far, the decision tree is reproducing the analysis I have already made.

The syllables whose onsets come from English voiced obstruents (Node 3) split twice more according to stress. As it turns out, this is one of only two places in the entire decision tree where splits are made by stress. That is, although in Section 3.4 I found overall significant differences in tonal assignment for syllables with different English stress levels, the recursive partitioning algorithm concludes that English stress influences tonal assignment only in two subsets of the corpus. One of them is the set of loanword syllables whose onsets derive from voiced obstruents. The second will be discussed below.

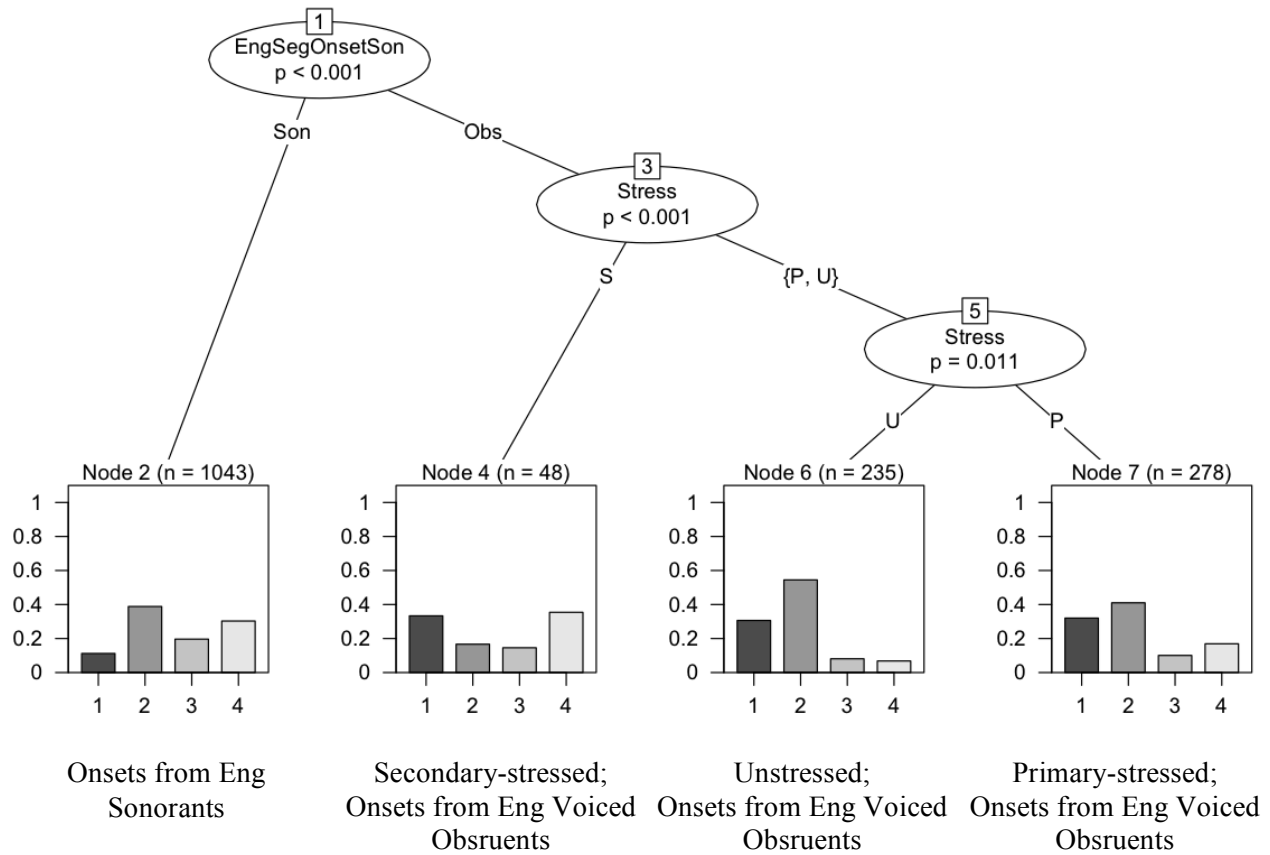


Figure 5: Decision Tree for All Non-epenthetic Loanword Syllables—EngSegOnsetVoice: Voiced Branch

Returning to Node 3, we see that the loanword syllables that bear secondary stress in English are first split off from those bearing either primary stress or no stress. This is somewhat puzzling since my earlier investigation of stress showed primary- and secondary-stressed syllables patterning together in opposition to unstressed syllables. It appears from the graphs for terminal nodes 4, 6, and 7 that this split is made because both the primary-stressed and unstressed syllables in this subset prefer second tone overall while the secondary-stressed syllables do not. The Node 4 graph shows that the latter tend to be adapted with first or fourth tone. I have no particular explanation for this. It may be that the small number of syllables (N = 48) is behind this apparently anomalous behavior.

At Node 5, the remaining loanword syllables whose onsets come from English voiced obstruents are split into primary-stressed and unstressed groups. Second tone is the most frequently assigned tone for both these sets of syllables, unsurprisingly, since their onsets derive from voiced obstruents. The reason a split is made is because the distribution of assigned tones differs significantly between these two groups. Primary-stressed syllables receive second tone less often and first and fourth tone more often than unstressed syllables. This pattern is consistent with the stress-based trends I found in Section 3.4 and lends itself to a plausible phonetic explanation. The high pitch of English stressed syllables leads to greater use of the two tones that begin high. Overall, second tone is still most frequent for these primary-stressed syllables due to the effect of voicing, but stress plays a role as well. The graphs at nodes 6 and 7 illustrate this interaction. Mandarin tonal adaption seems to reflect the influence of multiple phonetic factors, with stress's role subordinate to voicing's.

I now consider the Voiceless/Null branch of the full tree, shown in Figure 6. It exhibits many more splits than the Voiced branch. The first split divides the syllables whose onsets derive from English segments with a feature value for aspiration from those whose onsets derive from segments without a value for aspiration. That is, the Aspirated/Unaspirated branch comprises syllables with onsets from voiceless stops and affricates while the null branch comprises syllables with onsets from voiceless fricatives and syllables from onsetless English syllables. The Aspirated/Unaspirated branch then splits according to aspiration (Node 15). The Unaspirated group (Node 16) prefers fourth tone, followed by first tone, while the Aspirated group (Node 17) prefers first tone, followed by third tone. I have little to say about how tonal assignment differs between loanword syllables whose onsets adapt aspirated voiceless segments and those whose

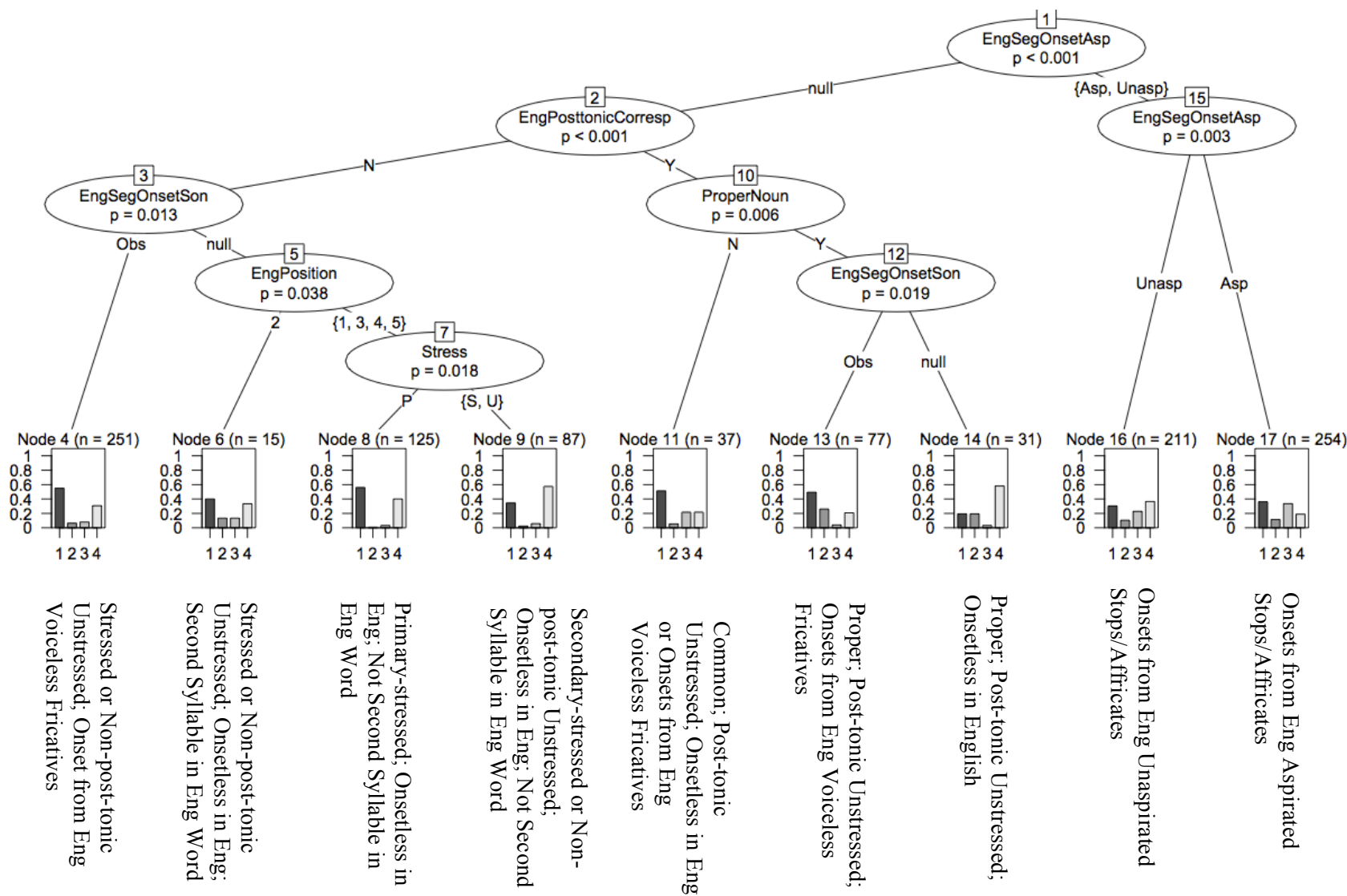


Figure 6: Decision Tree for All Non-epenthetic Loanword Syllables —EngSegOnsetVoice: Voiceless/Null Branch

onsets adapt unaspirated voiceless segments. Both types of syllables show very infrequent use of second tone, consistent with my previous findings about voicing.

Returning to Node 1 and following its left branch, we start to see some puzzling splits. The loanword syllables whose onsets correspond to voiceless fricatives or whose English correspondents lack onsets are split according to whether or not they adapt an English post-tonic syllable. Loanword syllables that correspond to post-tonic syllables necessarily correspond to unstressed syllables, but loanword syllables that do not correspond to post-tonic syllables may derive from unstressed syllables in other positions or from stressed syllables. Since the latter category is so diverse, it is somewhat surprising that the decision tree implements a split by EngPosttonicCorresp without an earlier split by stress.

The syllables that correspond to post-tonic (and thus unstressed) syllables are next split according to whether or not they adapt syllables from proper names (Node 10). Those that do not have a strong preference for first tone (Node 11), a preference I suspect emerges because most of these syllables' onsets correspond to English voiceless fricatives. As discussed in Section 3.3, voicelessness in English obstruents is associated with first tone. Meanwhile, the syllables that adapt post-tonic syllables from proper names are split a final time by EngSegOnsetSon (Node 12). Since all English sonorants are voiced and all syllables whose onsets come from English voiced segments were split off higher in the tree, the only values syllables at Node 12 can have for EngSegOnsetSon are Obstruent and Null. The syllables with the value Obstruent strongly prefer first tone, again, I suspect, because all these syllables' onsets correspond to English voiceless fricatives. The syllables with the value Null (those that adapt onsetless post-tonic syllables from proper names) overwhelmingly prefer fourth tone. Many of the loanword syllables

represented in the graph of Node 14 are tokens of *aò* and *yà*, which usually derive from the onsetless English syllables /əʊ/ and /ə/.

Despite splits by EngPosttonicCorresp, ProperNoun, and EngSegOnsetSon, the part of the decision tree in Figure 6 consisting of Node 2 and its right branch does not seem to offer any more insight into the properties of English syllables that affect tonal assignment in Mandarin. The graphs of terminal nodes 11, 13, and 14 only reflect what we already know about voiceless obstruents and perhaps a certain rigidity in the adaption of the English syllables /əʊ/ and /ə/.

Moving back up to Node 2, we follow the EngPosttonicCorresp: No branch (which, recall, includes syllables with different English stress levels) to another split by EngSegOnsetSon (Node 3). Again, at this point in the decision tree, this variable can no longer take on the value Sonorant. The tones assigned to the syllables whose onsets come from voiceless fricatives are shown in the graph of terminal node 4. Over half these syllables receive first tone, and the remaining syllables mostly take fourth tone. Again, I take this tonal distribution to reflect the influence of voicing.

