Tonal Adaptation in English Loanwords in Mandarin: A Corpus Study

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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 Mandarin Chinese when it borrows words from English. 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. The corpus study reveals English voicing to be the most reliable predictor of tone in Mandarin and suggests that English stress plays a secondary role, if any, in tonal adaptation.

2 Background

A common thread running through the literature on English-to-Chinese tonal adaptation is the relationship between English stress and lexical tone in Chinese languages. English stressed syllables tend to have longer duration, higher F0, and greater amplitude than unstressed syllables (Cutler 2008). These properties can also distinguish Chinese tones, so it is conceivable that a Chinese language may exhibit stress-to-tone correspondences.

This is the case in Cantonese. Cantonese syllables corresponding to stressed English syllables receive a high tone while Cantonese syllables corresponding to unstressed English syllables receive a mid or a low tone (Hao 2009). The tonal assignment of English loanwords in Cantonese thus seems to imitate English prosody.

Mandarin has four lexical tones, 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: Lexical Tones of Mandarin

Tone	Chao Digits (Chao 1930)	Pinyin
First (high)	55	mā
Second (rising)	35	má
Third (falling-rising)	214	mǎ
Fourth (falling)	51	mà

Not all Mandarin 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*[1], tend to lack rising 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 already present in the native lexicon.

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's corpus consisted of a little over 100 "established loans that are still in use today in Taiwan" (2006:230). Her main findings concerned the tonal adaptation of the initial syllables of English trochees. Wu found that these syllables were assigned either high or rising tone, presumably because they were stressed in English. The choice between high and rising tone depended on properties of the syllables' onset consonants in Mandarin. Syllables beginning with obstruents in their adapted form tended to bear high tone (e.g. English *curry* → Mandarin ***kā****lǐ*), and syllables beginning with sonorants tended to bear rising tone (e.g. English *modern* → Mandarin ***mó****dēng*). This pattern is consistent with evidence that sonorants have a depressive effect on F0 (Hombert, Ohala, & Ewan 1979).

Wu also identified aspiration as playing a role: adapted syllables with aspirated onsets were more likely to have rising tone (***kuí****níng* 'quinine') while those with unaspirated onsets were more likely to have high tone (***bēi****gé* 'boycott'). While the effect of aspiration on F0 is disputed, Wu cited evidence that, in Mandarin, aspiration lowers F0 at voicing onset across all four tones. This explains why loanword syllables with aspirated onsets received rising tone more often than high tone. However, Wu's discussion of tonal assignment and aspiration was based on just 35 syllables, only 7 of which had aspirated onsets.

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. The stimuli were designed such that every English nonce word had an expected Mandarin segmental adaptation. English voiced (unaspirated) stops were expected to be adapted with Mandarin voiceless unaspirated stops, and English voiceless (aspirated) stops were expected to be adapted with Mandarin voiceless aspirated stops. 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.

Chang & Bradley analyzed the tonal adaptations of the stressed syllables from the English nonce words and found that falling tone was the most frequently assigned tone overall. This was likely because the speaker who recorded the

[1] Note that symbols that represent voiceless obstruents in the IPA represent voiceless aspirated obstruents in Pinyin and symbols that represent voiced obstruents in the IPA represent voiceless unaspirated obstruents in Pinyin.

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.

Looking at just CV syllables, Chang & Bradley found that syllables with sonorant onsets were less likely to receive high tone than syllables with obstruent onsets and that syllables beginning with aspirated stops were more likely to receive rising 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 The present study's corpus

To further examine the tonal adaptation of English loanwords in Mandarin, I conducted a study of a larger corpus. The corpus consisted of 3,456 syllables from about 1,300 English loanwords in Mandarin and was assembled 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 included 292 place names and 577 first names. Dong's corpus accounted for about 85% of the syllables in my corpus. Wu's (2006) much smaller corpus overlapped somewhat with Dong's, but it contributed an additional 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 came from loanwords taken from MDBG. Following Dong, I assume that English loanwords in Mandarin are borrowed from British English, so English transcriptions reflect British pronunciation.