The right branch of Node 3 consists of adaptations of non-post-tonic onsetless syllables. This branch splits according to English position (EngPosition), which is puzzling. Loanword syllables corresponding to English syllables that are the second in their words are divided from loanword syllables corresponding to English syllables that are the first, third, fourth, or fifth in their words (Node 5). The tones assigned to the former set of syllables are shown in the graph of terminal node 6. These syllables are mostly assigned first or fourth tone, but I have no particular account for this. The English second-position syllables occur in words of varying length, not just disyllabic words. It is possible that the values the variable EngPosition takes on are not the most informative. That is, since my corpus contains polysyllabic words of different lengths, it may be

more meaningful to consider whether a syllable is word-initial, word-final, or neither than to count how far it is from the beginning of the word it appears in.

The remaining syllables, those whose English correspondents are in first, third, fourth, or fifth position, mostly take first and fourth tone too. Nevertheless, they are split once more by stress (Node 7). This time, primary-stressed syllables are divided from secondary-stressed and unstressed syllables. The primary-stressed syllables receive first tone more often than fourth tone (Node 8), which could be a reflection of first tone's association with English primary stress, though I am cautious about making such a claim. The secondary-stressed and unstressed syllables receive fourth tone more often than first tone (Node 9). As with Node 2 and its right branch, I am unconvinced that the section of the tree consisting of Node 2 and its left branch reveals anything new about the determinants of tone in English loanwords in Mandarin. It is difficult to imagine, for instance, why stress should matter for the tonal assignment of syllables in first, third, fourth, and fifth positions in English words but not for syllables in second position.

The decision tree confirms my earlier observations with regard to sonority and voicing. The fact that the tree's first split is by voicing suggests that this property is the single most influential factor in determining tone in adapted forms. The most significant new insight the decision tree provides is that stress may only affect the tonal assignment of loanword syllables whose onsets come from English voiced obstruents.

3.6 Standard Syllables in English-to-Mandarin Loanword Adaptation

This section examines the use of standard or conventional Mandarin syllables to adapt specific English phonemes or syllables. My corpus contains evidence of such standardization in two places: adaptations of epenthetic syllables and adaptations of segmentally identical syllables with different stress in English.

In Section 3.2, we saw that, contrary to Wu's (2006) claim, the epenthetic syllables in my corpus could bear all four tones. A closer examination of these syllables reveals that, very often, a single Mandarin syllable (and sometimes even a single character) is used to preserve a particular English segment. In other words, there is little flexibility in either the segments or the tones epenthetic syllables exhibit. For example, English liquids in coda position are often preserved in Mandarin with a VC syllable; if they are, that syllable is universally *er*. Out of 133 cases of coda liquid preservation, 130 of the epenthetic *ers* have third tone (the other three have second tone). Of the 130 *ers*, 126 are written with the character 尔. It is nearly possible to say that, if preserved, an English coda liquid will always be adapted as 尔 *ěr*. In this instance, the standard epenthetic syllable does bear the least salient Mandarin tone in terms of pitch, but this is not always true. English coda /n/s are sometimes preserved in Mandarin with an epenthetic VC syllable too. In the eleven times this occurs in my corpus, the syllable is always 恩 *ēn*. There are in fact very few characters with the pronunciation *en* (and none bear third tone), but it is still notable that only one of these characters serves as the epenthetic syllable for English coda /n/.

This rigidity in the choice of epenthetic syllables holds true across all English segments and seems to be even more pronounced in the adaptation of proper names. 106 out of 109 (97%) epenthetic syllables preserving English /k/ have the pronunciation *kè*; 104 of these syllables are written 克, and among proper names, 克 is the only character used to preserve English /k/. 83 out of 86 (97%) epenthetic syllables preserving English /d/ have the pronunciation *dé*, and all but one are written 德. Among proper nouns, *dé* is the only syllable used to preserve /d/. 普 *pǔ* is used 77% of the time as the epenthetic syllable preserving English /p/ (92% of the time in proper

names), and the syllable *sī* (most often written 斯) is used 97%, 76%, and 100% of the time to preserve English /s/, /z/, and /θ/, respectively. It seems clear that, for the most part, each English segment is associated with a particular Mandarin syllable (and character) that is epenthesized when that segment is preserved in adaptation. (In some ways, this one-to-one mapping is not surprising since an epenthetic syllable need only preserve one consonant, not attempt to match an entire English syllable with onset, nucleus, and coda.) Moreover, the set of standard epenthetic syllables is not limited to *sī* and syllables bearing third or fourth tone. As we have seen, /d/ is typically preserved with *dé*; similarly, /g/ is overwhelmingly preserved with *gé*. The full set of standard epenthetic CV syllables used in English loanwords is given in Table 10, which includes syllables that can only occur with one tone (see Section 3.1).

While the epenthetic syllables used in loanwords may be standardized, that does not preclude them from exhibiting effects of phonetic properties of English on tonal adaptation. That is, the properties of an English phoneme may influence which syllable, including tone, is chosen to standardly preserve it. Aspiration in English does not seem to play a role in determining the tone of the epenthetic syllable. English /p/, /t/, and /k/ are standardly preserved with *pǔ*, *tè*, and *kè* regardless of whether they are aspirated or unaspirated in the English word. It is difficult to draw any conclusions about the effect of sonority since Table 10 contains only two English sonorants, /m/ and /j/. The English coda segments that are preserved with epenthetic VC syllables are also sonorants (/l/, /r/, and /n/), but these cases may work differently because the English segment being preserved appears in coda position instead of onset position in Mandarin.

While I cannot find a clear effect of aspiration or sonority on the tones of epenthetic syllables, it looks as though there may be an effect of voicing. First consider the stop series. Two of the three English voiceless stops (/t/ and /k/) are preserved with epenthetic syllables that have

fourth tone. I showed in Section 3.3 that loanword syllables whose onsets correspond to English voiceless obstruents prefer first tone assignment, but fourth tone also begins high, so fourth tone assignment is also consistent with the hypothesis that voiceless obstruents are associated with higher pitch at onset. Two of the three English voiced stops (/d/ and /g/) are preserved with epenthetic syllables that bear second tone, whose contour begins at a mid pitch. This pattern is consistent with the lowering effect of voiced stops on F0.

Table 10: Epenthetic CV Syllables in English Loanwords by English Phoneme

English Phoneme	Standard Syllable	Frequency with which Standard Syllable Preserves English Phoneme
/p/ (N = 22)	<i>pǔ</i>	86%
/t/ (N = 82)	<i>tè</i>	93%
/k/ (N = 109)	<i>kè</i>	97%
/b/ (N = 37)	<i>bù</i>	81%
/d/ (N = 86)	<i>dé</i>	97%
/g/ (N = 30)	<i>gé</i>	93%
/tʃ/ (N = 6)	<i>qí</i>	50%
/dʒ/ (N = 12)	<i>zhì</i>	58%
/f/ (N = 24) (in onset ⁶)	<i>fú</i>	88%
/f/ (N = 10) (in coda)	<i>fū</i>	90%
/v/ (N = 9)	<i>fū</i>	89%
/s/ (N = 154)	<i>sī</i>	97%
/z/ (N = 38)	<i>sī</i>	76%
/θ/ (N = 14)	<i>sī</i>	100%
/ʃ/ (N = 8)	<i>shí</i>	50%
/m/ (N = 34)	<i>mǔ</i>	100%
/j/ (N = 10) (offglide of diphthong)	<i>yī</i>	100%

The affricates in Table 10 exhibit the opposite behavior of the expected voicing pattern: voiceless /tʃ/ is preserved with a second tone syllable while voiced /dʒ/ is preserved with a fourth

⁶ The choice of epenthetic syllable for /f/ depends on the phoneme's position in the English syllable, so I divide /f/s preserved from onsets (e.g. the /f/ in *Floyd*) from those preserved from codas (e.g. the /f/ in *golf*). No other phoneme shows this type of sensitivity to position.

tone syllable. However, the number of epenthetic syllables in my corpus preserving these English segments is small, and the Mandarin syllables that emerge as “standard” for the affricates are not as dominant as the standard syllables for other segments are (i.e. *qi* is used only 50% of the time for /tʃ/ and *zhi* only 58% of the time for /dʒ/, compared to *pu* being used 86% of the time for /p/, etc.).

At first glance, the voicing effect seems weak among the fricatives as well. Despite being voiced, the fricatives /v/ and /z/ are preserved with first tone epenthetic syllables instead of second tone ones. There is an explanation for this fact that reinforces the apparent voicing effect rather than contradicting it. Mandarin lacks voiced fricatives and thus has no segmental equivalents of English /v/ and /z/. Since Mandarin does have voiceless fricatives, it can preserve English /f/ and /s/ with epenthetic syllables beginning with these segments. *Fū* is used to render /f/ (from coda position) and *sī* to render /s/. Then, since /f/ and /s/ are the perceptually closest sounds to /v/ and /z/ available, Mandarin uses the same standard epenthetic syllables for these voiced fricatives as for the voiceless ones. Thus /v/ and /z/ are also preserved with *fū* and *sī*, respectively. If these syllables were first chosen as the most faithful adaptations of the English voiceless fricatives and only then extended to the English voiced fricatives, we would expect them to bear the tone that is preferred for English voiceless obstruents, namely first tone.

I have established that Mandarin has a tendency to use a fixed set of syllables (and in fact probably characters) in loanword adaptation, at least for epenthetic syllables. Nevertheless, the choice of these fixed epenthetic syllables, and in particular their tones, seems to be guided by the voicing of the English phonemes they preserve.

The tendency for one-to-one mappings from English phonemes to Mandarin characters that I discovered in epenthetic loanword syllables may exist in non-epenthetic loanword syllables

too, except with entire English syllables being mapped to Mandarin characters. The evidence for this comes from using a different approach to uncovering stress-to-tone principles in English-to-Mandarin loanword adaptation. I examine the most frequent syllables in my corpus to see whether differences in English stress level correlate with the assignment of different tones. In this miniature study, I consider only proper names, since in Section 3.4 I noted that common nouns do not exhibit much of an effect of stress on tonal adaptation.

Ideally, I would consider a particular English syllable and compare the tones it receives in Mandarin when it is stressed to the tones it receives when it is unstressed. These sorts of comparisons are very difficult to carry out, however, because stress and vowel quality are so intimately linked in English. Most syllables cannot appear with multiple stress levels because, as described in Section 2.1, the set of English vowels that can be stressed and the set of those that can be unstressed are almost mutually exclusive. Nevertheless, Table 11 shows the nine most frequent proper English syllables in my corpus that can have multiple stress levels and the tones they take in Mandarin depending on their English stress.

As can be seen in the table, the counts are very small, and often the vast majority of a given syllable's tokens are unstressed, making comparison difficult. In contrast with what we saw in Section 3.4, here there is scant evidence for an effect of stress level on tonal assignment. Moreover, all the syllables in Table 11 are overwhelmingly adapted with either one or two characters. This suggests that a given English syllable is usually adapted with the same Mandarin character for segmental (or even orthographic) reasons and tonal assignment is simply a side effect of the choice of character.

There are nevertheless some trends in the right directions. For instance, the English syllable /li/ is always adapted with fourth tone when it bears primary stress; this could be an

Table 11: Tones of Particular English Proper Syllables by English Stress

English Syllable	Stress	Tone 1	Tone 2	Tone 3	Tone 4
/li/	Primary (N = 2)	0	0	0	2
	Unstressed (N = 37)	0	1	1	35
/ri/	Primary (N = 5)	0	0	2	3
	Unstressed (N = 32)	0	0	22	10
/ni/	Primary (N = 1)	0	1	0	0
	Unstressed (N = 26)	0	26	0	0
/si/	Primary (N = 5)	5	0	0	0
	Unstressed (N = 12)	11	1	0	0
/di/	Primary (N = 1)	0	1	0	0
	Unstressed (N = 15)	0	13	1	1
/lɪ/	Primary (N = 8)	0	0	0	8
	Unstressed (N = 7)	0	2	0	5
/əʊ/	Primary (N = 5)	1	1	0	3
	Secondary (N = 5)	0	2	0	3
	Unstressed (N = 4)	0	1	0	3
/mɪ/	Primary (N = 6)	0	0	5	1
	Secondary (N = 2)	0	1	0	1
	Unstressed (N = 5)	0	0	4	1
/sɪ/	Primary (N = 5)	5	0	0	0
	Secondary (N = 1)	1	0	0	0
	Unstressed (N = 6)	4	0	0	2

appropriate adaptation because fourth tone begins high. When /lɪ/ is unstressed, it still receives fourth tone most of the time, but it also receives second tone twice, while stressed /lɪ/ never does. If second tone captures the lower pitch of unstressed syllables in English, then the behavior of /lɪ/ suggests some sensitivity to stress level in tonal adaptation. The numbers are so small, though, that it is hard to draw any meaningful conclusions.

Since it is so difficult to find sufficient tokens of the same English syllable with different stress levels, I approach the question from the Mandarin side instead. I consider the most common Mandarin syllables, disregarding tone, used in adapting proper names and check whether the tones they are realized with depend on the stress level of the English syllables they correspond to. Table 12 lists the tones the nine most common Mandarin syllables receive according to English stress level.