My corpus was originally larger, comprising syllables from 1,551 loanwords, but I removed loanwords whose adaptations into Mandarin were influenced by semantics. For example, *bungee (jumping)* is adapted as 蹦极 *bèngjí*, where 蹦 means 'jump' and 极 means 'extreme'. The choice of particular characters to reflect a loanword's meaning imposes tones on the Mandarin form, potentially overriding a process of tonal assignment rooted in phonetics.

I also excluded syllables that were subject to third tone sandhi. In Mandarin, when two underlyingly falling-rising tone syllables occur in a row, the first syllable is realized with rising tone. For loanword syllables subject to this rule, it is impossible to tell whether it is their surface rising tone or underlying falling-rising tone that reflects how tones are assigned to English loanwords in Mandarin. I removed 60 such syllables; an example is the first syllable in 法老 *fǎlǎo* 'pharaoh'.

Lastly, there were 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*. Assuming segmental adaptation constrains tonal adaptation, once one of these syllables is chosen to adapt an English syllable, the tone it receives is fixed. As a result, these syllables cannot tell us anything about principles of tonal assignment, so they

were excluded from the analyses. Syllables that can bear only two or three out of the four Mandarin tones were retained.

4 Testing past claims

Wu (2006) and Chang & Bradley (2012) found that English stressed syllables were less likely to receive high tone and more likely to receive rising tone if their Mandarin adaptations began with sonorants than if their 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). Fig. 1 shows that loanword syllables (including epenthetic syllables[2]) whose onsets correspond to obstruents in English most often get high tone while loanword syllables whose onsets correspond to sonorants in English most often get rising tone and rarely get high tone.

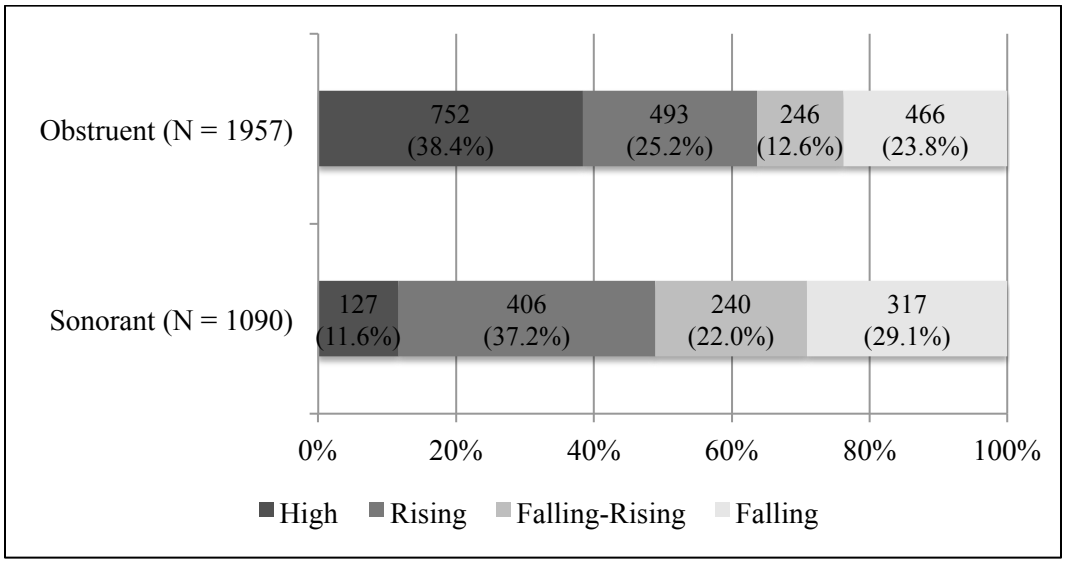

Figure 1: Tones of Loanword Syllables by Onset's Sonority in English

Wu and Chang & Bradley also found that English stressed syllables were more likely to receive rising tone if their onset in Mandarin was aspirated than if it was unaspirated. I was unable to replicate this finding. Fig. 2 shows the tonal assignment of loanword syllables whose onsets correspond to English stops or affricates according to their onsets' aspiration in Mandarin. Contrary to Wu and

[2] Epenthetic syllables are syllables that are inserted in the adapted form to preserve consonants from English clusters and codas while complying with Mandarin phonotactics. For example, the second syllable in *āsīpǐlín* 'aspirin' is epenthetic.