Table 12: Tones of Particular Mandarin Proper Syllables by English Stress

Mandarin Syllable	Stress	Tone 1	Tone 2	Tone 3	Tone 4
<i>li</i>	Primary (N = 37)	0	0	15	22
	Secondary (N = 1)	0	0	1	0
	Unstressed (N = 124)	0	0	50	74
<i>la</i>	Primary (N = 17)	17	0	0	0
	Secondary (N = 1)	1	0	0	0
	Unstressed (N = 41)	41	0	0	0
<i>luo</i>	Primary (N = 40)	1	28	0	11
	Secondary (N = 3)	0	2	0	1
	Unstressed (N = 16)	0	11	0	5
<i>xi</i>	Primary (N = 22)	22	0	0	0
	Secondary (N = 1)	1	0	0	0
	Unstressed (N = 32)	32	0	0	0
<i>ni</i>	Primary (N = 9)	0	9	0	0
	Unstressed (N = 45)	0	45	0	0
<i>ai</i>	Primary (N = 46)	26	0	0	20
	Secondary (N = 1)	1	0	0	0
	Unstressed (N = 3)	3	0	0	0
<i>wei</i>	Primary (N = 28)	14	10	4	0
	Secondary (N = 4)	1	0	3	0
	Unstressed (N = 18)	4	14	0	0
<i>di</i>	Primary (N = 13)	1	4	0	8
	Unstressed (N = 32)	0	21	1	10
<i>ya</i>	Primary (N = 5)	0	0	0	5
	Secondary (N = 4)	0	0	0	4
	Unstressed (N = 36)	0	0	2	34

Looking at Mandarin syllables provides higher counts to work with, but again there is little evidence that English stress is a strong determinant of tone at the level of individual syllables. For instance, the Mandarin syllable *li* receives third or fourth tone in loanwords (*li* can bear second, third, and fourth tone), but the proportions of *lis* that receive third and fourth tone are about the same whether *li* adapts an English stressed syllable or an unstressed one. The Mandarin syllables *la*, *xi*, and *ni* always receive the same tone regardless of the stress level of the English syllable they adapt even though all three syllables can occur with all four Mandarin tones. In fact, *la* is always written with 拉 *lā*, *ni* is always written with either 尼 *ní* or 妮 *nǐ*, and

44 out of 55 instances of *xi* are written with 西 *xī*. This again hints that segmental adaptation may be paramount and that as far as stress is concerned, tone is only incidental to whatever character happens to be standard for adapting a particular English syllable. Standard Mandarin syllables, including tone, may still be selected to reflect properties of the onset consonant in English; 尼 *ní* and 妮 *ní* bear second tone, which I expect for a syllable whose onset corresponds to the English sonorant /n/, and 西 *xī* bears first tone, which I expect for a syllable whose onset corresponds to an English voiceless fricative (most often /s/). To reflect stress as well, though, multiple standard syllables would have to be chosen to cover the different possible English stress levels for the same syllable, and it does not appear that this happens in Mandarin tonal adaptation.

The only syllables in Table 12 that show evidence of sensitivity to stress are *wei* and *di*. *Wei* is the most convincing example: the tone distributions of *weis* deriving from primary-stressed, secondary-stressed, and unstressed syllables differ significantly (Fisher's Exact Test: $p = 0.0006$). *Weis* from primary-stressed syllables modestly prefer first tone over second tone, consistent with the hypothesis that first tone best imitates the high pitch of stressed syllables. *Weis* from unstressed syllables strongly prefer second tone over first tone, in line with the idea that the lower relative pitch of unstressed syllables favors adaptation with a tone that starts lower than other tones. The case of *di* is less compelling: the difference in tone distributions between *di* from stressed syllables and *di* from unstressed syllables barely reaches significance (Fisher's Exact Test: $p = 0.0498$). Again, though, the trends go in a direction amenable to a phonetic account. *Dis* from stressed syllables are more likely to receive fourth tone, which starts high,

than second tone, which starts at a mid pitch, and *dis* from unstressed syllables are more likely to receive second tone than fourth tone.

While *wei* and *di* provide evidence of English stress determining tonal assignment in expected ways given the aggregate tendencies, the evidence for stress-to-tone principles in English-to-Mandarin adaptation at the individual syllable level is thin. This conflicts with and thus calls into question my earlier finding that English stress does have significant effects on tonal assignment in the aggregate. The decision tree discussed in Section 3.5 supports the relative unimportance of stress in Mandarin tonal adaptation since stress was only a significant determinant of tone for loanword syllables whose onsets came from English voiced obstruents. From Tables 11 and 12, it seems that once a character (or syllable with tone) is chosen to adapt a particular English syllable, presumably based on its segments, that character or syllable is used for most other adaptations of that English syllable no matter its stress level. The use of standard syllables in loanwords is apparently not limited to epenthetic syllables but applies to some degree in all loanword syllables. I will return to this topic in the analysis of the experimental results.

4. A Loanword Adaptation Experiment

After completing the corpus study, I carried out an experiment to examine whether the patterns that emerged from the corpus data would be reproduced in native Mandarin speakers' online adaptations of English words. The experiment was partially modeled on Chang & Bradley's (2012) experiment. Based on the results of the corpus study, I designed the experiment to test three main hypotheses. The first hypothesis is that adapted syllables whose onsets correspond to English sonorants will tend to receive second tone. The second hypothesis is that English voicing will be a significant determinant of tonal assignment. Specifically, loanword syllables whose onsets correspond to English voiceless obstruents will tend to receive first tone

while loanword syllables whose onsets correspond to English voiced obstruents will tend to receive second tone. The third hypothesis is that stressed English syllables will be more likely to receive first tone while unstressed English syllables will be less likely to receive first tone. Given the ambiguity of the importance of English stress in the corpus study, I also anticipated that stress might not emerge as a significant predictor of tonal assignment in the experiment, or that it would have a smaller effect than other factors such as voicing.

4.1 Method

4.1.1 Materials

The stimuli consisted of 80 disyllabic nonce English words. The nonce words were constructed such that each syllable had an expected segmental adaptation in Mandarin that could bear all four tones. Half the stimuli were trochees and half were iambs. The nonce words consisted of syllables of the form CV, CV_n, or [ʃəɪ]. The syllable [ʃəɪ] was used because it was relatively difficult to find licit English syllables that could occur in both stressed and unstressed position and have the same expected Mandarin segmental adaptation regardless of its stress. Additionally, the Mandarin segmental adaptation had to be able to bear all four tones. The English-Mandarin pair [ʃəɪ] – *shi* met all the criteria, which accounts for the inclusion of [ʃəɪ] in the set of stimuli syllables.

The onset consonants of the rest of the stimuli syllables were sonorants (/m/ or /j/), phonemically voiced stops/affricates (/b/, /g/, or /dʒ/), phonemically voiceless stops/affricates (/p/ or /tʃ/), or voiceless fricatives (/f/, /s/, or /ʃ/). The voiced stop/affricate onsets and voiceless stop/affricate onsets were each divided into two types based on presumed phonetic voicing. The phonemically voiced stops/affricates were categorized as voiced when in the onset of the final (unstressed) syllable of a trochee and as voiceless otherwise. The phonemically voiceless

stops/affricates were categorized as unaspirated when in the onset of the final (unstressed) syllable of a trochee and as aspirated otherwise. The vowels used in the stimuli were /ɑ/, /ɛ/, /i/, /ɪ/, /æ/, or /ə(ɪ)/ in stressed syllables and /ə/, /ɪ/, or /i/ in unstressed syllables (unstressed syllables with /i/ were always final).

The syllables that made up the 80 nonce words, including the number of times each syllable and each type of syllable occurred in the stimuli set, are given in Table 13. Expected Mandarin segmental adaptations are given in Pinyin in italics, and the phonetic realization of stimuli syllables are given in IPA in square brackets. Because English vowels in unstressed position are reduced, the phonetic realization of the “same” stimuli syllables varied according to whether they were in stressed or unstressed position. Nevertheless, their Mandarin segmental adaptations were expected to be the same.

The disyllabic nonce words were constructed by randomly concatenating possible initial and final syllables, with hand correction to ensure that no item consisted of two syllables with the same expected segmental adaptation or corresponded to a real English word. Because the stimuli set was designed to include an equal number of trochees and iambs and some syllable types are positionally restricted, it was not possible for each onset type to be equally represented. For instance, increasing the number of voiced obstruent-initial syllables and unaspirated stop/affricate-initial syllables, which can only occur in final unstressed position, would have required including more trochees than iambs in the stimuli set.

The nonce word stimuli were recorded by a male native speaker of American English with phonetic training who was naïve to the purpose of the study. The speaker read the stimuli in IPA transcription. The recordings were produced in a soundproof booth using a Shure SM-10A head-mounted microphone plugged into an XAudioBox. The recordings were done in the

program PCQuirerX with a sampling rate of 22,050 Hz. Each nonce word was produced in the frame “This is the word X. X.” That is, each word was uttered twice, first in sentence-final position and then in isolation.

Table 13: Syllables of Nonce Word Stimuli with Counts

	Initial		Final		Total
	Stressed	Unstressed	Stressed	Unstressed	
Sonorant	<i>ma</i> [ma] 2 <i>ya</i> [ja] 2 <i>yan</i> [jɛn] 2 <i>mi</i> [mi] 2	<i>ma</i> [mə] 2 <i>ya</i> [jə] 2 <i>yan</i> [jɛn] 2 <i>mi</i> [mɪ] 2	<i>ma</i> [ma] 2 <i>ya</i> [ja] 2 <i>yan</i> [jɛn] 2 <i>mi</i> [mi] 2	<i>ma</i> [mə] 1 <i>ya</i> [jə] 1 <i>yan</i> [jɛn] 1 <i>mi</i> [mi] 1	7 7 7 7 = 28
Voiced Obstruent				<i>ba</i> [bə] 4 <i>ga</i> [gə] 4 <i>zha</i> [dʒə] 4 <i>ji</i> [dʒi] 4	4 4 4 4 = 16
Devoiced Obstruent	<i>ba</i> [ba] 4 <i>ga</i> [gɑ] 4 <i>zha</i> [dʒɑ] 2 <i>ji</i> [dʒi] 2	<i>ba</i> [bə] 2 <i>ga</i> [gə] 2 <i>zha</i> [dʒə] 4 <i>ji</i> [dʒi] 4	<i>ba</i> [ba] 4 <i>ga</i> [gɑ] 4 <i>zha</i> [dʒɑ] 4 <i>ji</i> [dʒi] 4		10 10 10 10 = 40
Aspirated Stop/Affricate	<i>cha</i> [tʃɑ] 4 <i>pi</i> [pi] 4 <i>qi</i> [tʃi] 2 <i>pin</i> [pɪn] 2	<i>cha</i> [tʃə] 2 <i>pi</i> [pi] 2 <i>qi</i> [tʃi] 4 <i>pin</i> [pɪn] 4	<i>cha</i> [tʃɑ] 2 <i>pi</i> [pi] 2 <i>qi</i> [tʃi] 2 <i>pin</i> [pɪn] 2		8 8 8 8 = 32
Unaspirated Stop/Affricate				<i>cha</i> [tʃə] 4 <i>pi</i> [pi] 4 <i>qi</i> [tʃi] 4 <i>pin</i> [pɪn] 4	4 4 4 4 = 16
Voiceless Fricative	<i>fa</i> [fa] 2 <i>xi</i> [si] 2 <i>fan</i> [fæn] 2 <i>shi</i> [ʃəi] 2	<i>fa</i> [fə] 2 <i>xi</i> [si] 2 <i>fen</i> [fɛn] 2 <i>shi</i> [ʃəi] 2	<i>fa</i> [fa] 2 <i>xi</i> [si] 2 <i>fan</i> [fæn] 2 <i>shi</i> [ʃəi] 2	<i>fa</i> [fə] 1 <i>xi</i> [si] 1 <i>fen</i> [fɛn] 1 <i>shi</i> [ʃəi] 1	7 7 7 7 = 28
Total	40	40	40	40	160

Several acoustic properties of the stimuli were measured in anticipation of the analysis of the experimental results. Aspiration of the onset consonant was one factor to be considered as a potential determinant of tonal assignment. To show that the stop and affricate onsets did in fact differ in aspiration, I measured their VOT. Table 14 shows the average VOT for the four types of stop/affricate onsets: phonemically voiced obstruents (both those that were expected to be voiced

and those that were expected to be devoiced, based on their position) and phonemically voiceless stops/affricates (both those that were expected to be aspirated and those that were expected to be unaspirated, based on position). The first three types of onsets are coded as unaspirated and the fourth type as aspirated. Table 14 pools VOT measurements from the isolation and sentence contexts, so each stop/affricate-initial item is represented twice, once in each context.

Tukey tests show that voiceless unaspirated stops and affricates had significantly longer VOT than phonemically voiced stops and affricates ($p < 0.01$) and voiceless aspirated stops and affricates had significantly longer VOT than voiceless unaspirated stops and affricates ($p < 0.001$). Voiced stops and affricates and devoiced stops and affricates did not differ significantly in VOT. Looking at Table 14, it appears that stops differ in VOT by aspiration while affricates differ in VOT by voicing (i.e. phonemically voiced and phonemically voiceless affricates each have similar VOT instead of unaspirated sounds and aspirated sounds). For the purposes of this paper, however, stops and affricates are grouped in the same way with respect to aspiration.

Table 14: Average VOT of Stimuli Syllable Onsets

	Stop	Affricate ⁷	Average
Voiced Obstruent	10 ms (N = 16)	76 ms (N = 16)	43 ms (N = 32)
Devoiced Obstruent	20 ms (N = 40)	71 ms (N = 40)	46 ms (N = 80)
Unaspirated Stop/Aff	25 ms (N = 16)	113 ms (N = 16)	69 ms (N = 32)
Aspirated Stop/Aff	78 ms (N = 32)	116 ms (N = 32)	97 ms (N = 64)

Another factor to be included in the analyses was voicing. To show that the stimuli syllables' onset consonants differed in voicing, I measured the percentage of the consonant duration that was voiced. Table 15 gives the average percentage of the consonant that was voiced

⁷ VOT for affricates was measured from the release of the stop portion of the affricate to the beginning of voicing, an interval which usually included much of the affricate's frication period.

for the four types of stop/affricate onsets when the nonce words were uttered sentence-finally. For each phonemic voicing category, the syllables are broken down by stress and position since these factors are expected to affect phonetic voicing. Table 16 gives the average percentage of voicing when the nonce words were uttered in isolation. Table 16 contains no data for initial syllables because the closure durations of initial stops could not be determined when the nonce words were produced in isolation. No initial stop or affricate in the stimuli uttered in isolation exhibited prevoicing.

In the isolation context, phonemically voiced stops and affricates and phonemically voiceless stops and affricates differed significantly in the percentage of their duration that was voiced ($t = 9.5346, p < 0.0001$). Stops and affricates that were presumed to be phonetically voiced and phonetically devoiced did not differ significantly in the percentage of their duration that was voiced ($t = 0.4519, p = 0.6546$), suggesting that they were not actually different in their phonetic voicing. In the sentence context, phonemically voiced stops and affricates and phonemically voiceless stops and affricates also differed significantly in the percentage of their duration that was voiced ($t = 6.1715, p < 0.0001$). Unlike in the isolation context, presumably voiced and devoiced stops and affricates did differ significantly in the percentage of their duration that was voiced ($t = 3.6287, p = 0.014$). Moreover, devoiced stops and affricates in initial position did not differ from voiceless stops and affricates in how much of their duration was voiced ($t = -0.1175, p = 0.9074$). When not in final stressed position, devoiced stops and affricates patterned with voiceless stops and affricates in the sentence context, providing some evidence that expected phonetic voicing predicts the amount of actual voicing. In the isolation context, on the other hand, the pattern was by phonemic voicing, not phonetic voicing.

Table 15: Average Percentage of Consonant Duration Voiced – Sentence-Final Context

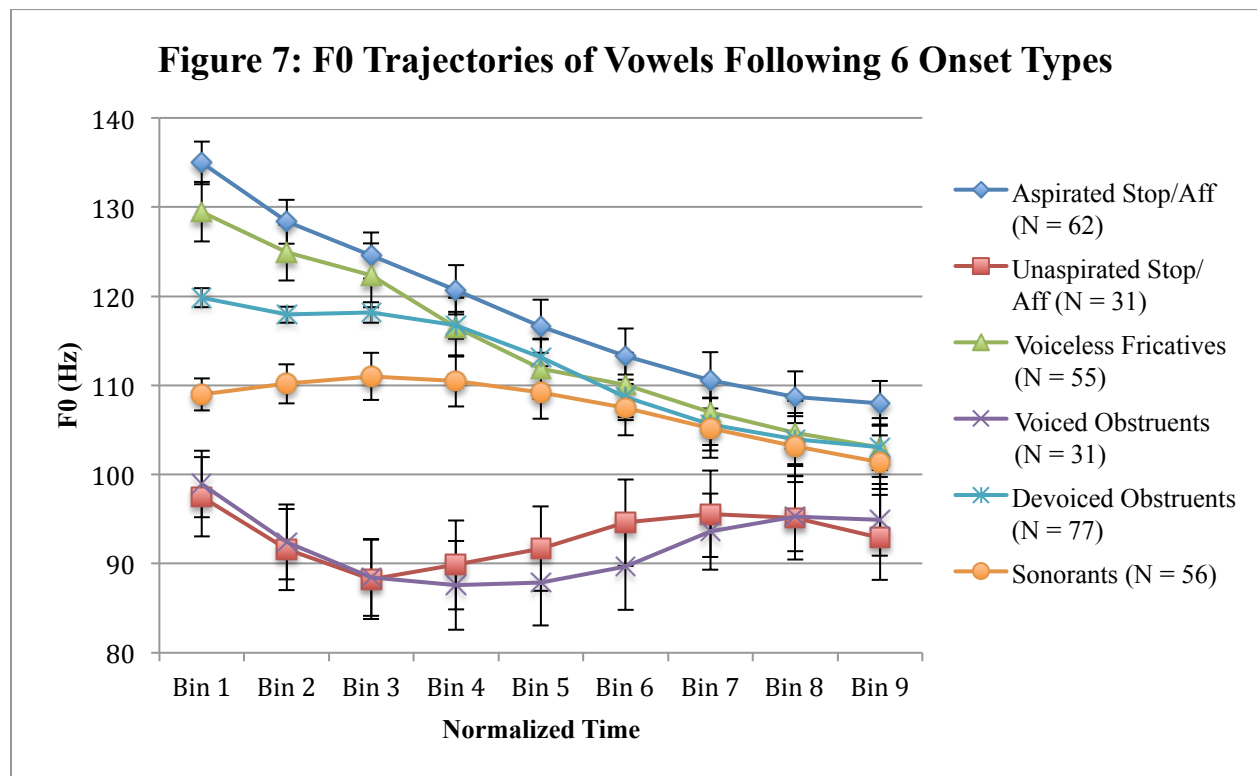
	Initial of Trochee	Final of Trochee	Initial of Iamb	Final of Iamb
Phonemically Voiced	<i>Devoiced</i> Affricate (N = 3): 0% Stop (N = 8): 23%	<i>Voiced</i> Affricate (N = 8): 28% Stop (N = 8): 91%	<i>Devoiced</i> Affricate (N = 8): 0% Stop (N = 4): 7%	<i>Devoiced</i> Affricate (N = 8): 35% Stop (N = 8): 68%
Phonemically Voiceless	<i>Aspirated</i> Affricate (N = 6): 0% Stop (N = 6): 0%	<i>Unaspirated</i> Affricate (N = 8): 9% Stop (N = 8): 8%	<i>Aspirated</i> Affricate (N = 6): 0% Stop (N = 6): 0%	<i>Aspirated</i> Affricate (N = 4): 3% Stop (N = 4): 5%

Table 16: Average Percentage of Consonant Duration Voiced – Isolation Context

	Initial of Trochee	Final of Trochee	Initial of Iamb	Final of Iamb
Phonemically Voiced	<i>Devoiced</i> —	<i>Voiced</i> Affricate (N = 8): 38% Stop (N = 8): 81%	<i>Devoiced</i> —	<i>Devoiced</i> Affricate (N = 8): 39% Stop (N = 8): 70%
Phonemically Voiceless	<i>Aspirated</i> —	<i>Unaspirated</i> Affricate (N = 8): 7% Stop (N = 8): 6%	<i>Aspirated</i> —	<i>Aspirated</i> Affricate (N = 4): 5% Stop (N = 4): 3%

My hypothesis that sonority and voicing will affect tonal assignment assumes that English sonority and voicing do cause perturbations in F0 at the beginning of a syllable. To show that F0 did differ after sonorants, voiced obstruents, and voiceless obstruents, I plot in Figure 7 the average F0 in 9 time bins following the 6 types of onsets in the stimuli. Tokens from the isolation and sentence contexts are pooled. F0 measurements were made using the program VoiceSauce (Shue et al. 2011). Eight tokens were omitted because VoiceSauce could not measure their F0. Note that syllables with voiced obstruent and unaspirated voiceless obstruent onsets were always final and unstressed; their overall lower pitch is attributable to the falling intonation of an English trochee uttered in a declarative sentence or in isolation. Error bars represent ± 1 standard error.

Figure 7 shows that F0 following aspirated voiceless stops and affricates and voiceless fricatives was similar and higher than after any other type of onset for about the first third of the vowel. F0 following devoiced stops and affricates was lower than after the aforementioned voiceless obstruents, and F0 following sonorants was even lower than after devoiced stops and affricates. Voiced obstruents and unaspirated voiceless stops and affricates cannot be compared to the other types of onsets because of their limited distribution, but they can be compared to each other. Unexpectedly, F0 following these two types of obstruents appears to have been the same during the first third of the vowel. In the middle of the vowel, F0 was lower in syllables with voiced obstruent onsets, but the difference does not look significant. Possibly if there had been more tokens with these two types of onsets, as there are for the other types, a significant difference would have emerged. Overall, Figure 7 provides evidence that the expected lowering effects of sonorancy and voicedness are present to a degree in the stimuli.



4.1.2 Subjects

The participants were fifteen UCLA students (both graduate and undergraduate) of Chinese nationality. They ranged in age from 18 to 24, with a median age of 18.5 years. Six subjects were male and nine female. All subjects were native speakers of Mandarin Chinese and reported having grown up in Mainland China. The age at which they began learning English ranged from 5 to 12 (median: 7). Nine subjects indicated that they spoke one or more languages in addition to English and Mandarin. These languages were Japanese (5 subjects), Cantonese (3 subjects), the Suzhou dialect (1 subject), and French (1 subject) (one subject spoke both Japanese and Cantonese). All subjects had lived in the United States for two years or less (range: 3 months to 24 months; median: 6 months).

4.1.3 Procedure

The experiment was implemented in the software E-Prime 2.0 and conducted in a soundproof booth on a computer. Subjects wore a Plantronics Audio 400 DSP headset. They first viewed written instructions in Mandarin informing them that they would hear made-up English words and that their task was to say and then write how they would most naturally adapt these English words into Mandarin. Subjects then completed four practice trials with the researcher present. After the practice phase, subjects had the opportunity to ask the researcher questions. The researcher then left the sound booth.

Subjects proceeded at their own pace through a single block of 80 trials corresponding to the 80 disyllabic nonce stimuli. The 80 trials were randomly ordered for each subject. Subjects had the option of taking a break after completing 40 trials. In each trial, subjects heard the nonce word in its frame while viewing a blank screen. Instructions in Mandarin then appeared on the screen, asking them to say out loud how they would adapt the nonce word into Mandarin. This

oral response was recorded. When they had given their oral response, subjects pressed the ENTER key, whereupon instructions in Mandarin appeared asking them to type in Pinyin, using numbers to indicate tone, the adaptation they had just spoken. Subjects were able to see what they typed on the screen and change the text they had entered. Their final written response was recorded. When they had entered their written response, subjects pressed the ENTER key, initiating the next trial. The total duration of the experiment was approximately 20 to 30 minutes.

The analysis was carried out on the subjects' oral responses. Each subject's oral responses were independently transcribed in Pinyin, using numbers to indicate tones, by two native Mandarin speakers. The transcribers did not have access to the English nonce word stimuli and were not aware of the researcher's hypotheses regarding factors that might influence tonal assignment in loanword adaptation. The overall degree of agreement between transcribers on each subject's responses was high. The rate of perfect agreement on transcription (i.e. segments and tones) ranged from 73% to 97% depending on the subject, with an average rate across subjects of 91%. The rate of agreement on the transcription of tones ranged from 79% to 98% with an average of 94%.

Tokens for which the transcribers' transcriptions did not match were flagged. The researcher listened to the recorded oral responses for these tokens and contributed a third independent transcription. If the researcher's transcription matched one of the transcriber's transcriptions, that transcription was chosen as the oral response for analysis. If no two of the three transcriptions matched, the token was excluded from the analysis.

Cases in which the transcribers agreed upon a tonal transcription that did not match the tone of the subject's written response were also flagged. In these cases, the researcher also listened to the recorded oral response and transcribed it without reference to the transcribers'

transcription or the subject's written response. In most cases, the researcher deemed the transcribers' tonal transcription to be correct and the tone of the written response to be an error (e.g. a typo, a failure to remember the adaptation just given orally, etc.). The very few tokens for which the researcher's tonal transcription matched the subject's written response and not the transcribers' agreed upon tonal transcription, or for which the researcher's tonal transcription matched neither the subject's written response nor the transcribers' transcription, were excluded from the analysis.

Tokens were also excluded from the analysis if third tone sandhi made it impossible to determine whether the intended response was second tone or third tone. When the first syllable of the adaptation bore second tone and the second syllable bore third tone, the first syllable could have been underlyingly second tone or underlyingly third tone and realized with second tone due to third tone sandhi. The first syllables in such cases were excluded.