Chang & Bradley's finding, loanword syllables with aspirated onsets receive rising tone less often than loanword syllables with unaspirated onsets. Additionally, Wu claimed that syllables with unaspirated onsets preferred high tone, but in my corpus they prefer rising tone. The results are precisely the opposite of those that were previously reported.

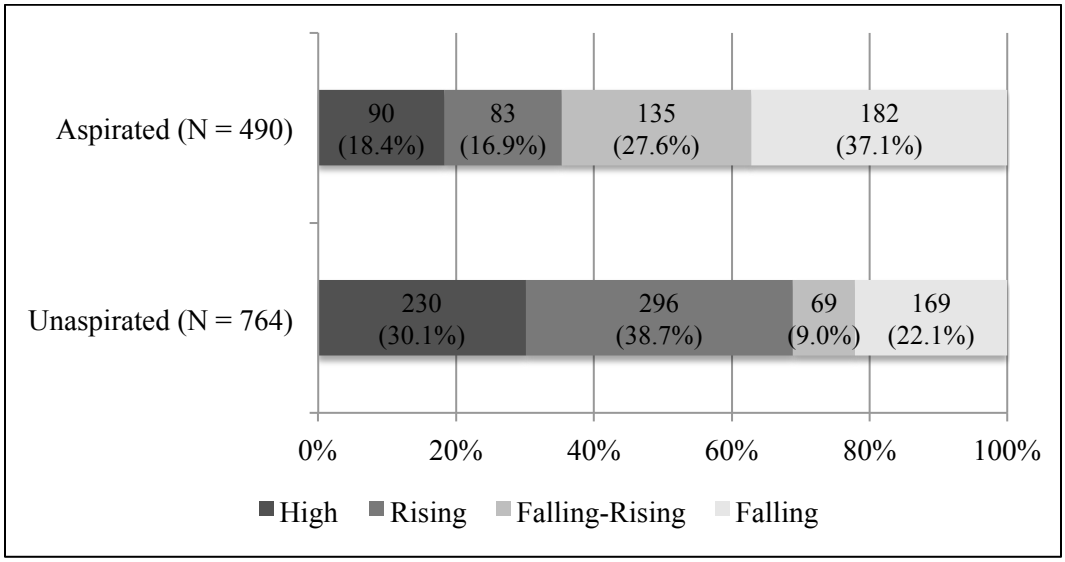

Figure 2: Tones of Loanword Syllables by Onset's Aspiration in Mandarin

In sum, 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.

5 Voicing

Another potential determinant of tonal assignment is voicing, a factor underexplored in the previous literature. 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 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.

As it turns out, though, English voicing does play a role in tonal adaptation. Fig. 3 shows the tones of non-epenthetic loanword syllables whose onsets correspond to English obstruents by the voicing of those obstruents in English. The large differences between the tone distributions shown in Fig. 3 are quite significant (χ-squared = 179.8687, $p < 0.001$). Loanword syllables whose