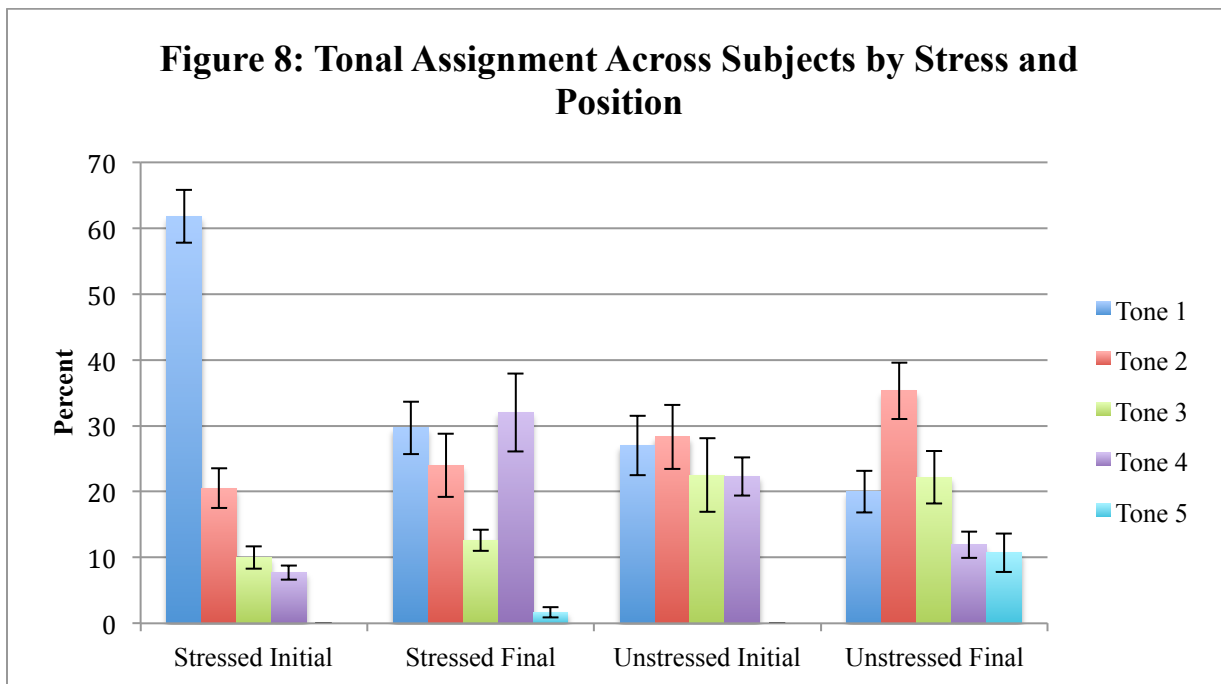
A small number of tokens were excluded due to unintelligibility or due to their not having been recorded because the subject began their oral response before the experiment prompted them to do so and began recording. Finally, a handful of tokens were excluded because subjects perceived the nonce word stimulus as a real word of English and gave as their oral response the Mandarin translation of the English word. The two stimuli that provoked this response in some subjects were [dʒə'pɪn] (expected segmental adaptation: *zhapin*) and [shəɪ'gɑ] (expected segmental adaptation: *shiga*). [dʒə'pɪn] was taken to be *Japan* and translated as *riběn* 'Japan'. [shəɪ'gɑ] was taken to be *cigar* and translated as *xuějiā* 'cigar,' which is in fact an English loanword.

The total number of tokens excluded was 118, leaving 2,282 analyzable tokens.

4.2 Results and Discussion

4.2.1 Tonal Assignment by Stress, Position, and Onset Type

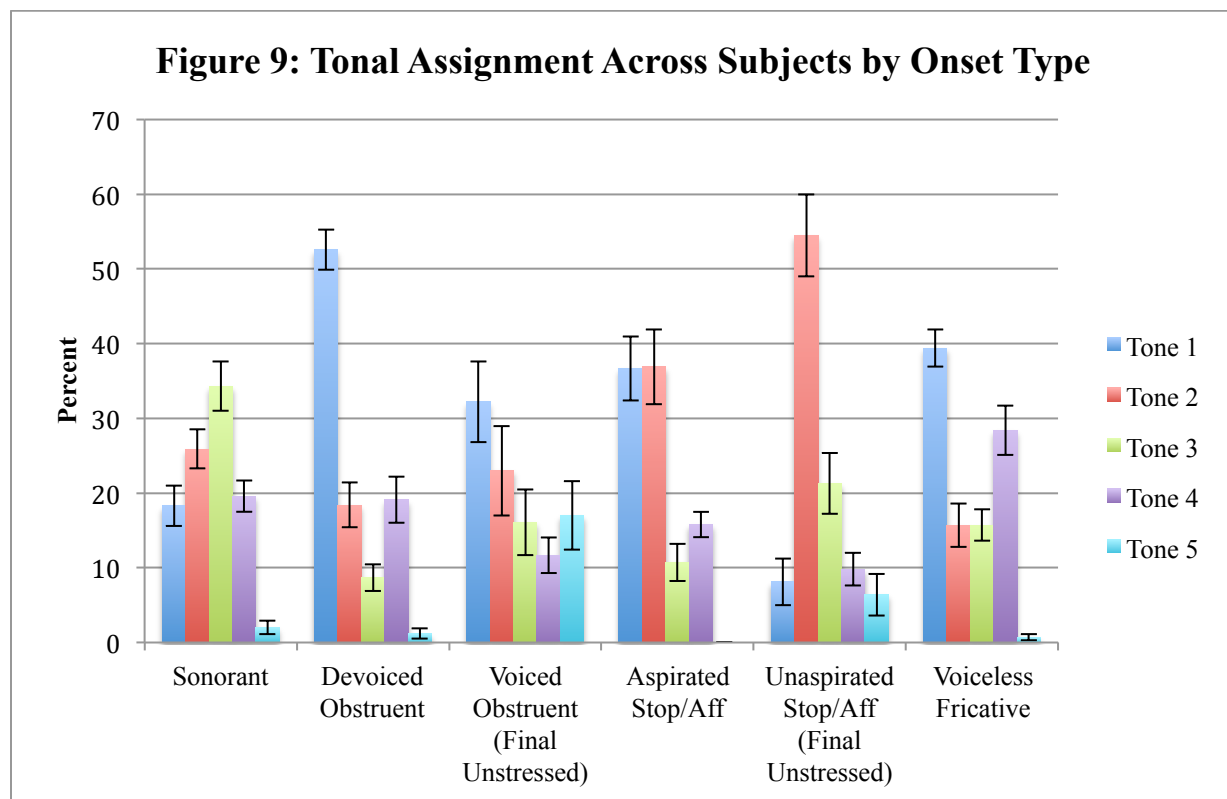
I first examine the basic tonal assignment patterns in the experimental results. Figure 8 shows the percentage of the time syllables were adapted with each of the five tones by the syllables' stress and position in English. Error bars represent ± 1 standard error.



Stressed initial syllables strongly prefer first tone assignment, while stressed final syllables receive a wider variety of tones but exhibit a preference for fourth tone not seen in stressed initial syllables. These preferences seem to reflect a tonal assignment strategy that seeks to imitate the stress-related pitch contours of English words. First tone captures the high pitch of an initial stressed syllable while fourth tone captures the falling contour of a final stressed syllable. There is less of a clear favorite among unstressed syllables, particularly unstressed initial syllables. Unstressed final syllables have a distinct preference for second tone, which recalls the fact that unstressed syllables in the corpus were more likely to be adapted with second

tone than stressed syllables (Section 3.4). I suggested that this pattern reflected the relatively lower pitch of English unstressed syllables, but the decision tree showed that stress was not a robust predictor of tone throughout the corpus. Based on Figure 8, it appears that stress may have played a more important role in the experiment.

Figure 9 shows the tones syllables were adapted with by the six types of onsets in the stimuli set. Recall that voiced obstruents and voiceless unaspirated stops and affricates only occurred as the onsets of final unstressed syllables. Additionally, devoiced obstruents and voiceless aspirated stops and affricates never occurred as the onsets of final unstressed syllables.



The most striking result in Figure 9 is that the tonal adaptation of syllables beginning with voiced and voiceless stops/affricates contradicts the hypothesis I proposed based on the corpus results. I predicted that syllables with voiceless stop/affricate onsets would prefer first tone while syllables with voiced stop/affricate onsets would prefer second tone due to the

lowering effect of voiced obstruents on F0. In Figure 9, both the Devoiced Obstruent and Voiced Obstruent groups receive first tone most often instead of the expected second tone. The Aspirated Stop/Affricate group receives first and second tone equally often when it was expected to show a first tone preference. The Unaspirated Stop/Affricate group, also predicted to prefer first tone, instead strongly prefers second tone, though the fact that these syllables are unstressed may also play a role in this preference. Roughly speaking, the tones that syllables beginning with voiced and voiceless stops/affricates prefer are precisely the opposite of what was hypothesized and moreover run counter to the phonetic explanation based on the effects of voicing on F0. These results might recall Wu's (2006) generalizations about tonal adaptation. She claimed that loanword syllables with unaspirated Mandarin onsets tended to receive first tone while those with aspirated Mandarin onsets tended to receive second tone. The expected segmental adaptations of the devoiced and voiced obstruent onsets are unaspirated Mandarin consonants, and the expected segmental adaptations of the aspirated and unaspirated stop/affricate onsets are aspirated Mandarin consonants. The actual adaptations of these consonants were of the expected type. From this perspective, then, Wu's claim seems to be borne out, even though that was not the case in the corpus study.

Figures 8 and 9 provide an initial picture of the experimental results, but when looking at only one or two variables at a time, it is not possible to uncover interactions in the data. To overcome this drawback, I next analyze the experimental results by generating a decision tree of the same type I used for the corpus results in Section 3.5.

4.2.2 Analyzing the Experimental Results with a Decision Tree

The decision tree for the experimental results shows the tones subjects used to adapt stimuli syllables. The independent variables supplied to the `crtree()` function were Stress

(Stressed or Unstressed), Position (Initial or Final), Sonority (Sonorant or Obstruent), PhonemicVoicing (Voiced or Voiceless), ExpAspiration (expected surface aspiration; Aspirated, Unaspirated, or Null, where Null is the value sonorant and fricatives onsets have), and PreviousSamePositionTone (the tone the subject used to adapt the syllable in the same position, initial or final, in the previous item; Tones 1-5). When the variable PhonemicVoicing is replaced with the variable ExpSurfVoicing (expected surface voicing), the resulting decision tree is identical, making all the same splits. The `cTree()` function does not classify the data differently when phonetic voicing is considered instead of phonemic voicing, so I present the tree that used PhonemicVoicing. Like the decision tree in Section 3.5, this one is too large to show all at once, so I divide it into two branches. The first split, which is not visible, is by Stress. This suggests Stress was the most important predictor of tone in the experimental adaptations. In contrast, the first split in the decision tree for the corpus loanwords was by English voicing.

The Stressed branch of the full decision tree is shown in Figure 10. The tokens represented in this branch are the adaptations by all fifteen subjects of the stressed syllables of the stimuli. Of the ten terminal node graphs in the Stressed branch of the tree, half (Nodes 3, 8, 9, 10, and 14, representing 739 out of 1,149 syllables, or 64%) exhibit a preference for first tone assignment. This echoes the finding from the corpus study that English stress is associated with Mandarin first tone assignment and supports my third hypothesis.

The adaptations of stressed stimuli syllables first split by ExpAspiration. This split divides adaptations of syllables with voiceless stop/affricate onsets from adaptations of syllables with voiced stop/affricate onsets (devoiced, since the syllables are stressed), voiceless fricative onsets, or sonorant onsets. The adaptations of syllables with voiceless stop/affricate onsets then split by Position (Node 2). The adaptations of initial syllables with voiceless stop/affricate onsets

(Node 3) most frequently bear first tone, though they bear second tone almost as often. Note that this matches Wu's (2006) broad generalization that English stressed initial syllables are adapted with first or second tone. The adaptations of final syllables with voiceless stop/affricate onsets (Node 4) most frequently bear second tone but bear fourth tone almost as often.

The adaptations of syllables with voiced stop/affricate onsets, voiceless fricative onsets, or sonorant onsets also split next by Position (Node 5). The adaptations of initial syllables split by Sonority (Node 6), isolating the adaptations of initial stressed syllables with sonorant onsets (Node 10). These syllables receive first tone most often but receive second and third tone quite frequently too. Comparing the graph in Node 10 with the graphs of Nodes 8 and 9, which represent the adaptations of initial stressed syllables with obstruent onsets, we see that the adaptations of the syllables with sonorant onsets receive first tone much less often and second tone (as well as third tone) much more often. This is consistent with my corpus finding that English sonorant onsets increase the likelihood of second tone assignment. The adaptations of initial stressed syllables with obstruent onsets finally split by ExpAspiration. Effectively, this split divides adaptations of syllables with voiced stop/affricate onsets from adaptations of syllables with voiceless fricative onsets. The tones these syllables bear in Mandarin are fairly similar, with a strong preference for first tone. The syllables with voiceless fricative onsets receive fourth tone more often than the syllables with voiced stop/affricate onsets.

Returning to Node 5, the adaptations of final stressed syllables with voiced stop/affricate onsets, voiceless fricative onsets, or sonorant onsets split by ExpAspiration. This divides the syllables with voiced stop/affricate onsets from those with voiceless fricative or sonorant onsets. Terminal Nodes 13 and 14 show the tones the former syllables are adapted with. Overall, they tend to receive first and fourth tones. Interestingly, the tree makes a split by

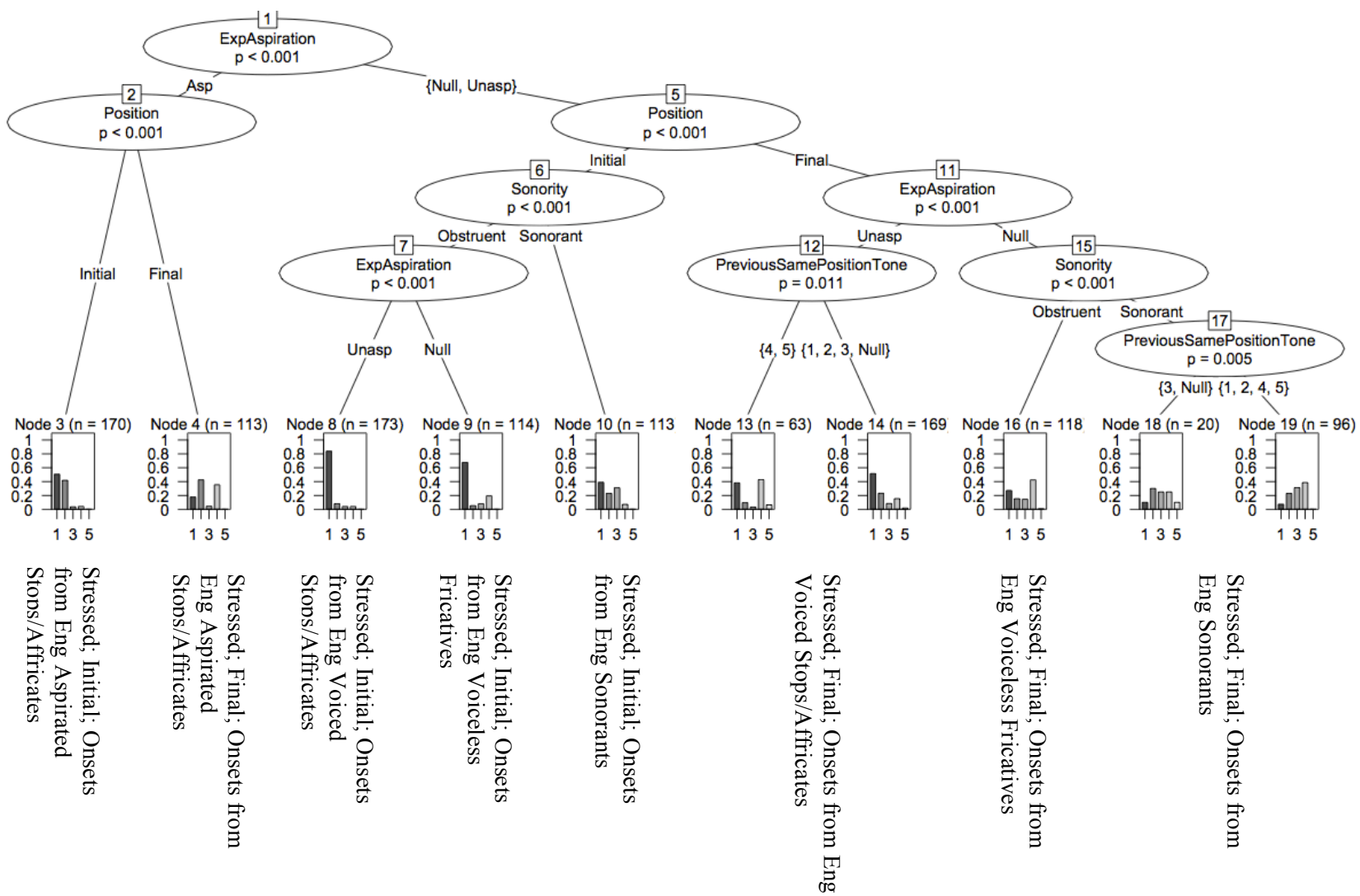


Figure 10: Decision Tree for Adapted Syllables — Stressed Branch

PreviousSamePositionTone. When subjects had adapted the final syllable of the previous item with first tone (or second or third or when there was no previous item), they most often chose first tone. When subjects had adapted the final syllable of the previous item with fourth tone (or fifth tone), they most often chose fourth tone. This suggests there is at least some effect of subjects falling into a pattern whereby they adapt the syllable of a new item with the same tone they used to adapt the syllable in the same position (initial or final) in the previous item.

Returning to Node 11, the adaptations of final stressed syllables with sonorant or voiceless fricative onsets split by Sonority (Node 15), meaning they split into syllables with sonorant onsets and syllables with voiceless fricative onsets. The final stressed syllables with voiceless fricative onsets receive fourth tone most often (Node 16). The final stressed syllables with sonorant onsets make one last split by PreviousSamePositionTone (Node 17). Here, the influence of the tone with which subjects adapted the previous final syllable is not so clear.

Amid the details of the many splits in the stressed branch of the decision tree, a few trends stand out. Though the first split after the split by Stress at the root node is by ExpAspiration, both branches split next by Position, hinting that, after Stress, Position may be one of the strongest predictors of tonal assignment in the experimental results. In the aggregate, stressed initial syllables (Nodes 3, 8, 9, and 10) most often receive first tone. Stressed final syllables (Nodes 4, 13, 14, 16, 18, and 19) receive a wider variety of tones, but a preference for first tone is less common than among the various types of stressed initial syllables, and fourth tone stands out as being frequently assigned. This is what we saw in Figure 8 in the previous section and supports the notion that tonal adaptation in stressed syllables exhibits faithfulness to English prosody. Stressed syllables with sonorant onsets, especially when final, receive first tone less often than other stressed syllables, which may be a reflection of the lowering effect of

sonorant onsets on F0. Finally, stressed syllables with phonemically voiced stop/affricate onsets (Nodes 8, 13, and 14) tend to receive first tone and, to a lesser extent, fourth tone, but not second tone, which is what I would have expected from my corpus results. The hypothesized association between English voiced obstruents and second tone assignment does not emerge, at least in the stressed branch of the decision tree.

The Unstressed branch of the decision tree is shown in Figure 11. The tokens in this decision tree are the adaptations by all fifteen subjects of the unstressed syllables of the stimuli. Overall, the terminal node graphs for the unstressed syllables show less extreme distributions of tones than the terminal node graphs for the stressed syllables. This is similar to what we saw in Figure 8. There is no one particular tone that stands out as preferred for the adaptation of unstressed syllables, though first tone assignment looks less likely overall for these syllables than for the adaptations of stressed syllables. This is consistent with the corpus finding that English unstressed syllables tend not to receive first tone and supports my third hypothesis.

The first split among the adaptations of unstressed syllables is by Position, again suggesting that Position is the most significant predictor of tonal assignment after Stress. The adaptations of initial unstressed syllables then split by PreviousSamePositionTone (Node 2). Subjects tended to adapt an initial unstressed syllable with third tone when they had adapted the initial syllable of the previous item with third tone (Node 3). The rest of the initial unstressed syllables split by Sonority (Node 4). Terminal Node 6 shows the tones used to adapt initial unstressed syllables with sonorant onsets. Second tone is most frequent and first tone least frequent, consistent with my previous findings about sonorants. Terminal Node 5 shows the tones used to adapt initial unstressed syllables whose onsets are devoiced stops/affricates,

voiceless aspirated stop/affricates, and voiceless fricatives. First, second, and fourth tone are all assigned fairly often to these syllables.

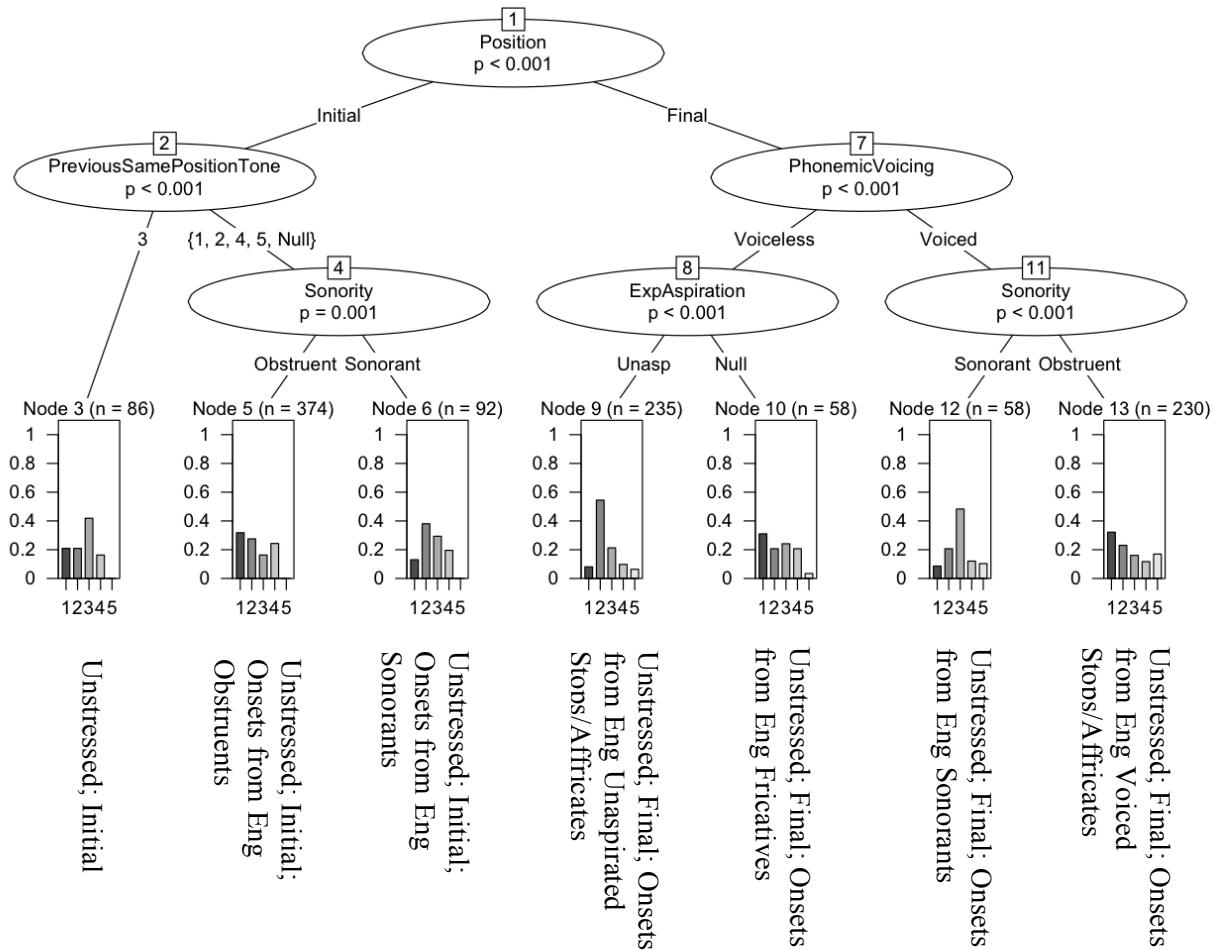


Figure 11: Decision Tree for Adapted Syllables — Unstressed Branch

The adaptations of final unstressed syllables split by PhonemicVoicing (Node 7). The voiceless branch includes adaptations of syllables whose onsets are voiceless unaspirated stops/affricates or voiceless fricatives, and the voiced branch includes adaptations of syllables whose onsets are voiced stops/affricates or sonorants. The final unstressed syllables with voiceless onsets split a final time by ExpAspiration (Node 8), dividing the syllables with stop/affricate onsets from those with fricative onsets. The adaptations of final unstressed syllables with voiceless unaspirated stop/affricate onsets have a strong tendency to bear second

tone (Node 9). A second tone preference is in line with my expectations for unstressed syllables overall (see Figure 8) but not for syllables with voiceless onsets in English. The adaptations of final unstressed syllables with voiceless fricative onsets do receive first tone most often (Node 10), as is expected given the onsets' voicelessness, but they receive second, third, and fourth tones almost as often.

Moving back up to Node 11, the final unstressed syllables with voiced onsets split a final time by Sonority, dividing the syllables with voiced stop/affricate onsets from those with sonorant onsets. The former receive first tone most often (Node 13), which is not expected given that the syllables are unstressed and have phonetically voiced obstruent onsets in English. Both these characteristics were associated with second tone assignment in the corpus study. The adaptations of the syllables with sonorant onsets have a strong tendency to receive third tone, though third tone was never preferred above all by any subset of syllables in the corpus. Third tone assignment here could reflect both the relatively low pitch of unstressed English syllables and the lowering effect of sonorant onsets. On the other hand, its prevalence may be related to the specific English syllables with sonorant onsets that were chosen for the stimuli.

Overall, the decision tree represented in Figures 10 and 11 suggests that stress and position are the most significant determinants of tonal assignment in the experimental results. Voicing does not play as important a role as in the corpus study, and when it does play a role, its effect is contrary to my expectations. Like Figure 9, the decision tree reveals an unexpected association between voicedness and first tone and between voicelessness and second tone.