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

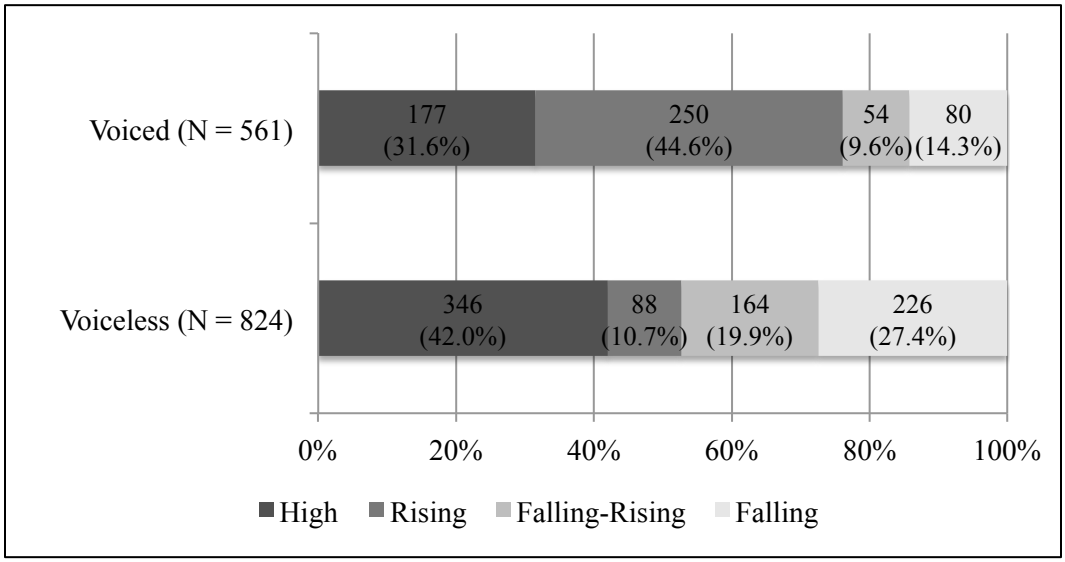

Figure 3: Tones of Non-Epenthetic Loanword Syllables with Onsets from English Obstruents by English Voicing

These patterns may be accounted for by the lowering effect of voiced obstruents on F0 (Hombert, Ohala, & Ewan 1979). Because of this effect, loanword syllables whose onsets come from voiced obstruents prefer to take rising tone. The relatively high incidence of high 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 rising tone. The fact that rising 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 rising tone preference.

Because F0 is higher after a voiceless obstruent onset than a voiced one, loanword syllables whose onsets correspond to English voiceless obstruents prefer high tone. After high tone, falling tone is the most frequent tone these syllables receive, and like high tone, falling tone begins high.

The tonal preferences based on voicing in English are more robust than those based on sonority and aspiration. In fact, the apparent effect of sonority on tonal

assignment may be an effect of voicing. Fig. 1 showed that loanword syllables whose onsets derived from English obstruents preferred high tone. However, 61.2% of those obstruents are voiceless, so it is likely that the association between English obstruents and high tone actually reflects a watered down version of the association between *voiceless* English obstruents and high tone. It appears that English voicing is the more successful predictor of tonal assignment in loanwords.

6 Stress-to-tone adaptation

I now revisit the question of stress-to-tone principles in the Mandarin adaptation of English words. I examine whether the different English stress levels are associated with particular tones, disregarding factors like sonority, aspiration, and voicing. I exclude epenthetic loanword syllables since they have no English correspondents and therefore no value for stress. Fig. 4 shows the tones non-epenthetic loanword syllables receive by their stress in English.