4.2.3 Standard Loanword Syllables in the Experiment

It is possible that the unexpected voicing effect found in the experiment does not reflect general principles of tonal adaptation but instead is related to the codification of loanword

syllables discussed in Section 3.6. Recall that my stimuli were constructed from a small set of English syllables. The set of expected Mandarin segmental adaptations was even smaller, since in all but one case the expected adaptation remained the same whether the English syllable appeared with a full vowel or a reduced vowel. In Section 3.6, I provided evidence that some English syllables in the corpus were being consistently adapted with a single syllable (including tone) or character regardless of their context, suggesting the influence of convention and standardization in English-to-Mandarin loanword adaptation. As I mentioned then, institutions like state committees and the Xinhua News Agency do dictate official adaptations of proper names. The stimuli in my experiment were nonce words and thus not proper names, and the frame in which they appeared would presumably bias subjects against treating them as proper names, since they were referred to as “words.” Nevertheless, familiarity with how English proper names are adapted into Mandarin according to official guidelines might lead subjects, consciously or unconsciously, to apply the same adaptation patterns to the experiment stimuli.

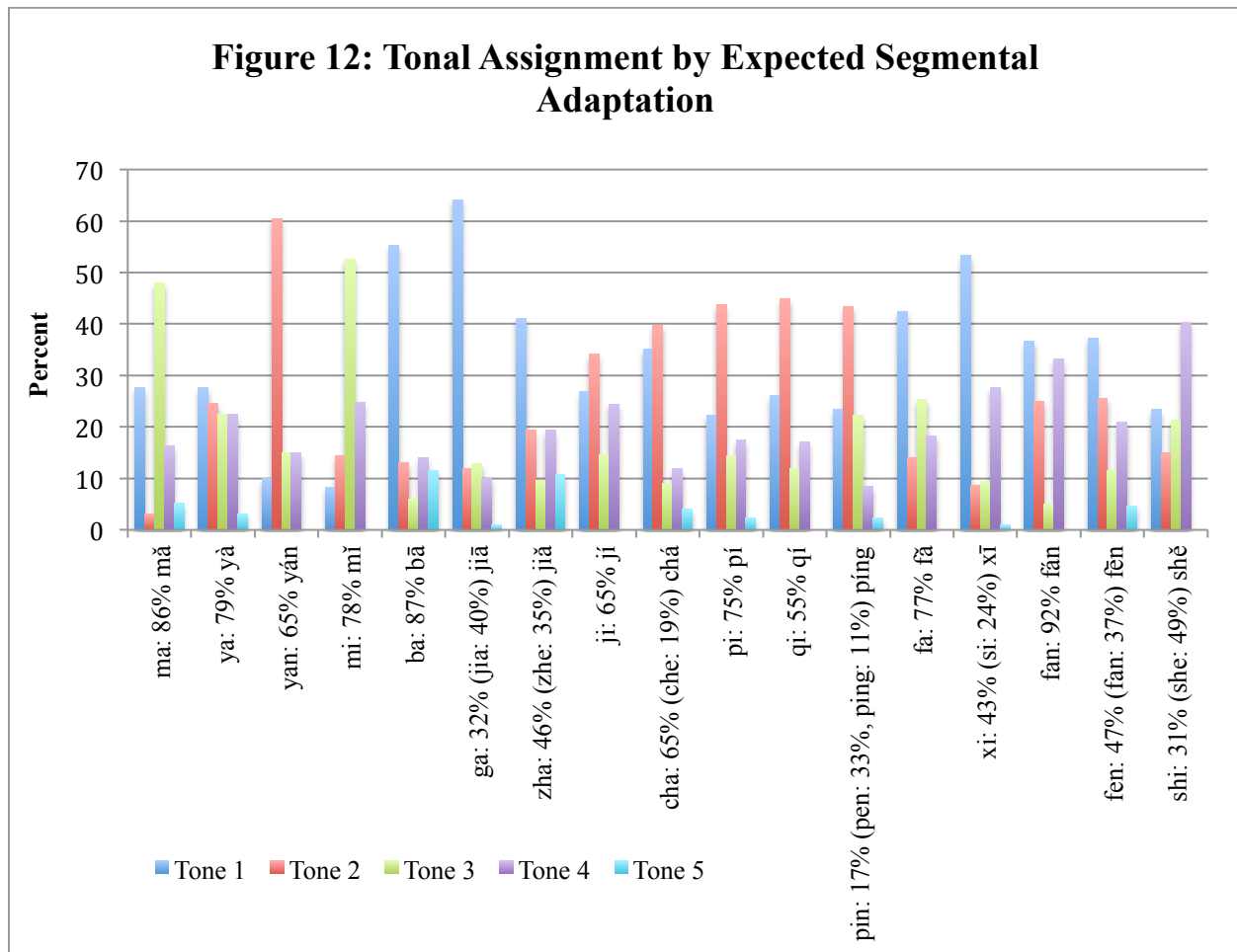
To assess the degree to which this might have been the case in the experiment, I looked up the English syllable that corresponded to each of the 17 expected Mandarin segmental adaptations in a transcription chart in *Names of the World's Peoples* (Xinhua News Agency 1993), a proper names dictionary. The transcription chart, which is specific to English, has columns corresponding to onset consonants and rows corresponding to vowel nuclei or syllable rimes. Each cell gives the character prescribed for the adaptation of a particular English syllable. For instance, the character in the cell for the English syllable /pi:/ is 皮 *pí*.

The disyllabic nonce word stimuli were constructed from 16 English syllables (setting vowel reduction aside). For 15 of the 16 syllables, the expected segmental adaptation was the same for the English syllable whether it was stressed, with a full vowel, or unstressed, with a

reduced vowel (schwa). In these cases, I looked up the English syllable in its stressed form, with the full vowel (e.g. for the English syllables [ba] and [bə], both of which had the expected Mandarin adaptation *ba*, I looked up [ba] in the chart and not [bə]). The syllable [fæn], which appeared as [fən] in unstressed position, did have different expected segmental adaptations depending on its stress (*fan* in stressed position and *fen* in unstressed position), so I looked up [fæn] and [fən] separately in the chart. Thus there were 17 distinct syllables instead of 16. Figure 12 shows the tones assigned to these individual syllables, regardless of their segmental adaptation. Each set of bars is labeled with the expected segmental adaptation of the given English syllable and the percentage of the time the expected Mandarin syllable (with any tone) was actually used by subjects. If a different Mandarin syllable was often used to adapt the given English syllable, it is listed in parentheses along with the percentage of the time it was used. Finally, I list the Mandarin syllable including tone listed in the Xinhua News Agency chart for the given English syllable.

Figure 12 reveals several interesting things about the experimental data. Firstly, subjects used the Mandarin segmental adaptation I expected a majority of the time for 11 out of the 17 English syllables. Secondly, in cases where the expected segmental adaptation did not match the segmental adaptation listed in the Xinhua News Agency chart, subjects often still used the segmental adaptation I predicted, sometimes more often than the “official” segmental adaptation. For instance, subjects adapted English [dʒɑ]/[dʒə] with the expected Mandarin syllable *zha* 46% of the time even though the chart indicates that the syllable *jiǎ* should be used for [dʒɑ] (moreover, the second most used syllable was *zhe*, not *jia*). The Xinhua News Agency chart gives *jiā* as the adaptation of English [gɑ], and 40% of the time subjects did use the syllable *jia* to adapt [gɑ]/[gə], suggesting they were familiar with this convention. However, they also used

Figure 12: Tonal Assignment by Expected Segmental Adaptation



ga, the segmental adaptation I had expected, 32% of the time. It seems they do not uniformly adhere to official standards or conventions but do try to match the English form as closely as possible. Mandarin has many more characters with the pronunciation *jia* than characters with the pronunciation *ga* (MDBG 2014), and words containing *jia* are more frequent than those containing *ga*. This difference in frequency may be behind the choice of *jiā* as the official adaptation of English [ga]. The fact that subjects still used *ga* almost a third of the time suggests that phonetic similarity can also resist frequency effects.

The third thing to notice in Figure 12 is that each syllable tends to exhibit a strong preference for a single tone. Moreover, in most cases the preferred tone is the tone of the syllable

listed in the Xinhua News Agency chart, suggesting that subjects have knowledge of official adaptation standards (or at least of syllables that are commonly used in English loanwords) and are applying this knowledge in their online adaptations. Consider the syllables with sonorant onsets. Three out of the four syllables, namely, those I expected to be adapted with *ma*, *yan*, and *mi*, have strong tendencies to be adapted with the tone the Xinhua News Agency chart states they should be adapted with. In the aggregate, this results in an overall dispreference for first tone and a preference for second and third tones on the part of syllables with sonorant onsets, a finding that emerged from the decision tree as well. What Figure 12 suggests, though, is that this pattern might not be due to a lowering effect of sonorant onsets on F0 but rather to adaptation conventions for the specific sonorant-initial syllables included in the stimuli set.

As I proposed for the standard epenthetic syllables in Section 3.6, the standard syllables in the Xinhua News Agency chart may themselves reflect phonetic principles. That is, *mǎ*, *yán*, and *mǐ* may have been selected, with those tones, as the official adaptations of English [ma], [jɛn], and [mi:] because sonorant onsets lower F0. However, I have no direct evidence that phonetic principles motivated the selection of particular standard syllables. It is equally conceivable that some other factor, like frequency or semantics, governed the choice of syllables. Additionally, the standard syllables for other types of English syllables do not reflect expected phonetic principles. Figure 12 suggests why, in direct contradiction to my hypothesis, English syllables with voiced stop or affricate onsets tended to receive first tone while those with voiceless stop or affricate onsets tended to receive second tone. The official Mandarin adaptations for two of the four syllables in the voiced category (*ba* and *ga*) bear first tone, and these syllables were in fact overwhelmingly adapted with first tone. The only syllable in the voiced category that exhibits a slight preference for second tone adaptation is *ji*, and this

syllable's standard adaptation bears second tone. It is reasonable to suppose that this syllable prefers second tone due to the influence of official standards and not the lowering effect of a voiced obstruent onset on F0, particularly since no other English syllable with a voiced obstruent onset prefers second tone assignment. Like *ba* and *ga*, the last syllable in the voiced category, *zha*, also has a strong tendency to be adapted with first tone, although the corresponding syllable from the Xinhua News Agency chart bears third tone. The reason for this discrepancy may be that English [dʒa]/[dʒə] were most often adapted with *zha* and not *jia*, the segmental adaptation listed in the chart.

Turning to the syllables in the voiceless stop/affricate category, all four have standard adaptations that bear second tone (*chá*, *pí*, *qí*, and *píng*), and all four are adapted most often with second tone. I expected syllables in this category to prefer first tone for phonetic reasons. The second tone preference may arise not because the voicing-to-tone hypothesis is incorrect but because the syllables chosen for the stimuli happen to be officially adapted with second tone and subjects' responses reflected official standards. One might again wonder whether the choice of tone for the standard Mandarin syllables in the Xinhua News Agency chart follows any phonetic principles and whether these could be at odds with the ones I have proposed. This question is not easy to answer, but it is not the case that all or even most English syllables with voiceless stop or affricate onsets are given second tone adaptations in the Xinhua News Agency chart.

To sum up, the reason the voicing effect that emerged from the experimental data is the opposite of the one that emerged from the corpus data seems to be because the stimuli syllables selected for the experiment happened to have standard adaptations which were adhered to. This resulted in apparent associations between phonemically voiced stop/affricate onsets and first tone and between phonemically voiceless stop/affricate onsets and second tone. There are two reasons

to favor the voicing effect from the corpus over the one from the experiment. First, the corpus contained a much wider variety of English syllables than the experiment's stimuli set, so the corpus study is more likely to have uncovered a valid generalization. Second, the voicing effect found in the corpus study has a phonetic basis while the one found in the experiment does not.

Because Figure 12 revealed that individual syllables had such strong tendencies to be adapted with particular tones, I carried out another analysis designed to uncover tonal adaptation patterns beyond individual syllables' preferences. The approach I took was to model the experimental data with a maxent grammar.

4.2.4 Analyzing the Experimental Results with a Maxent Grammar

A maxent grammar (Hayes & Wilson 2008) is a probabilistic constraint-based grammar that can handle variation. The grammar's constraints have weights, and candidates for each input receive harmony scores, which are the sum of their weighted constraint violations. The harmony scores are used to generate a probability of occurrence for each candidate. A successful maxent grammar model generates candidate probabilities that closely match candidates' observed frequencies.

To analyze my experimental results, I used the Maxent Grammar Tool (Wilson & George 2009) to find weights for a predetermined constraint set. The Maxent Grammar Tool takes an input file with inputs, candidates, candidates' observed frequencies, constraints, and constraint violations and finds the constraint weights that enable the grammar to best predict candidates' observed frequencies. In this case, the inputs were the 80 disyllabic English nonce words that constituted the experiment stimuli. The candidates for each input were all possible tone combinations for a disyllabic adapted form. Fifth tone can only occur finally (no subject ever

produced an adaptation with a fifth tone syllable anywhere but in final position), so there are 20 possible tonal adaptations (4 tones for initial syllables x 5 tones for final syllables = 20).