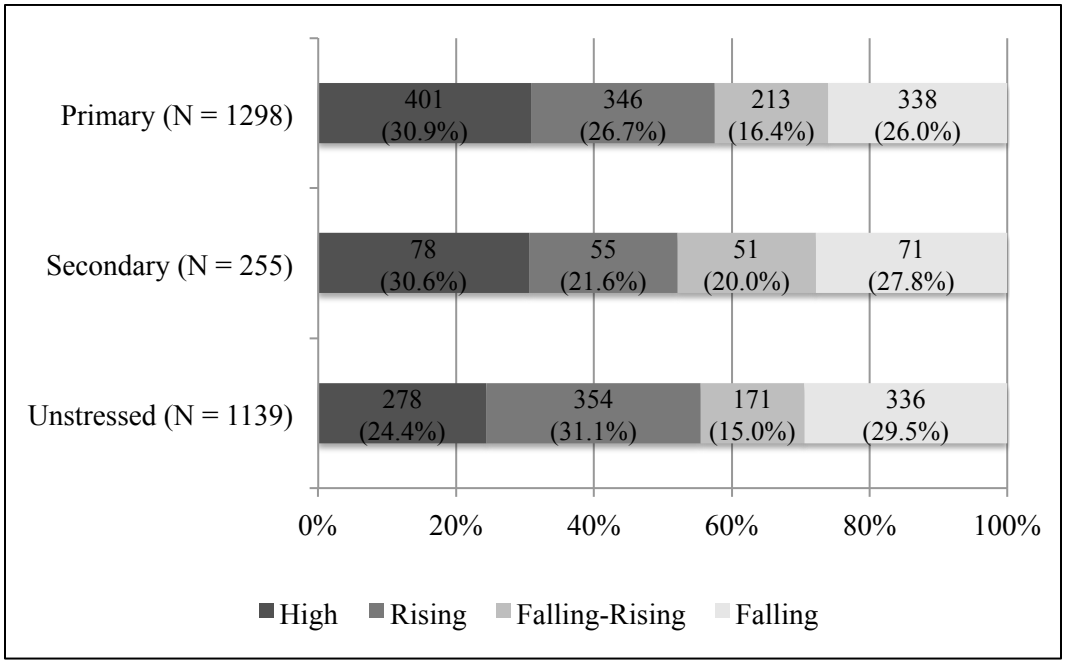

Figure 4: Tones of Non-Epenthetic Loanword Syllables by English Stress

There are overall differences in the tone distributions among the different levels of stress (χ-squared = 24.0637, $p < 0.001$). Primary-stressed and secondary-stressed syllables receive high and falling tone about the same percentage of the time, while secondary-stressed syllables receive rising tone somewhat less often and falling-rising 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 high tone less often and rising tone more often than both kinds of stressed syllables. Indeed, chi-squared tests of the first and third bars and second and third bars of Fig. 4 reveal significant differences (χ-squared = 16.6695, $p < 0.001$ and χ-squared = 12.9904, $p < 0.005$, 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 high tone overall, recalling the Cantonese adaptation strategy whereby all English stressed syllables receive a high tone. This preference for adaptation with high 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 high tone, a decrease that is made up for mostly by an increase in rising tone assignment. Mandarin may use a tone that starts at a mid pitch instead of one that begins high to reflect the lower average pitch of English unstressed syllables.

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.

7 Exploring 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. The input data for the decision tree was limited to non-epenthetic loanword syllables, and the predictors supplied to the `ctree()` function are listed in Table 2. The variables EngPretonicCorresp, PreTonicCorresp, PostTonicCorresp, and TotalEngSyll did not emerge as significant predictors in the decision tree.

The tree is too large to show in a single figure, so it is split into two parts. Consequently, its root node is not visible. The variable that triggers the first split in the decision tree is EngSegOnsetVoice. Loanword syllables whose onsets correspond to voiced English segments (Voiced) are separated from loanword syllables whose onsets correspond to voiceless English segments (Voiceless) and loanword syllables that correspond to onsetless English syllables (Null). The subtree descending from the Voiced branch is shown in Fig. 5, and the subtree descending from the Voiceless/Null branch is shown in Fig. 6.

The Voiced branch of the decision tree 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 rising tone. In the decision tree in Fig. 5, the graphs at three out of four terminal nodes show rising tone as the most frequently assigned tone. This is as expected, given my previous analysis of the corpus.

Table 2: Decision Tree Predictors

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

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, rising tone assignment is most common, followed by falling tone assignment, just as in Fig. 1 (though Fig. 1 included epenthetic loanword syllables, which this decision tree does not).

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 6 I found overall significant differences in tonal assignment for syllables with different English stress levels, the recursive partitioning algorithm suggests that English stress influences tonal assignment only in a subset of the corpus.

At Node 3, the loanword syllables that bear secondary stress in English are 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 rising tone overall while the secondary-stressed syllables do not. The Node 4 graph shows that the latter tend to be adapted with high or falling tone (despite having onsets from English voiced obstruents). I have no particular explanation for this. It may be that the small number of syllables (N = 48) is behind this apparently anomalous behavior.