The candidates' observed frequencies were taken directly from the results of the experiment, with all subjects' responses pooled. Thus there were 15 observed forms for each input (except in cases where an experimental token was excluded; see Section 4.1.3). For instance, the input ['baga] was adapted twice as first tone-first tone, 3 times as first tone-second tone, 6 times as first tone-third tone, 3 times as first tone-fourth tone, and once as first tone-fifth tone. Therefore the observed frequencies for the candidates 1-1 (for first tone-first tone), 1-2, 1-3, 1-4, and 1-5 were 2, 3, 6, 3, and 1, respectively, while all remaining candidates for ['baga] had observed frequencies of zero. With regard to second tone-third tone adaptations, these were excluded from the maxent grammar models just as in other analyses. I treated the maxent grammar as though it was modeling underlying forms, and I could not determine the underlying form of a surface second tone-third tone sequence. I retained 2-3 and 3-3 (the two possible underlying forms of a surface second tone-third tone sequence) as candidates, however, since for the adapted forms I did include in the model, it was known that they had not been adapted with 2-3 or 3-3.

The constraints I included in the maxent grammar expressed the same stimuli characteristics I used to predict tonal adaptation in the decision tree. I chose to use positive constraints (e.g. if stressed in English, be adapted with first tone) rather than negative constraints (e.g. if stressed in English, do not be adapted with first tone) because they make it easier to evaluate my hypotheses and are more amenable to comparison with the generalizations drawn from the decision tree. I began with a full set of constraints for the variables Stress, Position, Sonority, and PhonemicVoicing. I also included constraints that enforced syllables beginning

with fricatives being adapted with each of the five tones because no other constraint or combination of constraints could single out fricative onsets. I did not include constraints for the variables ExpSurfVoicing or ExpAspiration because such constraints are in fact conjoined constraints consisting of some combination of other constraints. For example, syllables that are expected to be voiced on the surface are syllables whose onsets are sonorants or final unstressed syllables whose onsets are phonemically voiced obstruents. Finally, because of individual syllables' preferences for certain tones, as evidenced by Figure 12, I included a set of constraints that enforced the adaptation of each of the seventeen distinct syllables with the tone it is officially supposed to take according to the Xinhua News Agency chart. For instance, since the character listed in the chart for the English syllable [ba] (expected Mandarin segmental adaptation: *ba*) is 巴 *bā*, I created a constraint BA1, which assigns one violation to any candidate whose input includes the English syllable [ba] or [bə] and which does not adapt this syllable with first tone.

In modeling the experimental data with a maxent grammar, I was principally interested in the weights of the constraints in the best model. A constraint's weight indicates the degree to which attested forms obey it. In the case of my loanword adaptation experiment, weights reveal the strengths of the adaptation principles the constraints express. For example, if the constraint INITIAL1 receives a high weight, it means initial syllables tend to be adapted with first tone and that this tendency is stronger than tendencies expressed by lower-weighted constraints. The purpose of the constraints formulated from the Xinhua News Agency chart is to absorb the weight that comes from individual syllables' preferences for specific tones. They are akin to a random effect for syllable in a regression model. They allow me to be more confident that the weights of other constraints in the model represent actual patterns in loanword adaptation and not

just the fact that all the individual syllables in a particular category happen to be standardly adapted with the same tone. More concretely, with the constraints CHA2, PI2, QI2, and PIN2 included in the grammar (recall that all four stimuli syllables with phonemically voiceless stop/affricate onsets have official adaptations that bear second tone), if the constraint VOICELESS1 still receives a non-trivial weight, this suggests that beyond these syllables' tendencies to be assigned second tone there is a tendency for syllables with voiceless stop/affricate onsets to receive first tone.

I began with the full set of 62 constraints and used the Maxent Grammar Tool to find the weights. I removed constraints that received a weight of zero from the model. Thereafter, I continued removing the lowest-weighted constraints from the model until removing a single constraint made the model's fit significantly worse. I determined whether a trimmed model was significantly worse than a larger model by using the likelihood ratio test, which compares the likelihood of two nested models. If the likelihood of a model is significantly worse than a model with more constraints, then those constraints are worth keeping in the model. On the other hand, if removing one or more constraints from the model does not significantly worsen the model's likelihood, those constraints are not contributing to the model and can be removed.

The optimal model found through this process included the constraints and weights given in Table 17, with constraints listed in ascending order by weight. The model contains 27 of the original 62 constraints. Fourteen of the 17 constraints designed for individual syllables are included in the final model, confirming that stimuli syllables with particular expected segmental adaptations did have strong preferences for the tones the Xinhua News Agency chart prescribed for them. What are of interest are the constraints that remain in the grammar in addition to the individual syllable constraints. The highest-weighted of these constraints is STRESS1. This tells

us that the strongest tonal adaptation principle in the experimental data is the assignment of first tone to stressed English syllables. The maxent model reinforces what was seen with the graph in Figure 8 and in the decision tree, which made its first split by English stress. This finding supports my hypothesis about the relationship between stress and tone.

Table 17: Constraints and Weights of the Maxent Model of the Experimental Results

FA3	0.6287
BA1	0.6732
SHI3	0.6963
STRESS2	0.7420
FRIC4	0.7462
FAN2	0.7674
FINAL3	0.7935
OBSTRUENT1	0.7945
XI1	0.8091
VOICELESS4	0.8181
VOICELESS1	0.8789
Ji2	0.9483
UNSTRESS5	0.9896
CHA2	0.9992

GA1	1.0398
FINAL2	1.0592
PIN2	1.0706
VOICELESS2	1.0729
Qi2	1.1196
STRESS4	1.1205
FINAL4	1.1595
PI2	1.1607
VOICELESS3	1.2625
YAN2	1.6237
MA3	1.6515
STRESS1	1.7820
Mi3	1.9135

Several other constraints also confirm findings from the other analyses. The relatively high weight of FINAL4 indicates there is an association between final position and fourth tone assignment. Figure 8 shows that this constraint's high weight is driven by final *stressed* syllables, and I noted earlier that fourth tone imitates the pitch contour of English final stressed syllables. Similarly, the relatively high weight of STRESS4 also derives from the fourth tone preference of *final* stressed syllables. In the same vein, the fairly strong weight of FINAL2 may be due more to final *unstressed* syllables' second tone preference, shown in Figure 8. Although subjects rarely used fifth tone overall, final unstressed syllables receive fifth tone more than any other type of syllable, making it not unreasonable that UNSTRESS5, the constraint enforcing fifth tone adaptation of unstressed syllables, should be included in the grammar. STRESS2 has one of the

lowest weights, but its inclusion recalls Wu's claim that (initial) stressed syllables are adapted with first or second tone.

Another notable constraint in the final maxent model is OBSTRUENT1. This constraint is closer to the bottom in terms of its weight, but its presence does suggest that beyond the preferences of individual syllables, English syllables with obstruent onsets tend to be adapted with first tone. I found the same thing in the corpus study, though I then argued that the association between obstruent onsets and first tone assignment was actually an association between voiceless obstruents and first tone assignment. In contrast, no SONORANT constraint appears in the final model. My hypothesis about sonority would have predicted the inclusion of SONORANT2. That no SONORANT constraint survived the top-down model selection suggests there was no effect of sonorancy in the experiment, only the individual preferences of sonorant-initial syllables.

Finally, as far as the effect of voicing is concerned, the model includes four constraints that enforce the adaptation of syllables with voiceless onsets with particular tones but no constraints that enforce the adaptation of syllables with voiced onsets with particular tones. The absence of the latter constraints suggests that beyond the individual tonal adaptation preferences of the stimuli syllables with voiced onsets, there are no associations between voicing in English onsets and tonal assignment in Mandarin. In particular, the constraint VOICED2, which expresses the association I hypothesized would exist, does not appear in the final model. On the other hand, the constraints VOICELESS3, VOICELESS2, VOICELESS1, and VOICELESS4 are included, in that order from highest- to lowest-weighted. The presence of all four is somewhat difficult to interpret, but it suggests that, beyond individual voiceless-onset syllables' tonal preferences, syllables with voiceless onsets tend to receive all four lexical tones, to different degrees. It is

interesting that VOICELESS2 still comes out with a relatively high weight even with CHA2, PI2, QI2, and PIN2 in the grammar too. I also especially note the inclusion of VOICELESS1 because this constraint expresses my hypothesis that syllables with voiceless obstruent onsets would tend to be adapted with first tone. Its presence suggests there may be something to this hypothesis, but VOICELESS1 has a lower weight than both VOICELESS2 and VOICELESS3, so it is not very compelling evidence.

The maxent model is helpful in that it is able to abstract away from some of the random tone preferences that stem from the choice of stimuli syllables. In doing so, it confirms that stress is the most important determinant of tone in the experimental results. Specifically, stressed syllables tend to be adapted with first tone. It is also consistent with the other analyses of the experimental data in not finding the expected, or indeed any very clear, effects of voicing on tonal adaptation.

5. Conclusion

The goal of this two-pronged study was to deepen our understanding of how English loanwords in Mandarin Chinese are assigned tones. I built on earlier research by using a much larger corpus of loanwords than Wu (2006) did and by investigating the effects of properties beyond those that Wu and Chang & Bradley (2012) considered. Previous studies claimed that sonorant onsets are associated with more frequent assignment of second tone. My corpus confirmed this association, but it was not present in the experiment once individual syllables' tonal preferences were taken into account. Earlier work also claimed that aspirated onsets increase the likelihood of second tone assignment, but neither my corpus study nor my experiment supported this claim.

In the corpus study, the property that triggered the strongest preferences for adaptation with a particular tone was the voicing of the English segment a loanword syllable's onset corresponded to. Loanword syllables whose onsets derived from voiceless obstruents had a robust tendency to receive first tone while loanword syllables whose onsets derived from voiced obstruents had a robust tendency to receive second tone. In the experiment, the only effect of voicing at first appeared to be precisely the opposite, but further analyses showed this was not necessarily the case. The decision tree revealed that voicing played less of a role in tonal assignment in the experiment than in the corpus study, and the maxent grammar uncovered no effect of voicedness and effects of voicelessness that were difficult to interpret.

For English loanwords in Cantonese, tonal assignment depends almost entirely on English stress. The corpus study and the experiment gave different results for the effect of stress in Mandarin. In the corpus, English stressed syllables were more likely to be adapted with first tone while English unstressed syllables were more likely to be adapted with second tone. On the other hand, tokens of individual syllables did not seem to be assigned different tones in Mandarin when they had different stress levels in English, and the decision tree indicated that stress only affected tonal assignment in loanword syllables whose onsets came from English voiced obstruents. For the experimental results, the decision tree established that stress was the single best predictor of tone, and the maxent grammar confirmed that the strongest tendency in the data was for stressed syllables to be adapted with first tone. The latter finding matches what was found in the aggregate in the corpus. Subjects also tended to adapt stressed final syllables with fourth tone.

The corpus results point to sonority and voicing as the most important determinants of tone in Mandarin adaptation, suggesting that tonal assignment reflects the perturbations in F0

caused by different types of onset consonants. In the experiment, stress and position were the most important determinants of tone, suggesting that tonal assignment reflects the overall intonation of English disyllabic words and not minor variations in F0. There are a number of possible reasons for these conflicting findings.

First, the corpus included a much wider variety of English syllables than the experiment, which relied on a limited stimuli set, so the patterns the corpus exhibited may be more reliable. The adaptations analyzed in the two studies were also very different. The experiment was an online task, which may have led subjects to model their adaptations closely on the intonation of the stimulus they had just heard. The corpus loanwords, on the other hand, may have undergone a more gradual process of adaptation that involved an entire speech community settling upon a final, accepted form. If not all the speakers participating in this process were directly exposed to the English forms, the adaptations may have strayed farther from the original English intonation.

In the experiment, stimuli were presented in auditory form only, not in written English. The adapters of the real loanwords in the corpus likely had access to English written forms in many cases, and perhaps in some cases *only* written forms. This is another reason stress may not have been an important factor in the corpus. English orthography does not mark stress, and there may have been a preference for using a single Mandarin adaptation for an English orthographic syllable regardless of its stress level. Note, though, that for the corpus loanwords to reveal effects of F0 perturbations, there must have been exposure to the auditory English forms at some level.

Something that emerged in both the corpus study and the experiment was evidence of standardization in Mandarin loanword adaptation. In the corpus, I uncovered a near one-to-one mapping between English segments and the Mandarin epenthetic syllables that were used to preserve them, as well as signs of such one-to-one mapping between full English syllables and

non-epenthetic loanword syllables. The experimental adaptations exhibited the influence of officially prescribed loanword syllables. It is not clear whether the tones of these standard Mandarin syllables themselves reflect adaptation principles rooted in phonetics. The tones of the standard epenthetic syllables are largely consistent with the proposed voicing effect, but the tones of the official loanword syllables recommended by the Xinhua News Agency for proper names are often not.

The results of these two studies demonstrate that tonal adaptation in Mandarin is highly complex. Tonal assignment is influenced by multiple competing phonetic factors and constrained by the tonotactic gaps (whether accidental or systematic) of the native lexicon. There is also interference from official standards. In the future, it could be fruitful to model the corpus and experimental results with mixed effects multinomial regressions in order to better uncover patterns beyond the individual syllables' tonal preferences. The current analysis would also be enriched by a deeper exploration of the relationship between tonal assignment in loanwords and tonal patterns in the native lexicon. It would be interesting to explore the possibility of frequency matching between loanword and native tone distributions, to examine whether loanword tonal assignment reinforces tendencies already present in Mandarin, and to investigate whether historical consonant effects on tone that are no longer active in the native lexicon are still active in loanword tonal assignment.

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