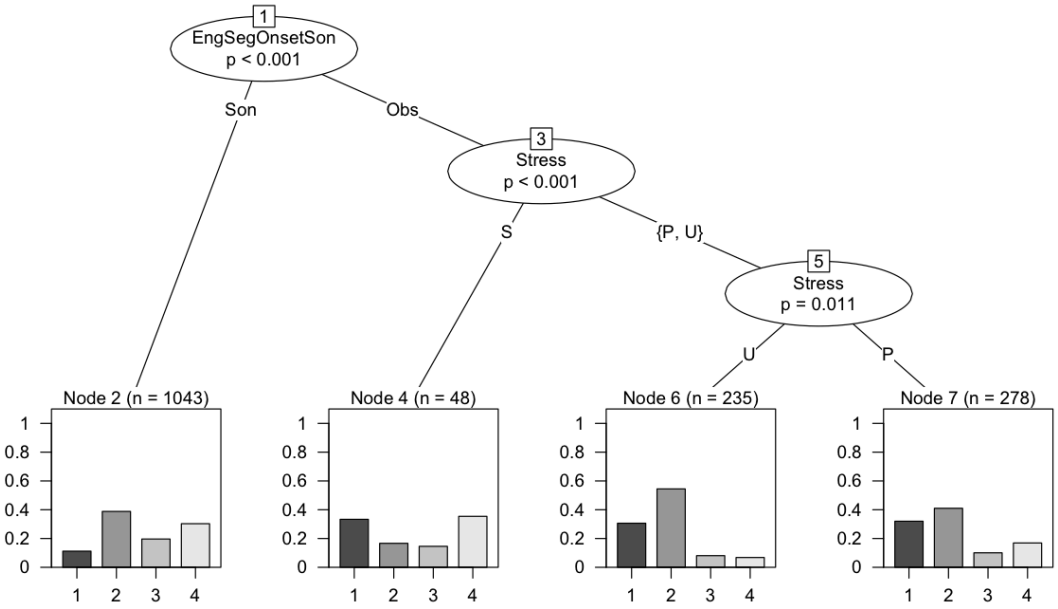

Figure 5: Decision Tree for All Non-Epenthetic Loanword Syllables—EngSegOnsetVoice: Voiced Branch

At Node 5, the remaining loanword syllables whose onsets come from English voiced obstruents are split into primary-stressed and unstressed groups. Rising 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 rising tone less often and high and falling tone more often than unstressed syllables. This pattern is consistent with the stress-based effects described in Section 6 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, rising 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.

The Voiceless/Null branch of the full tree, shown in Fig. 6, includes loanwords syllables whose onsets correspond to English voiceless obstruents and loanword syllables that correspond to onsetless English syllables. This branch exhibits many more splits than the Voiced branch. The first split by

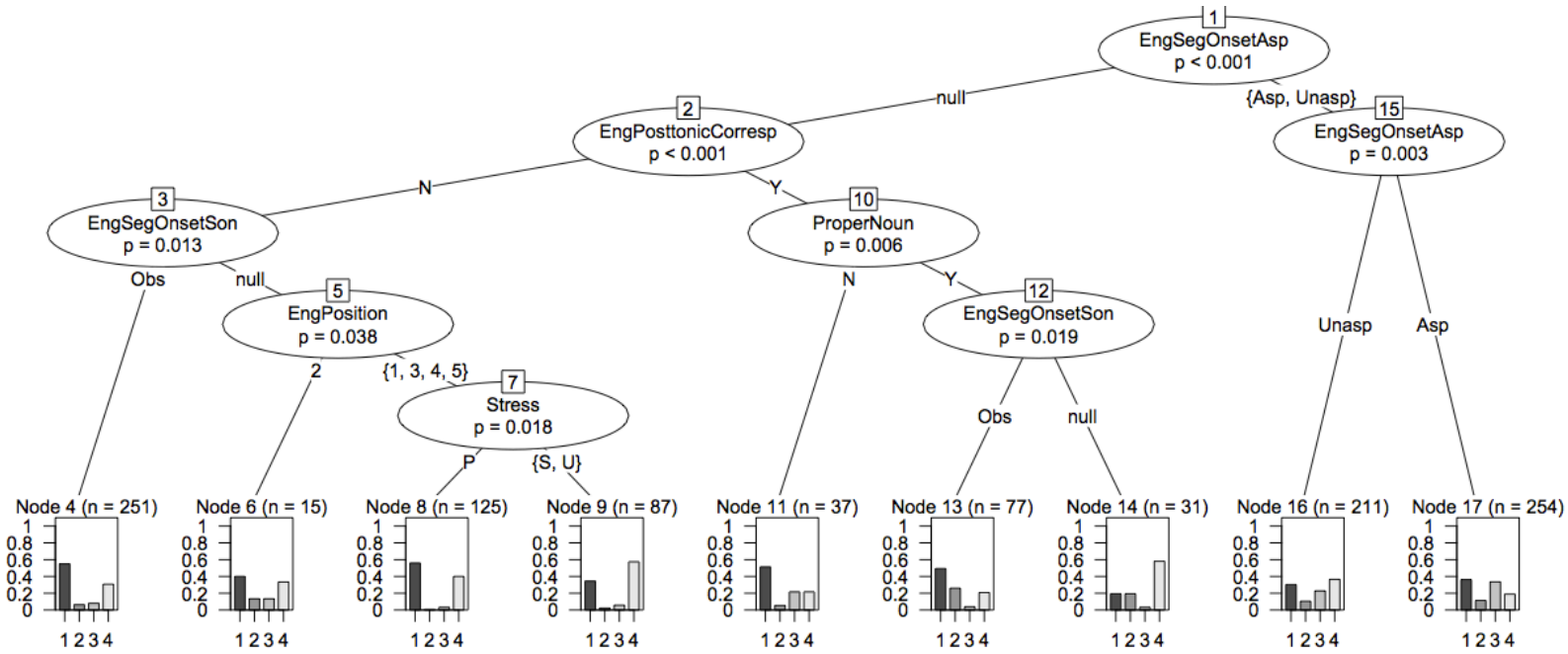

Figure 6: Decision Tree for All Non-Epenthetic Loanword Syllables— EngSegOnsetVoice: Voiceless/Null Branch

EngSegOnsetAsp divides syllables whose onsets derive from English voiceless stops and affricates (Aspirated/Unaspirated branch) from syllables whose onsets derive from voiceless fricatives and syllables from onsetless English syllables (Null branch). The syllables with onsets from English voiceless stops and affricates then split by aspiration (Node 15). Both the Unaspirated group (Node 16) and the Aspirated group (Node 17) rarely receive rising tone, consistent with my previous findings about voicing.

The part of the Voiceless/Null branch consisting of Node 2 and below exhibits a series of sometimes puzzling splits, which I will not discuss in detail. In general, the terminal nodes in this part of the tree show little rising tone assignment and strong preferences for high tone assignment, falling tone assignment, or both. Preferences for high tone are probably driven by syllables whose onsets correspond to English voiceless fricatives while preferences for falling tone are probably driven by loanword syllables that correspond to onsetless English syllables. For instance, many of the loanword syllables represented in Node 14 are tokens of *aò* and *yà*, which usually derive from the English syllables /əʊ/ and /ə/.

Node 7 is the second place in the full tree where a split is made by Stress, but this split is uninformative. It is difficult to imagine why stress should matter for the tonal assignment of syllables in first, third, fourth, and fifth positions in English words (the right branch of Node 5) but not for syllables in second position (the left branch of Node 5). It is possible that EngPosition is not the most useful variable. 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 occurs in.

In its entirety, 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. Additionally, stress may only affect the tonal assignment of loanword syllables whose onsets come from English voiced obstruents.

8 Standard syllables in English-to-Mandarin loanword adaptation

Another way to investigate the strength of stress-to-tone principles in English-to-Mandarin loanword adaptation is to ask whether segmentally identical syllables are assigned different tones depending on their English stress level. This approach reveals a tendency for particular Mandarin syllables to be used to adapt particular English syllables. That is, there appears to be some standardization in the set of syllables used in English loanwords.

Table 3 shows the eight most frequent proper[3] Mandarin syllables in my

[3] I include only syllables from proper names here because it turns out that stress is not a significant determinant of tone for syllables from common nouns. While proper loanword syllables exhibit the same patterns seen for all non-epenthetic loanword syllables in Fig. 4 (68.8% of which come from proper names), common loanword syllables exhibit no significant differences between the tones received by primary-stressed, secondary-stressed, and unstressed syllables.

corpus and the tones they take in Mandarin depending on the stress of their English correspondents (primary and secondary stress are combined).

Table 3: Tones of Particular Proper Mandarin Syllables by English Stress

Mandarin Syllable	Stress	Tone 1	Tone 2	Tone 3	Tone 4
li	Primary (N = 38)	0	0	16	22
	Unstressed (N = 124)	0	0	50	74
la	Primary (N = 18)	18	0	0	0
	Unstressed (N = 41)	41	0	0	0
luo	Primary (N = 43)	1	30	0	12
	Unstressed (N = 16)	0	11	0	5
xi	Primary (N = 23)	23	0	0	0
	Unstressed (N = 32)	32	0	0	0
ni	Primary (N = 9)	0	9	0	0
	Unstressed (N = 45)	0	45	0	0
ai	Primary (N = 47)	27	0	0	20
	Unstressed (N = 3)	3	0	0	0
wei	Primary (N = 32)	15	10	7	0
	Unstressed (N = 18)	4	14	0	0
di	Primary (N = 13)	1	4	0	8
	Unstressed (N = 32)	0	21	1	10

Table 3 offers little evidence that English stress is a strong determinant of tone at the level of individual syllables. For instance, the Mandarin syllable *li* receives falling-rising or falling tone in loanwords (*li* can bear rising, falling-rising, and falling tone), but the proportions of *li*s that receive falling-rising and falling 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 *ní*, and 44 out of 55 instances of *xi* are written with 西 *xī*. This 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 or set of syllables. Standard Mandarin syllables, including tone, may still be selected to reflect properties of the onset consonant in English: 尼 *ní* and 妮 *ní* bear rising tone, which I expect for a syllable whose onset corresponds to the English sonorant /n/, and 西 *xī* bears high 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, and this does not appear to be happening in Mandarin tonal adaptation.

The only syllables in Table 3 that show evidence of sensitivity to stress are *wei* and *di*. *Wei* is the most convincing example: the tone distributions of *wei*s derived from stressed and unstressed syllables differ significantly (Fisher's Exact Test: $p = 0.0035$). *Wei*s from stressed syllables modestly prefer high tone over rising tone, consistent with the hypothesis that high tone best imitates the high pitch of stressed syllables. *Wei*s from unstressed syllables strongly prefer rising tone over high 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 the tone distributions for *di* from stressed syllables and *di* from unstressed syllables barely reaches significance (Fisher's Exact Test: $p = 0.0498$). Again, though, the trends are amenable to a phonetic account. *Di*s from stressed syllables are more likely to receive falling tone, which starts high, than rising tone, which starts at a mid pitch, and *di*s from unstressed syllables are more likely to receive rising tone than falling 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 7 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 Table 3, it seems that once a character (or syllable with tone) is chosen to adapt a particular syllable (or set of syllables) in English, presumably for segmental reasons, that character or syllable is used for most other adaptations of that English syllable no matter its stress level.

9 Conclusion

The goal of this corpus 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 both sonorant onsets and aspirated onsets are associated with more frequent assignment of rising tone; my corpus confirmed this association for sonorants, but not for aspirated segments. I found that the property that triggers the strongest preferences for adaptation with a particular tone is the voicing of the English segment a loanword syllable's onset corresponds to, when that segment is an obstruent. Loanword syllables whose onsets derive from voiceless obstruents have a robust tendency to receive high tone while loanword syllables whose onsets derive from voiced obstruents have a robust tendency to receive rising tone. This pattern can be accounted for by the perturbations in F0 caused by different types of English onset consonants,

suggesting that low-level phonetic details of English syllables affect their tonal adaptation.

For English loanwords in Cantonese, tonal assignment depends almost entirely on English stress. In Mandarin, the effect of stress is weaker. English stressed syllables are more likely to be adapted with high tone while English unstressed syllables are more likely to be adapted with rising tone. However, a software-generated decision tree indicated that stress only affects tonal assignment in loanword syllables whose onsets come from English voiced obstruents, and tokens of individual Mandarin syllables do not seem to be assigned different tones when they correspond to English syllables with different stress levels. Instead, particular characters seem to be preferred for all adaptations of certain English syllables, pointing to a degree of standardization in the syllables, including tone, used in loanword adaptation.

The results of the corpus study demonstrate that tonal adaptation in Mandarin is highly complex, exhibiting the influence of multiple competing phonetic factors. In a different study, I examined Mandarin speakers' online adaptations of English nonce words and found that stress and position, not voicing, were the most important determinants of tone (Glewwe 2015). In the future, it would be interesting to investigate the reasons for the differences between these two studies' results, as well as to explore further the relationship between tonal assignment in loanwords and tonal patterns in the native Mandarin lexicon.

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